LIBERATION

LInking farmland Biodiversity to Ecosystem seRvices for effective eco-functional intensificATION

Collaborative Project
Grant Agreement No.: 311781 – LIBERATION – CP – FP

Deliverable 7.2
Name of deliverable: Annotated Bibliography on Ecological Intensification

Deliverable date: 27.11.2013

Lead Participant: FAO

LInking farmland Biodiversity to Ecosystem seRvices for effective eco-functional intensificATION

311781 – LIBERATION – CP – FP

SEVENTH FRAMEWORK PROGRAMME
THEME KBBE.2012.1.2-02
Managing semi-natural habitats and on-farm biodiversity to optimise ecological services

Collaborative Project

Annotated Bibliography on Ecological Intensification

Prepared by FAO, November 2013

Introduction

Increasingly, the global community has recognized that while the last half-century has witnessed striking increases in global food production through intensive use of inputs, such practices may deplete natural resources and impair the ability of agro-ecosystems to sustain production into the future.

However, the Food and Agriculture Organization of the United Nations (FAO, 2011a) along with numerous recent reviews (The Royal Society 2009; Clay 2011; Foley et al. 2011, Bommarco et al. 2013) have highlighted that it is both possible and highly advantageous to address future needs by transitioning to systems of food production that are based on "ecological intensification"—using land, water, biodiversity and nutrients efficiently and in ways that are regenerative, while minimizing negative impacts. Ecological intensification may be formally defined as a knowledge-intensive process that requires optimal management of nature's ecological functions and biodiversity to improve agricultural system performance, efficiency and farmers' livelihoods.

Areas of the world where agricultural productivity is extremely high - such as in Europe or North America- often depend on unsustainable high levels of external inputs. Here the challenge for ecological intensification is to reduce reliance on external inputs while maintaining high productivity levels by reestablishment of soil and landscape ecosystem services). In other places where productivity is less high, the challenge is to enhance productivity by optimising ecosystem services rather than by increasing agricultural inputs. A further challenge for ecological intensification is the development of novel poly-cropping systems and landscape-scale management of matrix habitats to increase the stability of agricultural production systems and provide 'ecological resilience'.

FAO in its role in leading a work package on Communication, Dissemination and Training of Effective Ecological Intensification in the EU FP7-funded project LIBERATION is providing tools and documents to help policy-makers and practitioners understand and utilize the concepts of ecological intensification in agricultural production.

One of the challenges of ecological intensification is to move agricultural research out of a focus on singular focal areas – e.g., improved seed, pest control, water management – to solutions that integrate all components of the farming system. As such, the canon of knowledge supporting ecological intensification is transdisciplinary, focusing on the biological components of farming systems and agroecological practices but extending as well to considerations of policy and farmer and societal benefits. As the biodiversity benefits of ecological intensification, along with the negative externalities of conventional agriculture are an important motivation for ecological intensification, we have included literature on these topic, as well as references that relate climate change to ecosystem services in agriculture.

The annotated bibliography presented here is compiled on this basis, to identify the literature relevant to ecological intensification, with respect to the following categories:

1. Ecosystem services

2. Agroecology and agroecological practices
3. Farmer and societal benefits from enhancing ecosystem services
4. Biodiversity benefits of ecological intensification
5. Agriculture-induced impacts
6. Climate change
7. Policy

Within the category of ecosystem services, it has been noted in the keywords if the relevant study addresses one or several of the key ecosystem services underpinning ecological intensification in agriculture: pollination, pest regulation or soil nutrients/cycling. (Bommarco et al. 2013)

The bibliography has been assembled by a joint effort of Helga Gruberg and Toby Hodgkin (Platform for Agrobiodiversity Research) and FAO (Barbara Gemmill-Herren and Benjamin Gräub).

Annotated Bibliography

Abildtrup, J., E. Audsley, M. Fekete-Farkas, C. Giupponi, M. Gylling, P. Rosato and M. Rounsevell (2006). "Socio-economic scenario development for the assessment of climate change impacts on agricultural land use: a pairwise comparison approach." Environmental Science & Policy **9**(2): 101-115.

Category: Climate change

Keywords: *Scenario development, climate change, agricultural land use, pairwise comparison*

Abstract: Assessment of the vulnerability of agriculture to climate change is strongly dependent on concurrent changes in socio-economic development pathways. This paper presents an integrated approach to the construction of socio-economic scenarios required for the analysis of climate change impacts on European agricultural land use. The scenarios are interpreted from the storylines described in the intergovernmental panel on climate change (IPCC) special report on emission scenarios (SRES), which ensures internal consistency between the evolution of socio-economics and climate change. A stepwise downscaling procedure based on expert-judgement and pairwise comparison is presented to obtain quantitative socio-economic parameters, e.g. prices and productivity estimates that are input to the ACCELERATES integrated land use model. In the first step, the global driving forces are identified and quantified for each of the four SRES scenario families. In the second step, European agricultural driving forces are derived for each scenario from global driving forces. Finally, parameters for the agricultural land use model are quantified. The stepwise procedure is appropriate when developing socio-economic scenarios that are consistent with climate change scenarios used in climate impact studies. Furthermore, the pairwise comparison approach developed by Saaty [Saaty, T.L., 1980. The Analytic Hierarchy Process. McGraw Hill, New York] provides a useful tool for the quantification from narrative storylines of scenario drivers and model parameters. Descriptions of the narratives are, however, helpful at each step to facilitate the discussion and communication of the resulting scenarios.

Aizen, M. and L. Harder (2009). "The Global Stock of Domesticated Honey Bees Is Growing Slower Than Agricultural Demand for Pollination." Current Biology **19**(11): 915-918.
Category: Ecosystem services
Keywords: *Domesticated honey bees, pollination, crop production*

Abstract: The prospect that a global pollination crisis currently threatens agricultural productivity has drawn intense recent interest among scientists, politicians, and the general public 1, 2, 3, 4 and 5. To date, evidence for a global crisis has been drawn from regional or local declines in pollinators themselves 6, 7, 8 and 9 or insufficient pollination for particular crops 9 and 10. In contrast, our analysis of Food and Agriculture Organization (FAO) [11] data reveals that the global population of managed honey-bee hives has increased 45% during the last half century and suggests that economic globalization, rather than biological factors, drives both the dynamics of the global managed honey-bee population and increasing demands for agricultural pollination services [12]. Nevertheless, available data also reveal a much more rapid (>300%) increase in the fraction of agriculture that depends on animal pollination during the last half century, which may be stressing global pollination capacity. Although the primary cause of the accelerating increase of the pollinator dependence of commercial agriculture seems to be economic and political and not biological, the rapid expansion of cultivation of many pollinator-dependent crops has the potential to trigger future pollination problems for both these crops and native species in neighboring areas. Such environmental costs merit consideration during the development of agriculture and conservation policies.

Alcamo, J., K. Kok, G. Busch and J. Priess (2008). Searching for the Future of Land: Scenarios from the Local to Global Scale. Developments in Integrated Environmental Assessment, Elsevier. **Volume 2:** 67-103.
Category: Climate change
Keywords: *Scenario analysis; qualitative scenarios; Quantitative scenarios; land use and cover;*

Abstract: Much of the scientific research concerned with land-use and land-cover issues is motivated by questions related to global environmental change. For example, will deforestation continue, and if yes, where, and at what rate? How will demographic changes affect future land use and cover? How will economic growth influence future land use and cover? What will be the magnitude of emissions of greenhouse gases related to land use and cover? A common characteristic of these and other issues related to global environmental change is that they stimulate questions not only about past and present changes in land use and cover but also about their future changes (Brouwer and McCarl 2006). The main objective of this chapter is to summarize the state of understanding about the future of land. What are the range and predominant views of this future? What are the views on the global, continental, regional and local levels? We review what (we think) we know and don't know about the future of land by reviewing published scenarios from the global to local scale. Our aim is to identify the main messages of these scenarios especially relevant to global change issues, and to recommend how scenarios can be improved to better address the outstanding questions about global change and land use/cover.

Allan, E., W. Weisser, A. Weigelt, C. Roscher, M. Fischer and H. Hillebrand (2011). "More diverse plant communities have higher functioning over time due to turnover in complementary dominant species." Proceedings of the National Academy of Sciences **108**(41): 17034-17039.

Category: Ecosystem services

Keywords: *Jena Experiment, redundancy, grassland, species richness, evenness, diversity, production*

Abstract: More diverse communities have been shown to have higher and more temporally stable ecosystem functioning than less diverse ones, suggesting they should also have a consistently higher level of functioning over time. Diverse communities could maintain consistently high function because the species driving function change over time (functional turnover) or because they are more likely to contain key species with temporally stable functioning. Across 7 y in a large biodiversity experiment, we show that more diverse plant communities had consistently higher productivity, that is, a higher level of functioning over time. We identify the mechanism for this as turnover in the species driving biomass production; this was substantial, and species that were rare in some years became dominant and drove function in other years. Such high turnover allowed functionally more diverse communities to maintain high biomass over time and was associated with higher levels of complementarity effects in these communities. In contrast, turnover in communities composed of functionally similar species did not promote high biomass production over time. Thus, turnover in species promotes consistently high ecosystem function when it sustains functionally complementary interactions between species. Our results strongly reinforce the argument for conservation of high biodiversity.

Altieri, M. A. (1989). "Agroecology: a new research and development paradigm for world agriculture." Agriculture, Ecosystems & Environment **27**(1): 37-46.

Category: Agroecology and agroecological practices

Keywords: *Agroecology; research and development; rural poverty; technological development; rural development;*

Abstract: In its several conceptions, agroecology has emerged as a scientific approach used to study, diagnose and propose alternative low-input management of agroecosystems. Solving the sustainability problem of agriculture is the primary aim of agroecology. It is maintained here, however, that simply focusing on the technological aspects of the problem, even though promoted technol- ogies are low-input, obscures the fundamental problems that lie behind the technology-induced environmental crisis and rural poverty affecting the agricultural regions of the world. Agroecology can provide the ecological guidelines to point technological development in the right direction, but in the process, technological issues must assume their corresponding role within a strategy of rural development that incorporates social and economic problems.

Altieri, M. A. (1999). "The ecological role of biodiversity in agroecosystems." Agriculture, Ecosystems & Environment **74**(1): 19-31.
Category: Agroecology and agroecological practices
Keywords: *agroecology; antagonists; biodiversity; biological control, organic farming, sustainable agriculture, traditional farming;*

Abstract: In its several conceptions, agroecology has emerged as a scientific approach used to study, diagnose and propose alternative low-input management of agroecosystems. Solving the sustainability problem of agriculture is the primary aim of agroecology. It is maintained here, however, that simply focusing on the technological aspects of the problem, even though promoted technologies are low-input, obscures the fundamental problems that lie behind the technology-induced environmental crisis and rural poverty affecting the agricultural regions of the world. Agroecology can provide the ecological guidelines to point technological development in the right direction, but in the process, technological issues must assume their corresponding role within a strategy of rural development that incorporates social and economic problems.

Altieri, M. A. (2002). "Agroecology: the science of natural resource management for poor farmers in marginal environments." Agriculture, Ecosystems & Environment **93**(1): 1-24.
Category: Agroecology and agroecological practices
Keywords: *Agroecology, resource-poor farmers, natural resource management, marginal environments, sustainable agriculture*

Abstract: Throughout the developing world, resource-poor farmers (about 1.4 billion people) located in risk-prone, marginal environments, remain untouched by modern agricultural technology. A new approach to natural resource management must be developed so that new management systems can be tailored and adapted in a site-specific way to highly variable and diverse farm conditions typical of resource-poor farmers. Agroecology provides the scientific basis to address the production by a biodiverse agroecosystem able to sponsor its own functioning. The latest advances in agroecological research are reviewed in order to better define elements of a research agenda in natural resource management that is compatible with the needs and aspirations of peasants. Obviously, a relevant research agenda setting should involve the full participation of farmers with other institutions serving a facilitating role. The implementation of the agenda will also imply major institutional and policy changes.

Angelsen, A. (2010). "Policies for reduced deforestation and their impact on agricultural production." Proceedings of the National Academy of Sciences **107**(46): 19639-19644.
Category: Policy; Agriculture-induced impacts
Keywords: *Climate, Reducing Emissions from Deforestation and Forest Degradation, tropical forests, protected areas, yield; land sparing, land sharing*

Abstract: Policies to effectively reduce deforestation are discussed within a land rent (von Thünen) framework. The first set of policies attempts to reduce the rent of extensive agriculture, either by neglecting extension, marketing, and infrastructure, generating alternative income opportunities, stimulating intensive agricultural

production or by reforming land tenure. The second set aims to increase either extractive or protective forest rent and—more importantly—create institutions (community forest management) or markets (payment for environmental services) that enable land users to capture a larger share of the protective forest rent. The third set aims to limit forest conversion directly by establishing protected areas. Many of these policy options present local win–lose scenarios between forest conservation and agricultural production. Local yield increases tend to stimulate agricultural encroachment, contrary to the logic of the global food equation that suggests yield increases take pressure off forests. At national and global scales, however, policy makers are presented with a more pleasant scenario. Agricultural production in developing countries has increased by 3.3–3.4% annually over the last 2 decades, whereas gross deforestation has increased agricultural area by only 0.3%, suggesting a minor role of forest conversion in overall agricultural production. A spatial delinking of remaining forests and intensive production areas should also help reconcile conservation and production goals in the future.

Anton, C., J. Young, P. Harrison, M. Musche, G. Bela, C. Feld, R. Harrington, J. Haslett, G. Pataki, M. Rounsevell, M. Skourtos, J. Sousa, M. Sykes, R. Tinch, M. Vandewalle, A. Watt and J. Settele (2010). "Research needs for incorporating the ecosystem service approach into EU biodiversity conservation policy." Biodiversity and Conservation **19**(10): 2979-2994.
Category: Policy
Keywords: *Biodiversity, conservation policy, ecosystem services, indicators, knowledge base, research priorities, valuation*

Abstract: Using a range of different methods including extensive reviews, workshops and an electronic conference, 70 key research recommendations and 12 priority research needs to integrate the ecosystem services approach into biodiversity conservation policy and funding were identified by a cross-disciplinary group of over 100 scientists and 50 stakeholders, including research funders and policy-makers. These recommendations focus on the ecological underpinning of ecosystem services, drivers that affect ecosystems and their services, biological traits and ecosystem services, the valuation of ecosystem services, spatial and temporal scales in ecosystem service assessment, indicators of ecosystem services, and habitat management, conservation policy and ecosystem services. The recommendations in this paper help steer the research agenda on ecosystem services into policy-relevant areas, agreed upon by funders, researchers and policy-makers. This research agenda will only succeed with increased collaboration between researchers across disciplines, thereby providing a challenge to the research community and research funders to work in new, interdisciplinary ways.

Asgedom, H. and E. Kebreab (2011). "Beneficial management practices and mitigation of greenhouse gas emissions in the agriculture of the Canadian Prairie: a review." Agronomy for Sustainable Development **31**(3): 433-451.
Category: Climate change
Keywords: *BMP, Canadian Prairie, cropping systems, GHG, livestock, pasture*

Abstract: Climate change is one of the main global issues of modern time. Ever

increasing demand for food/feed and the need for higher environmental standards require shaping of the agricultural activities toward ecological and more sustainable efficient systems. One of the principal ways of attaining higher productivity and environmental standards is identification and adoption of beneficial management practices (BMP) by reviewing the conventional agricultural activities. The BMP are agricultural practices that promote sustainable land stewardship and maintain/increase profitability of farms. The BMP are from both crop and animal production systems and tradeoffs between the two systems could provide several opportunities in reducing, removing and/or avoiding of greenhouse gases (GHG) emissions. Despite that, few reviews have presented them together. This review covers GHG emissions related to the BMP in the crop and animal production systems of farms relevant to Canadian Prairie. These BMP include: (1) use of inorganic N fertilizers, (2) livestock and feed management, (3) manure management, (4) cropping systems, (5) tillage practices and (6) improved pasture and grazing management. In addition, sources of variations, quantification methods and adoptability are discussed. Quantified GHG emissions from direct and indirect measurements of researches from Canada and other part of the world are included. Since most experiments are conducted under multiple biophysical scenarios while adopting various methodologies, summarizing the findings was difficult. The effect of BMP on GHG is determined by ecological processes. Such determinants are discussed and knowledge gaps are identified. Integration of crop and livestock production systems could further lead toward higher energy and resource use efficiency; hence less GHG emissions.

Ayanu, Y. Z., C. Conrad, T. Nauss, M. Wegmann and T. Koellner (2012). "Quantifying and Mapping Ecosystem Services Supplies and Demands: A Review of Remote Sensing Applications." Environmental Science & Technology **46**(16): 8529-8541.
Category: Ecosystem services
Keywords: *ecosystem services; mapping;*

Abstract: Ecosystems provide services necessary for the livelihoods and well-being of people. Quantifying and mapping supplies and demands of ecosystem services is essential for continuous monitoring of such services to support decision-making. Area-wide and spatially explicit mapping of ecosystem services based on extensive ground surveys is restricted to local scales and limited due to high costs. In contrast, remote sensing provides reliable area-wide data for quantifying and mapping ecosystem services at comparatively low costs, and with the option of fast, frequent, and continuous observations for monitoring. In this paper, we review relevant remote sensing systems, sensor types, and methods applicable in quantifying selected provisioning and regulatory services. Furthermore, opportunities, challenges, and future prospects in using remote sensing for supporting ecosystem services' quantification and mapping are discussed.

Baan, L., R. Alkemade and T. Koellner (2013). "Land use impacts on biodiversity in LCA: a global approach." The International Journal of Life Cycle Assessment **18**(6): 1216-1230.
Category: Agriculture-induced impacts

Keywords: *biodiversity, global characterization factors, land use, life cycle assessment, regionalization*

Abstract: Land use is a main driver of global biodiversity loss and its environmental relevance is widely recognized in research on life cycle assessment (LCA). The inherent spatial heterogeneity of biodiversity and its non-uniform response to land use requires a regionalized assessment, whereas many LCA applications with globally distributed value chains require a global scale. This paper presents a first approach to quantify land use impacts on biodiversity across different world regions and highlights uncertainties and research needs.

Badgley, C., J. Moghtader, E. Quintero, E. Zakem, M. J. Chappell, K. Aviles-Vazquez, A. Samulon and I. Perfecto (2007). "Organic agriculture and the global food supply." Renewable agriculture and food systems **22**(2): 86-108.

Category: Agroecology and agroecological practices; Policy

Keywords: *Organic agriculture, conventional agriculture, organic yields, global food supply, cover crop*

Abstract: The principal objections to the proposition that organic agriculture can contribute significantly to the global food supply are low yields and insufficient quantities of organically acceptable fertilizers. We evaluated the universality of both claims. For the first claim, we compared yields of organic versus conventional or low-intensive food production for a global dataset of 293 examples and estimated the average yield ratio (organic : non-organic) of different food categories for the developed and the developing world. For most food categories, the average yield ratio was slightly <1.0 for studies in the developed world and >1.0 for studies in the developing world. With the average yield ratios, we modeled the global food supply that could be grown organically on the current agricultural land base. Model estimates indicate that organic methods could produce enough food on a global per capita basis to sustain the current human population, and potentially an even larger population, without increasing the agricultural land base. We also evaluated the amount of nitrogen potentially available from fixation by leguminous cover crops used as fertilizer. Data from temperate and tropical agroecosystems suggest that leguminous cover crops could fix enough nitrogen to replace the amount of synthetic fertilizer currently in use. These results indicate that organic agriculture has the potential to contribute quite substantially to the global food supply, while reducing the detrimental environmental impacts of conventional agriculture. Evaluation and review of this paper have raised important issues about crop rotations under organic versus conventional agriculture and the reliability of grey-literature sources. An ongoing dialogue on these subjects can be found in the Forum editorial of this issue.

Baldi, A. and P. Batary (2011). "Spatial heterogeneity and farmland birds: different perspectives in Western and Eastern Europe." Ibis **153**(4): 875-876.

Category: Ecosystem services

Keywords: *Europe, farmland birds, wild biodiversity, ecosystem, vertebrata, agroecosystem, heterogeneity*

(no abstract)

Baldi, A. and P. Batary (2011). "The past and future of farmland birds in Hungary." Bird Study **58**(3): 365-377.

Category: Ecosystem services

Keywords: *Farmland birds, density, diversity, UK, Hungary, Europe, wild biodiversity*

Abstract: Capsule Populations of birds on farmland are larger and more stable in Hungary than in the UK and may provide baseline targets when planning population restoration programmes in more intensively farmed regions of Europe.

Aims: To review the available evidence on farmland bird populations and their changes over the past century in Hungary, and to compare this with similar data for the UK.

Methods: Published papers and grey literature were searched to determine long-term bird population trends for birds on farmland in Hungary, and for research evidence on the relationship between farmland management and bird diversity in Hungary.

Results: Population density of common farmland birds is higher and trends are more positive in Hungary compared to the UK. These findings correlate with the recent change to generally less intensive agriculture in Hungary. However, while the birdlife associated with farmland in Hungary can be considered to have high diversity and density, it is still lower than it was in the first half of the 20th century and earlier. The few studies available showed that low-intensity traditional management promotes a rich biodiversity in both grasslands and arable systems in Hungary. Agri-environment schemes were introduced when Hungary joined the EU in 2004; however, their influence on biodiversity has not been systematically monitored.

Conclusions: Insights emerging from farmland bird research in those European countries which still practice extensive agricultural techniques could be used to set general baseline targets for restoring biodiversity in regions where farmlands are now intensively managed. At the European scale urgent tasks are to: (1) investigate the relationships between management and bird diversity and density on a much wider geographical scale, (2) evaluate the geographical generality of the existing evidence base (which is mainly based on studies conducted in more intensively farmed regions), and (3) enhance the policy impact of conservation research.

Baldi, A., P. Batary and D. Kleijn (2013). "Effects of grazing and biogeographic regions on grassland biodiversity in Hungary - analysing assemblages of 1200 species." Agriculture, Ecosystems & Environment **166**(0): 28-34.

Category: Biodiversity benefits of ecological intensification

Keywords: *Agri-environment scheme, arthropod, assemblage composition, bird, Central Europe, plant Intensification, extensive farming*

Abstract: Agricultural intensification is a major threat to biodiversity. Agri-environment schemes, the main tools to counteract negative impacts of agriculture on the environment, are having mixed effects on biodiversity. One reason for this may be the limited number of species (groups) covered by most studies. Here, we compared species richness and abundance of 10 different species groups on

extensively (0.5 cattle/ha) and intensively (1.0–1.2 cattle/ha) grazed semi-natural pastures in 42 fields in three Hungarian regions. Plants, birds and arthropods (leafhoppers, true bugs, orthopterans, leaf-beetles, weevils, bees, carabids, spiders) were sampled. We recorded 347 plant species, 748 territories of 43 bird species, and 51,883 individuals of 808 arthropod species. Compared to West European farmlands, species richness was generally very high. Grazing intensity had minor effects on α and β diversity, abundance and composition of the species assemblages. Region had significant effects on species richness and abundance of four taxa, and had strong effects on β diversity and species composition of all taxa. Regional differences therefore contributed significantly to the high overall biodiversity. We conclude that both grazing regimes deliver significant biodiversity benefits. Agri-environmental policy at the EU level should promote the maintenance of large scale extensive farming systems. At the national level, the effectiveness of agri-environment schemes should be improved via promoting and using research evidence.

Balmford, A., L. Bennun, B. Ten Brink, D. Cooper, I. Cote, P. Crane, A. Dobson, N. Dudley, I. Dutton and R. Green (2005). "The Convention on Biological Diversity´s 2010 Target." Science **307**(5707): 212-213.

Category: Policy

Keywords: *Convention on Biological Diversity, Earth's biological diversity, biological, geophysical, and geochemical processes interact, scientific knowledge*

Abstract: Governments are often accused of responding only to short-term and parochial considerations. It is therefore remarkable that representatives of 190 countries recently committed themselves at the Convention on Biological Diversity to reducing biodiversity loss. This presents conservation biologists with perhaps their greatest challenge of the decade. The authors of this Policy Forum describe approaches to identifying more of the earth's biological diversity; understanding how biological, geophysical, and geochemical processes interact; and presenting scientific knowledge in time to contribute to and achieve the 2010 target.

Balvanera, P., A. Pfisterer, N. Buchmann, J.-S. He, T. Nakashizuka, D. Raffaelli and B. Schmid (2006). "Quantifying the evidence for biodiversity effects on ecosystem functioning and services." Ecology Letters **9**(10): 1146-1156.

Category: Ecosystem services

Keywords: *Biodiversity–ecosystem functioning, diversity manipulations, ecosystem property, ecosystem services, ecosystem type, experimental design, meta-analysis, stability, trophic level*

Abstract: Concern is growing about the consequences of biodiversity loss for ecosystem functioning, for the provision of ecosystem services, and for human well being. Experimental evidence for a relationship between biodiversity and ecosystem process rates is compelling, but the issue remains contentious. Here, we present the first rigorous quantitative assessment of this relationship through meta-analysis of experimental work spanning 50 years to June 2004. We analysed 446 measures of biodiversity effects (252 in grasslands), 319 of which involved primary producer manipulations or measurements. Our analyses show that: biodiversity effects are

weaker if biodiversity manipulations are less well controlled; effects of biodiversity change on processes are weaker at the ecosystem compared with the community level and are negative at the population level; productivity-related effects decline with increasing number of trophic links between those elements manipulated and those measured; biodiversity effects on stability measures ('insurance' effects) are not stronger than biodiversity effects on performance measures. For those ecosystem services which could be assessed here, there is clear evidence that biodiversity has positive effects on most. Whilst such patterns should be further confirmed, a precautionary approach to biodiversity management would seem prudent in the meantime.

Bangash, R., A. Passuello, M. Sanchez-Canales, M. Terrado, A. Lopez, F. Elorza, G. Ziv, V. Acuña and M. Schuhmacher (2013). "Ecosystem services in Mediterranean river basin: Climate change impact on water provisioning and erosion control." Science of The Total Environment **458-460**(0): 246-255.
Category: Climate change
Keywords: *Hydrological ecosystem services, ecosystem services mapping, water scarcity, sediment retention, climate change*

Abstract: The Mediterranean basin is considered one of the most vulnerable regions of the world to climate change and such changes impact the capacity of ecosystems to provide goods and services to human society. The predicted future scenarios for this region present an increased frequency of floods and extended droughts, especially at the Iberian Peninsula. This paper evaluates the impacts of climate change on the water provisioning and erosion control services in the densely populated Mediterranean Llobregat river basin of. The assessment of ecosystem services and their mapping at the basin scale identify the current pressures on the river basin including the source area in the Pyrenees Mountains. Drinking water provisioning is expected to decrease between 3 and 49%, while total hydropower production will decrease between 5 and 43%. Erosion control will be reduced by up to 23%, indicating that costs for dredging the reservoirs as well as for treating drinking water will also increase. Based on these data, the concept for an appropriate quantification and related spatial visualization of ecosystem service is elaborated and discussed.

Bardgett, R. (2005). The biology of soil: a community and ecosystem approach, Oxford University Press on Demand.
Category: Ecosystem services
Keywords: *Soil biota, ecosystems*

(no abstract)

Barrett, C. B., M. F. Bellemare and J. Y. Hou (2010). "Reconsidering conventional explanations of the inverse productivity-size relationship." World Development **38**(1): 88-97.
Category: Policy
Keywords: *Inverse relationship, productivity, market failures, soil characteristics, sub-Saharan Africa, Madagascar, smallscale agriculture*

Abstract: The inverse productivity–size relationship is one of the oldest puzzles in development economics. Two conventional explanations for the inverse relationship have emerged in the literature: (i) factor market imperfections that cause cross-sectional variation in household-specific shadow prices and (ii) the omission of soil quality measurements. This study employs precise soil quality measurements at the plot level with multiple plots per household so as to test both conventional explanations simultaneously. Empirical results show that only a small portion of the inverse productivity–size relationship is explained by market imperfections and none of it seems attributable to the omission of soil quality measurements.

Barrios, E. (2007). "Soil biota, ecosystem services and land productivity." Ecological Economics **64**(2): 269-285.

Category: Ecosystem services

Keywords: *Agriculture, ecosystem services, soil biodiversity, soil biological processes, soil, soil fertility, nutrient cycling, soil nutrients/cycling*

Abstract: The soil environment is likely the most complex biological community. Soil organisms are extremely diverse and contribute to a wide range of ecosystem services that are essential to the sustainable function of natural and managed ecosystems. The soil organism community can have direct and indirect impacts on land productivity. Direct impacts are those where specific organisms affect crop yield immediately. Indirect effects include those provided by soil organisms participating in carbon and nutrient cycles, soil structure modification and food web interactions that generate ecosystem services that ultimately affect productivity. Recognizing the great biological and functional diversity in the soil and the complexity of ecological interactions it becomes necessary to focus in this paper on soil biota that have a strong linkage to functions which underpin 'soil based' ecosystem services. Selected organisms from different functional groups (i.e. microsymbionts, decomposers, elemental transformers, soil ecosystem engineers, soil-borne pest and diseases, and microregulators) are used to illustrate the linkages of soil biota and ecosystem services essential to life on earth as well as with those associated with the provision of goods and the regulation of ecosystem processes. These services are not only essential to ecosystem function but also a critical resource for the sustainable management of agricultural ecosystems. Research opportunities and gaps related to methodological, experimental and conceptual approaches that may be helpful to address the challenge of linking soil biodiversity and function to the provision of ecosystem services and land productivity are discussed. These include: 1) integration of spatial variability research in soil ecology and a focus on 'hot spots' of biological activity, 2) using a selective functional group approach to study soil biota and function, 3) combining new and existing methodological approaches that link selected soil organisms, the temporal and spatial dynamics of their function, and their contribution to the provision of selected 'soil based' ecosystem services, 4) using understanding about hierarchical relationships to manage soil biota and function in cropping systems, 5) using local knowledge about plants as indicators of soil quality, remote sensing and GIS technologies, and plant-soil biota interactions to help understand the impacts of soil biota at landscape scale, and 6) developing land quality monitoring systems that inform land users about their land's ecosystem

service performance, improve capacities to predict and adapt to environmental changes, and support policy and decision-making.

Bartomeus, I. and R. Winfree (2013). "Pollinator declines: reconciling scales and implications for ecosystem services." F1000Research **2**(146).

Category: Ecosystem services

Keywords: *Pollination and ecosystem services, crop pollination, food security, pollination*

Abstract: Despite the widespread concern about the fate of pollinators and the ecosystem services they deliver, we still have surprisingly scarce scientific data on the magnitude of pollinator declines and its actual contribution to crop pollination and food security. We use recently published data from northeastern North America to show that studies at both the local and regional scales are needed to understand pollinator declines, and that species-specific responses to global change are broadly consistent across scales. Second, we show that bee species that are currently delivering most of the ecosystem services (i.e. crop pollination) are not among the species showing declining trends, but rather appear to thrive in human-dominated landscapes.

Batáry, P., A. Báldi, D. Kleijn and T. Tscharntke (2011). "Landscape-moderated biodiversity effects of agri- environmental management – a meta-analysis." Proceedings of the Royal Society B: Biological Sciences **278**: 1894–1902.

Category: Biodiversity benefits of ecological intensification

Keywords: *biodiversity benefits of ecological intensification, ecological intensification, agri-environment schemes, complex landscape, cropland, grassland, organic farming, simple landscape*

Abstract: Agri-environmental management (AEM) is heralded as being key to biodiversity conservation on farmland, yet results of these schemes have been mixed, making their general utility questionable. We test with meta-analysis whether the benefits of AEM for species richness and abundance of plants and animals are determined by the surrounding landscape context. Across all studies (109 observations for species richness and 114 observations for abundance), AEM significantly increased species richness and their abundance. More specifically, we test the hypothesis that AEM benefits species richness and abundance (i.e. increases the difference between fields with and without AEM) more in simple than in complex landscapes. In croplands, species richness but not abundance was significantly enhanced in simple but not in complex landscapes. In grasslands, AEM effectively enhanced species richness and abundance regardless of landscape context. Pollinators were significantly enhanced by AEM in simple but not in complex landscapes in both croplands and grasslands. Our results highlight that the one-size-fits-all approach of many agri-environmental programmes is not an efficient way of spending the limited funds available for biodiversity conservation on farmland. Therefore, we conclude that AEM should be adapted to landscape structure and the species groups at which they are targeted.

Baumgartner, S. (2007). "The insurance value of biodiversity in the provision of ecosystem services." Natural Resource Modeling **20**(1): 87-127.

Category: Ecosystem services

Keywords: *Biodiversity, ecosystem functioning, ecosystem services, insurance, risk aversion, uncertainty*

Abstract: Biodiversity provides insurance against the uncertain provision of ecosystem services which are being used by risk-averse economic agents. I present a conceptual ecological-economic model that combines (i) current results from ecology about the relationships between biodiversity, ecosystem functioning, and the provision of ecosystem services with (ii) economic methods to study decision-making under uncertainty. In this framework I (1) determine the insurance value of biodiversity, (2) study the optimal allocation of funds in the trade-off between investing into biodiversity protection and the purchase of financial insurance, and (3) analyze the effect of different institutional regimes in the market for fi- nancial insurance on biodiversity protection. I conclude that biodiversity acts as a form of natural insurance for risk-averse ecosystem managers against the over- or under-provision with ecosystem services. Therefore, biodiversity has an insurance value, which is a value component in addition to the usual value arguments, such as direct or indirect use or non-use val- ues. In this respect, biodiversity and financial insurance are substitutes. Hence, the availability, and exact institutional de- sign, of financial insurance influence the level of biodiversity protection.

Beddington, J., M. Asaduzzaman, M. Clark, A. Bremauntz, M. Guillou, D. Howlett, M. Jahn, E. Lin, T. Mamo and C. Negra (2012). "What next for agriculture after Durban?" Science **335**: 289-290.

Category: Climate change

Keywords: *Agriculture, climate change, Durban, FCCC, sustainable intensification, climate-smart agriculture*

Abstract: Global agriculture must produce more food to feed a growing population. Yet scientif ic assessments point to climate change as a growing threat to agricul- tural yields and food security (1–4). Recent droughts and floods in the Horn of Africa, Russia, Pakistan, and Australia affected food production and prices. The Intergovernmental Panel on Climate Change predicts that the frequency of such extreme weather events will increase (5), which, when combined with poverty, weak governance, conflict, and poor market access, can result in hunger and famine. At the same time, agriculture exacerbates climate change when greenhouse gases (GHGs) are released by land clearing, inappropriate fertilizer use, and other practices (6).

Benayas, J. M. R., A. C. Newton, A. Diaz and J. M. Bullock (2009). "Enhancement of biodiversity and ecosystem services by ecological restoration: a meta-analysis." Science **325**(5944): 1121-1124.

Category: Biodiversity benefits of ecological intensification

Keywords: *ecological restoration, ecosystem services, meta-analysis, biodiversity*

Abstract: Ecological restoration is widely used to reverse the environmental

degradation caused by human activities. However, the effectiveness of restoration actions in increasing provision of both biodiversity and ecosystem services has not been evaluated systematically. A meta-analysis of 89 restoration assessments in a wide range of ecosystem types across the globe indicates that ecological restoration increased provision of biodiversity and ecosystem services by 44 and 25%, respectively. However, values of both remained lower in restored versus intact reference ecosystems. Increases in biodiversity and ecosystem service measures after restoration were positively correlated. Results indicate that restoration actions focused on enhancing biodiversity should support increased provision of ecosystem services, particularly in tropical terrestrial biomes.

Bengtsson, J. (2010). Applied (meta) community ecology: diversity and ecosystem services at the intersection of local and regional processes. Community Ecology. P. J. Morin and H. A. Verhoef, Oxford Univ. Press**:** 115-130.

Category: Ecosystem services

Keywords: *Biodiversity, community ecology, evolution, food webs, networks, population dynamics*

Abstract: It is argued that community ecology should provide useful knowledge for managing ecological interactions and biological resources sustainably. In the context of managing biodiversity and ecosystem services in human-dominated landscapes, a theoretical and historical background to metacommunity ecology (Chapter 5) is presented and some case studies showing the interplay between theory and applied questions in agricultural landscape ecology are discussed. Several expectations from metacommunity theory on the effects of land use intensification are suggested, based on the fact that both local and regional processes are important for diversity and ecosystem functioning. Some rules of thumb for landscape management based on metacommunity theory and empirical studies are suggested: maintain local conditions by management; manage whole landscapes and not only single patches; maintain diversity of local conditions in region; maintain connections between patches without homogenizing landscape; maintain disturbance regimes close to natural.

Bengtsson, J., J. Ahnstrom and A. C. Weibull (2005). "The effects of organic agriculture on biodiversity and abundance: a meta-analysis." Journal of applied ecology **42**(2): 261-269.

Category: Biodiversity benefits of ecological intensification

Keywords: *Density; diversity; farming systems,; organic farming; species richness;*

Abstract:

1. The efficiency of agricultural subsidy programmes for preserving biodiversity and improving the environment has been questioned in recent years. Organic farming operates without pesticides, herbicides and inorganic fertilizers, and usually with a more diverse crop rotation. It has been suggested that this system enhances biodiversity in agricultural landscapes. We analysed the effects of organic farming on species richness and abundance using meta-analysis of literature published before December 2002.

2. Organic farming usually increases species richness, having on average 30% higher

species richness than conventional farming systems. However, the results were variable among studies, and 16% of them actually showed a negative effect of organic farming on species richness. We therefore divided the data into different organism groups and according to the spatial scale of the study.
3. Birds, insects and plants usually showed an increased species richness in organic farming systems. However, the number of studies was low in most organism groups (range 2–19) and there was significant heterogeneity between studies. The effect of organic farming was largest in studies performed at the plot scale. In studies at the farm scale, when organic and conventional farms were matched according to landscape structure, the effect was significant but highly heterogeneous.
4. On average, organisms were 50% more abundant in organic farming systems, but the results were highly variable between studies and organism groups. Birds, predatory insects, soil organisms and plants responded positively to organic farming, while non-predatory insects and pests did not. The positive effects of organic farming on abundance were prominent at the plot and field scales, but not for farms in matched landscapes.
5. Synthesis and applications. Our results show that organic farming often has positive effects on species richness and abundance, but that its effects are likely to differ between organism groups and landscapes. We suggest that positive effects of organic farming on species richness can be expected in intensively managed agricultural landscapes, but not in small-scale landscapes comprising many other biotopes as well as agricultural fields. Measures to preserve and enhance biodiversity should be more landscape- and farm- specific than is presently the case.

Bennett, G. Peterson and L. Gordon (2009). "Understanding relationships among multiple ecosystem services." Ecology Letters **12**(12): 1394-1404.
Category: Ecosystem services
Keywords: *Ecosystem services, ecosystem management, resilience, social-ecological systems*

Abstract: Ecosystem management that attempts to maximize the production of one ecosystem service often results in substantial declines in the provision of other ecosystem services. For this reason, recent studies have called for increased attention to development of a theoretical understanding behind the relationships among ecosystem services. Here, we review the literature on ecosystem services and propose a typology of relationships between ecosystem services based on the role of drivers and the interactions between services. We use this typology to develop three propositions to help drive ecological science towards a better understanding of the relationships among multiple ecosystem services. Research which aims to understand the relationships among multiple ecosystem services and the mechanisms behind these relationships will improve our ability to sustainably manage landscapes to provide multiple ecosystem services.

Bennett, A., G. Bending, D. Chandler, S. Hilton and P. Mills (2012). "Meeting the demand for crop production: the challenge of yield decline in crops grown in short rotations." Biological Reviews **87**(1): 52-71.
Category: Agroecology and agroecological practices

Keywords: *Continuous cropping, crop rotation, monoculture, replant disease, replant problem, rotation effect, soil sickness, sustainable agriculture, yield*

Abstract: There is a trend world-wide to grow crops in short rotation or in monoculture, particularly in conventional agriculture. This practice is becoming more prevalent due to a range of factors including economic market trends, technological advances, government incentives, and retailer and consumer demands. Land-use intensity will have to increase further in future in order to meet the demands of growing crops for both bioenergy and food production, and long rotations may not be considered viable or practical. However, evidence indicates that crops grown in short rotations or monoculture often suffer from yield decline compared to those grown in longer rotations or for the first time. Numerous factors have been hypothesised as contributing to yield decline, including biotic factors such as plant pathogens, deleterious rhizosphere microorganisms, mycorrhizas acting as pathogens, and allelopathy or autotoxicity of the crop, as well as abiotic factors such as land management practices and nutrient availability. In many cases, soil microorganisms have been implicated either directly or indirectly in yield decline. Although individual factors may be responsible for yield decline in some cases, it is more likely that combinations of factors interact to cause the problem. However, evidence confirming the precise role of these various factors is often lacking in field studies due to the complex nature of cropping systems and the numerous interactions that take place within them. Despite long-term knowledge of the yield-decline phenomenon, there are few tools to counteract it apart from reverting to longer crop rotations or break crops. Alternative cropping and management practices such as double-cropping or inter-cropping, tillage and organic amendments may prove valuable for combating some of the negative effects seen when crops are grown in short rotation. Plant breeding continues to be important, although this does require a specific breeding target to be identified. This review identifies gaps in our understanding of yield decline, particularly with respect to the complex interactions occurring between the different components of agro-ecosystems, which may well influence food security in the 21st Century.

Benton, T., D. Bryant, L. Cole and H. Crick (2002). "Linking agricultural practice to insect and bird populations: a historical study over three decades." Journal of applied ecology **39**(4): 673-687.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Farming, farmland, generalized additive models, population trend, suction trap*

Abstract:

1.There is continuing debate about the impact of agricultural practices on farmland wildlife. In particular, it has been postulated that a general decline in insect abundance linked with intensification of agriculture may have contributed to farmland bird decline. While some autecological studies have supported this hypothesis, larger-scale and long-term studies are needed.

2. Suction traps mounted on 12·2-m towers (Rothamsted-type) have been sampling aerial insects for nearly 40 years throughout the UK. Their catches are correlated over large spatial scales. We analysed insect catch data from a single suction trap run for 27 years in a rural location in Scotland, and showed that insect numbers have

changed significantly over time, although non-linearly. The multivariate data set (numbers from the 12 common arthropod groups) was summarized using principal components analysis (PCA) to extract three components explaining 62% of the variation.
3. We also used PCA to describe agricultural change, using published agricultural data for eight measures of farming in Scotland. Arthropod abundance and principal component (PC) scores were significantly related to the agricultural PC scores as well to summary climatic measures.
4. Using Scottish data from the British Trust for Ornithology Common Birds Census, we extracted three PC to describe the time-dependent average densities of 15 common farmland birds in Scotland. Measures of bird density were significantly related to insect abundance and PC scores and, independently, to measures of agriculture and climate.
5. These data from a broad suite of species provide support for linked temporal change between farmland birds, invertebrate numbers and agricultural practice in Scotland. Although entirely correlative, the results are consistent with the view that agricultural change has influenced birds through changes in food quality or quantity. The work also shows how large-scale invertebrate sampling, in this case using suction traps, is useful for monitoring farmland biodiversity.

Benton, T., J. Vickery and J. Wilson (2003). "Farmland biodiversity: is habitat heterogeneity the key?" Trends in ecology & evolution **18**(4): 182-188.
Category: Ecosystem services
Keywords: *Review, temperate zone, ecological recovery, cultural practice, agroecosystem, ecological damage, heterogeneity, habitat, biodiversity, loss, wild biodiversity*
Abstract: Agricultural intensification has led to a widespread decline in farmland biodiversity measured across many different taxa. The changes in agricultural practices affect many different aspects of the farmland habitat, but agricultural industry, policy and much previous research has tended to be concerned with specific sectors or practices (e.g. pesticide use or cereal husbandry). Here, we review the empirical literature to synthesize the research effort that has been directed to investigate specific practices or goals to make general statements regarding the causes and consequences of farmland biodiversity decline. We argue that the loss of ecological heterogeneity at multiple spatial and temporal scales is a universal consequence of multivariate agricultural intensification and, therefore, that future research should develop cross-cutting policy frameworks and management solutions that recreate that heterogeneity as the key to restoring and sustaining biodiversity in temperate agricultural systems.

Bergez, J. E., N. Colbach, O. Crespo, F. Garcia, M. H. Jeuffroy, E. Justes, C. Loyce, N. Munier-Jolain and W. Sadok (2010). "Designing crop management systems by simulation." European Journal of Agronomy **32**(1): 3-9.
Category: Agroecology and agroecological practices
Keywords: *Design, simulation, crop management system, modelling, evaluation*
Abstract: To help agricultural advisors to propose innovative crop management

systems, simulation models can be a complementary tool to field experiments and prototyping. Crop management systems can be modelled either by using a vector representing dates and quantities used as input parameters in crop models or by developing specific decision models linked with biophysical models. The general design process of crop management systems by simulation follows a four-step loop (GSEC): (i) generation; (ii) simulation; (iii) evaluation; (iv) comparison and choice. The Generation step can follow different approaches: from blind generation before simulation to optimization procedures using artificial intelligence algorithms during the loop process. Simulation is mainly an engineering problem. Evaluation process means assigning a vector of indicators to the simulated crop management systems. A three-point evaluation can be carried out on the simulated crop management systems: global, agronomic and analytical. Comparison and choice of different simulated crop management systems raise the question of "monetary" versus "non-monetary" comparison and how to aggregate different quantities such as drainage, nitrogen fertilisers, labour, etc. Different examples are given to illustrate the GSEC loop on the basis of research programs conducted in France. Methodological advances and challenges are then discussed.

Bezemer, T. M., G. B. De Deyn, T. M. Bossinga, N. M. Van Dam, J. A. Harvey and W. H. Van der Putten (2005). "Soil community composition drives aboveground plant–herbivore–parasitoid interactions." Ecology Letters **8**(6): 652-661.

Category: Ecosystem services

Keywords: *Aboveground–belowground interactions, aphid, Aphidius colemani, fitness, herbivory, microcosm, nematode, parasitoid, Rhopalosiphum padi*

Abstract: Soil organisms can influence higher trophic level aboveground organisms, but only very few studies have considered such effects. We manipulated soil community composition of model grassland ecosystems by introducing nematode communities, microorganisms, neither or both groups. Above ground, aphids (Rhopalosiphum padi) and parasitoids (Aphidius colemani) were introduced, and we measured individual performance and population dynamics of plants, aphids and parasitoids. In microcosms with nematode inoculations either with or without microorganism inoculation, aphids offspring production was significantly reduced by 31%. Aphid populations on both host plants Agrostis capillaris and Anthoxanthum odoratum were lowest in microcosms with combined nematode and microorganism inoculations. Opposite results were found for parasitoids. While the number of emerged parasitoids did not differ between treatments, parasitoid mortality and the proportion of males were significantly lower in microcosms with nematode and microorganism inoculations. Parasitized aphids were significantly larger in microcosms with nematodes inoculated. Plant biomass did not differ, but in the preferred host plant A. odoratum, foliar phenolic content was reduced in the presence of nematodes, and also the concentration of amino acids in the phloem. This study shows that the composition of the soil community matters for aboveground multitrophic interactions.

Bezemer, T. M., M. T. Fountain, J. M. Barea, S. Christensen, S. C. Dekker, H. Duyts, R. van

Hal, J. A. Harvey, K. Hedlund, M. Maraun, J. Mikola, A. G. Mladenov, C. Robin, P. C. de Ruiter, S. Scheu, H. Setala, P. Å milauer and W. H. van der Putten (2010). "Divergent composition but similar function of soil food webs of individual plants: plant species and community effects." Ecology **91**(10): 3027-3036.

Category: Ecosystem services

Keywords: *Plantaginaceae, Spermatophyta, Angiospermae, Dicotyledones, Leguminosae, fauna, Plantago lanceolata, Lotus corniculatus, biocenosis, biota, microfauna ; macrofauna, models, ecosystem functioning, biodiversity, plant community, food web, soils, composition*

Abstract: Soils are extremely rich in biodiversity, and soil organisms play pivotal roles in supporting terrestrial life, but the role that individual plants and plant communities play in influencing the diversity and functioning of soil food webs remains highly debated. Plants, as primary producers and providers of resources to the soil food web, are of vital importance for the composition, structure, and functioning of soil communities. However, whether natural soil food webs that are completely open to immigration and emigration differ underneath individual plants remains unknown. In a biodiversity restoration experiment we first compared the soil nematode communities of 228 individual plants belonging to eight herbaceous species. We included grass, leguminous, and non-leguminous species. Each individual plant grew intermingled with other species, but all plant species had a different nematode community. Moreover, nematode communities were more similar when plant individuals were growing in the same as compared to different plant communities, and these effects were most apparent for the groups of bacterivorous, carnivorous, and omnivorous nematodes. Subsequently, we analyzed the composition, structure, and functioning of the complete soil food webs of 58 individual plants, belonging to two of the plant species, Lotus corniculatus (Fabaceae) and Plantago lanceolata (Plantaginaceae). We isolated and identified more than 150 taxa/groups of soil organisms. The soil community composition and structure of the entire food webs were influenced both by the species identity of the plant individual and the surrounding plant community. Unexpectedly, plant identity had the strongest effects on decomposing soil organisms, widely believed to be generalist feeders. In contrast, quantitative food web modeling showed that the composition of the plant community influenced nitrogen mineralization under individual plants, but that plant species identity did not affect nitrogen or carbon mineralization or food web stability. Hence, the composition and structure of entire soil food webs vary at the scale of individual plants and are strongly influenced by the species identity of the plant. However, the ecosystem functions these food webs provide are determined by the identity of the entire plant community.

Bianchi, F., C. Booij and T. Tscharntke (2006). "Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control." Proceedings of the Royal Society B: Biological Sciences **273**(1595): 1715-1727.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *agroecosystems, biological control, ecosystem functioning, landscape, diversity, parasitoid, predator, pest regulation*

Abstract: Agricultural intensification has resulted in a simplification of agricultural

landscapes by the expansion of agricultural land, enlargement of field size and removal of non-crop habitat. These changes are considered to be an important cause of the rapid decline in farmland biodiversity, with the remaining biodiversity concentrated in field edges and non-crop habitats. The simplification of landscape composition and the decline of biodiversity may affect the functioning of natural pest control because non-crop habitats provide requisites for a broad spectrum of natural enemies, and the exchange of natural enemies between crop and non-crop habitats is likely to be diminished in landscapes dominated by arable cropland. In this review, we test the hypothesis that natural pest control is enhanced in complex patchy landscapes with a high proportion of non-crop habitats as compared to simple large-scale landscapes with little associated non- crop habitat. In 74% and 45% of the studies reviewed, respectively, natural enemy populations were higher and pest pressure lower in complex landscapes versus simple landscapes. Landscape-driven pest suppression may result in lower crop injury, although this has rarely been documented. Enhanced natural enemy activity was associated with herbaceous habitats in 80% of the cases (e.g. fallows, field margins), and somewhat less often with wooded habitats (71%) and landscape patchiness (70%). The similar contributions of these landscape factors suggest that all are equally important in enhancing natural enemy populations. We conclude that diversified landscapes hold most potential for the conservation of biodiversity and sustaining the pest control function.

Biesmeijer, J., S. Roberts, M. Reemer, R. Ohlemuller, M. Edwards, T. Peeters, A. Schaffers, S. Potts, R. Kleukers, C. Thomas, J. Settele and W. Kunin (2006). "Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands." Science **313**(5785): 351-354.
Category: Ecosystem services
Keywords: *Pollinators, pollination services, declines, Britain, Netherlands*

Abstract: Despite widespread concern about declines in pollination services, little is known about the patterns of change in most pollinator assemblages. By studying bee and hoverfly assemblages in Britain and the Netherlands, we found evidence of declines (pre-versus post-1980) in local bee diversity in both countries; however, divergent trends were observed in hoverflies. Depending on the assemblage and location, pollinator declines were most frequent in habitat and flower specialists, in univoltine species, and/or in nonmigrants. In conjunction with this evidence, outcrossing plant species that are reliant on the declining pollinators have themselves declined relative to other plant species. Taken together, these findings strongly suggest a causal connection between local extinctions of functionally linked plant and pollinator species.

Birkhofer, K., T. M. Bezemer, J. Bloem, M. Bonkowski, S. Christensen, D. Dubois, F. Ekelund, A. Fliesbach, L. Gunst, K. Hedlund, P. Mader, J. Mikola, C. Robin, H. Setala, F. Tatin-Froux, W. Van der Putten and S. Scheu (2008). "Long-term organic farming fosters below and aboveground biota: Implications for soil quality, biological control and productivity." Soil Biology and Biochemistry **40**(9): 2297-2308.
Category: Ecosystem services

Keywords: *DOK trial, ecosystem functioning, farming system, fertilization, generalist predators, microbial community, nutrient cycling, natural enemies, soil fauna, soil quality, sustainability*

Abstract: Organic farming may contribute substantially to future agricultural production worldwide by improving soil quality and pest control, thereby reducing environmental impacts of conventional farming. We investigated in a comprehensive way soil chemical, as well as below and aboveground biological parameters of two organic and two conventional wheat farming systems that primarily differed in fertilization and weed management strategies. Contrast analyses identified management related differences between "herbicide-free" bioorganic (BIOORG) and biodynamic (BIODYN) systems and conventional systems with (CONFYM) or without manure (CONMIN) and herbicide application within a long-term agricultural experiment (DOK trial, Switzerland). Soil carbon content was significantly higher in systems receiving farmyard manure and concomitantly microbial biomass (fungi and bacteria) was increased. Microbial activity parameters, such as microbial basal respiration and nitrogen mineralization, showed an opposite pattern, suggesting that soil carbon in the conventional system (CONFYM) was more easily accessible to microorganisms than in organic systems. Bacterivorous nematodes and earthworms were most abundant in systems that received farmyard manure, which is in line with the responses of their potential food sources (microbes and organic matter). Mineral fertilizer application detrimentally affected enchytraeids and Diptera larvae, whereas aphids benefited. Spider abundance was favoured by organic management, most likely a response to increased prey availability from the belowground subsystem or increased weed coverage. In contrast to most soil-based, bottom-up controlled interactions, the twofold higher abundance of this generalist predator group in organic systems likely contributed to the significantly lower abundance of aboveground herbivore pests (aphids) in these systems. Long-term organic farming and the application of farmyard manure promoted soil quality, microbial biomass and fostered natural enemies and ecosystem engineers, suggesting enhanced nutrient cycling and pest control. Mineral fertilizers and herbicide application, in contrast, affected the potential for top-down control of aboveground pests negatively and reduced the organic carbon levels. Our study indicates that the use of synthetic fertilizers and herbicide application changes interactions within and between below and aboveground components, ultimately promoting negative environmental impacts of agriculture by reducing internal biological cycles and pest control. On the contrary, organic farming fosters microbial and faunal decomposers and this propagates into the aboveground system via generalist predators thereby increasing conservation biological control. However, grain and straw yields were 23% higher in systems receiving mineral fertilizers and herbicides reflecting the trade-off between productivity and environmental responsibility.

Bjorklund, J., K. Limburg and T. Rydberg (1999). "Impact of production intensity on the ability of the agricultural landscape to generate ecosystem services: an example from Sweden." Ecological Economics **29**(2): 269-291.
Category: Agroecology and agroecological practices
Keywords: *Ecosystem services, agricultural intensification, landscape mosaic, biodiversity,*

ecosystem function, land use, environmental support system

Abstract: This paper identifies a number of essential ecosystem services, and estimates their generation by the Swedish agricultural landscape under different production intensities. This is exemplified with data from a low-intensity period (1950s) and a high-intensity one (1990s). The services are described in qualitative and, to the extent possible, quantitative terms, and the ecological functions that support these services are identified. About 20% of Swedish agricultural land has been removed from production during the past 40 years. Production has been strongly intensified with respect to external inputs, and specialized regionally. Local landscape mosaics have been substantially altered, which resulted in a decreased ability of agricultural landscapes to support natural ecosystem components and processes. We argue that all of these changes affect the ability of the landscape to generate ecosystem services. Local, ecological 'goods and services' have largely been replaced by fossil fuel driven technology and the regulation of the system is now driven much more by external factors. However, there is no notable change in the system's ability to assimilate solar energy, measured by net primary production (NPP) and corrected for the cost of production (external inputs considered as foregone NPP). Most of the measures we derive indicate a loss of ecosystem services from the Swedish agricultural landscape. This is tantamount to losing an important form of 'local ecological insurance', and could lead to serious problems in a future with lower access to external resources, or with an altered energy policy.

Blake, R. J., D. B. Westbury, B. A. Woodcock, P. Sutton and S. G. Potts (2012). "Enhancement of buffer strips can improve provision of multiple ecosystem services." Outlooks on Pest Management **23**(6): 258-262.

Category: Agriculture-induced impacts

Keywords: *agri-environment schemes; bumblebees; butterflies; buffer strips; ecosystem services; graminicide; spiders; pest control; pollination; pest regulation*

Abstract: Agricultural intensification has resulted in a simplification of agricultural landscapes by the expansion of agricultural land, enlargement of field size and removal of non-crop habitat. These changes are considered to be an important cause of the rapid decline in farmland biodiversity, with the remaining biodiversity concentrated in field edges and non-crop habitats. The simplification of landscape composition and the decline of biodiversity may affect the functioning of natural pest control because non-crop habitats provide requisites for a broad spectrum of natural enemies, and the exchange of natural enemies between crop and non-crop habitats is likely to be diminished in landscapes dominated by arable cropland. In this review, we test the hypothesis that natural pest control is enhanced in complex patchy landscapes with a high proportion of non-crop habitats as compared to simple large-scale landscapes with little associated non- crop habitat. In 74% and 45% of the studies reviewed, respectively, natural enemy populations were higher and pest pressure lower in complex landscapes versus simple landscapes. Landscape-driven pest suppression may result in lower crop injury, although this has rarely been documented. Enhanced natural enemy activity was associated with herbaceous habitats in 80% of the cases (e.g. fallows, field margins), and somewhat less often with wooded habitats (71%) and landscape patchiness (70%). The similar

contributions of these landscape factors suggest that all are equally important in enhancing natural enemy populations. We conclude that diversified landscapes hold most potential for the conservation of biodiversity and sustaining the pest control function.

Blitzer, E., C. Dormann, A. Holzschuh, A. M. Klein, T. Rand and T. Tscharntke (2012). "Spillover of functionally important organisms between managed and natural habitats." Agriculture, Ecosystems & Environment **146**(1): 34-43.

Category: Ecosystem services

Keywords: *Edge effects, herbivory, mosaic landscapes, pollination, seed dispersal, pest regulation*

Abstract: Land-use intensification has led to a landscape mosaic that juxtaposes human-managed and natural areas. In such human-dominated and heterogeneous landscapes, spillover across habitat types, especially in systems that differ in resource availability, may be an important ecological process structuring communities. While there is much evidence for spillover from natural habitats to managed areas, little attention has been given to flow in the opposite direction. This paper synthesizes studies published to date from five functionally important trophic groups, herbivores, pathogens, pollinators, predators, and seed dispersers, and discusses evidence for spillover from managed to natural systems in all five groups. For each of the five focal groups, studies in the natural to managed direction are common, often with multiple review articles on each subject which document dozens of examples. In contrast, the number of studies which examine movement in the managed to natural direction is generally less than five studies per trophic group. These findings suggest that spillover in the managed to natural direction has been largely underestimated. As habitat modification continues, resulting in increasingly fragmented landscapes, the likelihood and size of any spillover effect will only increase.

Bommarco, R., S. Firle and B. Ekbom (2007). "Outbreak suppression by predators depends on spatial distribution of prey." Ecological Modelling **201**(2): 163-170.

Category: Ecosystem services

Keywords: *Aphididae, Rhopalosiphum padi, Carabidae, Pest control, Foraging behavior, pest regulation*

Abstract: The capacity of a predator population to suppress a prey population that varies in abundance and spatial distribution is explored in a lattice simulation model. The model is based on empirically derived parameters for particular species. Within season predation by Pterostichus cupreus (Coleoptera: Carabidae) of varying densities and distributions of the prey Rhopalosiphum padi (Homoptera: Aphididae) in spring cereals was simulated. From these spatially explicit simulations prey population suppression was found to be largely dependent on the spatial distribution of the prey. A possible mechanism was that high degrees of prey aggregation provided refuge for the prey that, when aggregated, escaped detection by P. cupreus. In contrast, P. cupreus was found to efficiently suppress incipient outbreaks for evenly distributed prey populations, even at high prey densities. A

higher predator density compensated for the lowered control ability of the predators for highly aggregated prey populations and hastened the decline of the prey population.

Bommarco, R., D. Kleijn and S. Potts (2013). "Ecological intensification: harnessing ecosystem services for food security." Trends in ecology & evolution **28**(4): 230-238.
Category: Ecosystem services
Keywords: *Green revolution, ecological intensification, ecosystem services, supporting and regulating services, food security, biodiversity conservation, pollination, pest control, soil nutrients, soil fertility, pest regulation, soil nutrients/cycling*

Abstract: Rising demands for agricultural products will increase pressure to further intensify crop production, while negative environmental impacts have to be minimized. Ecological intensification entails the environmentally friendly replacement of anthropogenic inputs and/or enhancement of crop productivity, by including regulating and supporting ecosystem services management in agricultural practices. Effective ecological intensification requires an understanding of the relations between land use at different scales and the community composition of ecosystem service-providing organisms above and below ground, and the flow, stability, contribution to yield, and management costs of the multiple services delivered by these organisms. Research efforts and investments are particularly needed to reduce existing yield gaps by integrating context-appropriate bundles of ecosystem services into crop production systems.

Bommarco, R., O. Lundin, H. G. Smith and M. Rundlof (2011). "Drastic historic shifts in bumble-bee community composition in Sweden." Proceedings of the Royal Society B: Biological Sciences **279**(1727): 309-315.
Category: Ecosystem services
Keywords: *Bombus spp., ecosystem service, pollination, Trifolium pratense, red clover*

Abstract: The species richness of flower-visiting insects has declined in past decades, raising concerns that the ecosystem service they provide by pollinating crops and wild plants is threatened. The relative commonness of different species with shared ecological traits can play a pervasive role in determining ecosystem functioning, but information on changes in abundances of pollinators over time is lacking. We gathered data on relative abundances of bumble-bee species in Swedish red clover fields during three periods in the last 70 years (1940s, 1960s and present), and on clover seed yields since 1921. We found drastic decreases in bumble-bee community evenness, with potential consequences for level and stability of red clover seed yield. The relative abundances of two short-tongued bumble-bees have increased from 40 per cent in the 1940s to entirely dominate present communities with 89 per cent. Average seed yield declined in recent years and variation in yield doubled, suggesting that the current dependence on few species for pollination has been especially detrimental to stability in seed yield. Our results suggest a need to develop management schemes that promote not only species-rich but also more evenly composed communities of service-providing organisms.

Bommarco, R., L. Marini and B. Vaissiere (2012). "Insect pollination enhances seed yield, quality, and market value in oilseed rape." Oecologia **169**(4): 1025-1032.

Category: Ecosystem services

Keywords: *Brassica napus, pollination, honey bee, hoverflies, landscape heterogeneity*

Abstract: The relationships between landscape intensification, the abundance and diversity of pollinating insects, and their contributions to crop yield, quality, and market value are poorly studied, despite observed declines in wild and domesticated pollinators. Abundance and species richness of pollinating insects were estimated in ten fields of spring oilseed rape, Brassica napus var. SW Stratos™, located along a gradient of landscape compositions ranging from simple landscapes dominated by arable land to heterogeneous landscapes with extensive cover of semi-natural habitats. In each field, we assessed the contribution of wind and insect pollination to seed yield, seed quality (individual seed weight and oil and chlorophyll contents), and market value in a block experiment with four replicates and two treatments: (1) all flowers were accessible to insects, self and wind pollination, and (2) flowers enclosed in tulle net bags (mesh: 1 × 1 mm) were accessible only to wind and self pollination. Complex landscapes enhanced the overall abundance of wild insects as well as the abundance and species richness of hoverflies. This did not translate to a higher yield, probably due to consistent pollination by honey bees across all fields. However, the pollination experiment showed that insects increased seed weight per plant by 18% and market value by 20%. Seed quality was enhanced by insect pollination, rendering heavier seeds as well as higher oil and lower chlorophyll contents, clearly showing that insect pollination is required to reach high seed yield and quality in oilseed rape. Our study demonstrates considerable and previously underestimated contributions from pollinating insects to both the yield and the market value of oilseed rape.

Bommarco, R., F. Miranda, H. Bylund and C. Bjorkman (2011). "Insecticides Suppress Natural Enemies and Increase Pest Damage in Cabbage." Journal of Economic Entomology **104**(3): 782-791.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Nicaragua, Brassicae oleracea, Plutella xylostella, Diadegma insulare, Polybia sp, pest control, pest regulation*

Abstract: Intensive use of pesticides is common and increasing despite a growing and historically well documented awareness of the costs and hazards. The benefits from pesticides of increased yields from sufficient pest control may be outweighed by developed resistance in pests and killing of beneficial natural enemies. Other negative effects are human health problems and lower prices because of consumers' desire to buy organic products. Few studies have examined these trade-offs in the field. Here, we demonstrate that Nicaraguan cabbage (Brassica spp.) farmers may suffer economically by using insecticides as they get more damage by the main pest diamondback moth, Plutella xylostella (L.) (Lepidoptera: Plutellidae), at the same time as they spend economic resources on insecticides. Replicated similarly sized cabbage fields cultivated in a standardized manner were either treated with insecticides according common practice or not treated with insecticides over two

seasons. Fields treated with insecticides suffered, compared with nontreated fields, equal or, at least in some periods of the seasons, higher diamondback moth pest attacks. These fields also had increased leaf damage on the harvested cabbage heads. Weight and size of the heads were not affected. The farmers received the same price on the local market irrespective of insecticide use. Rates of parasitized diamondback moth were consistently lower in the treated fields. Negative effects of using insecticides against diamondback moth were found for the density of parasitoids and generalist predatory wasps, and tended to affect spiders negatively. The observed increased leaf damages in insecticide-treated fields may be a combined consequence of insecticide resistance in the pest, and of lower predation and parasitization rates from naturally occurring predators that are suppressed by the insecticide applications. The results indicate biological control as a viable and economic alternative pest management strategy, something that may be particularly relevant for the production of cash crops in tropical countries where insecticide use is heavy and possibly increasing.

Boody, G., B. Vondracek, D. Andow, M. Krinke, J. Westra, J. Zimmerman and P. Welle (2005). "Multifunctional agriculture in the United States." BioScience **55**(1): 27-38.

Category: Ecosystem services; Policy

Keywords: *Suspended sediment ,nutrient runoff, greenhouse gases, carbon sequestration, farm policy*

Abstract: We evaluated possible changes to current farming practices in two Minnesota watersheds to provide insight into how farm policy might affect environmental, social, and economic outcomes. Watershed residents helped develop four scenarios to evaluate alternative future trends in agricultural management and to project potential economic and environmental outcomes. We found that environmental and economic benefits can be attained through changes in agricultural land management without increasing public costs. The magnitude of these benefits depends on the magnitude of changes to agricultural practices. Environmental benefits include improved water quality, healthier fish, increased carbon sequestration, and de- creased greenhouse gas emissions, while economic benefits include social capital formation, greater farm profitability, and avoided costs. Policy transitions that emphasize functions of agriculture in addition to food production are crucial for creating change. We suggest that redirecting farm payments by using alternative incentives could lead to substantial environmental changes at little or no extra cost to the taxpayer.

Bot, A. and B. Benites (2005). The importance of soil organic matter. Key to drought-resistant soil and sustained food production. FAO SOILS BULLETIN Rome.

Category: Agroecology and agroecological practices

Keywords: *Soil organic matter, drought resistant soil, conservation agriculture, food production, organic matter deposition, carbon sequestration*

Abstract: Soil organic matter - the product of on-site biological decomposition - affects the chemical and physical properties of the soil and its overall health. Its composition and breakdown rate affect: the soil structure and porosity; the water

infiltration rate and moisture holding capacity of soils; the diversity and biological activity of soil organisms; and plant nutrient availability. This Soils Bulletin concentrates on the organic matter dynamics of cropping soils and discusses the circumstances that deplete organic matter and their negative outcomes. It then moves on to more proactive solutions. It reviews a "basket" of practices in order to show how they can increase organic matter content and discusses the land and cropping benefits that then accrue.

Brady, M., K. Kellermann, C. Sahrbacher and L. Jelinek (2009). "Impacts of decoupled agricultural support on farm structure, biodiversity and landscape mosaic: some EU Results." Journal of Agricultural Economics **60**(3): 563-585.

Category: Agriculture-induced impacts

Keywords: *Biodiversity, Common Agricultural Policy decoupling, landscape mosaic, modelling, policy*

Abstract: The decoupling of direct payments from production represents a substantial reform of the Common Agricultural Policy (CAP). Farmers are no longer required to produce commodities to be entitled to support but only to keep land in Good Environmental and Agricultural Condition. If output declines as a result, there is concern that landscape services produced jointly with commodities will also decline. The aim of this paper is to assess the long-term effects of the 2003 reform on farm structure, landscape mosaic and biodiversity for a sample of EU regions. Impacts are quantified using a spatial agent-based modelling approach by simulating agricultural development with links to indicators of landscape value. Our results demonstrate that eliminating the link between support payments and production has possible negative consequences for the landscape, but only under particular circumstances. It is shown that these effects could be offset by strengthening (Pillar II) agri-environmental schemes. Further the single payment scheme results in higher land rental prices which reduces its ability to achieve its goal of providing income security for farmers. Implications of these results for the direction of continued CAP reform are discussed.

Breeze, T. D., A. P. Bailey, K. G. Balcombe and S. G. Potts (2011). "Pollination services in the UK: How important are honeybees?" Agriculture, Ecosystems & Environment **142**(3-4): 137-143.

Category: Ecosystem services

Keywords: *pollination, honey bee, ecosystem services, crop pollination*

Abstract: Pollination services are known to provide substantial benefits to human populations and agriculture in particular. Although many species are known to provide pollination services, honeybees (Apis mellifera) are often assumed to provide the majority of these services to agriculture. Using data from a range of secondary sources, this study assesses the importance of insect pollinated crops at regional and national scales and investigates the capacity of honeybees to provide optimal pollination services to UK agriculture. The findings indicate that insect pollinated crops have become increasingly important in UK crop agriculture and, as of 2007, accounted for 20% of UK cropland and 19% of total farmgate crop value.

Analysis of honeybee hive numbers indicates that current UK populations are only capable of supplying 34% of pollination service demands even under favourable assumptions, falling from 70% in 1984. In spite of this decline, insect pollinated crop yields have risen by an average of 54% since 1984, casting doubt on long held beliefs that honeybees provide the majority of pollination services. Future land use and crop production patterns may further increase the role of pollination services to UK agriculture, highlighting the importance of measures aimed at maintaining both wild and managed species.

Brenner, J., S. Lavallato, M. Cherry and E. Hileman (2013). "Land use determines interest in conservation easements among private landowners." Land Use Policy **35**(0): 24-32.

Category: Farmer and societal benefits

Keywords: *Working landscapes, land trusts, conservation easements, private land conservation, land use*

Abstract: Protection of private lands through conservation easements has garnered recent attention from scientists and conservation practitioners. Questions remain, however, about the specific characteristics and activities driving landowners' interest in conservation easements and their willingness to consider granting them. Resolving these questions could improve prospects for private land conservation by helping land conservation organizations identify and better understand potential easement grantors. We conducted a survey of 513 private landowners in a peri-urban fringe area in the Finger Lakes region of upstate New York, USA. Logistic regression analysis returned seven significant predictors of landowner willingness to consider granting conservation easements. Participation in environmental organizations, recreational land-use activities, wild food gathering, and land entitlement were the strongest factors promoting interest in conservation easements. Long-term residency, male gender, and hunting or fishing, on the other hand, significantly decreased the likelihood of considering conservation easements. The findings suggest that landowners most interested in to granting conservation easements are active land users. Notably, among all the land-use activities reported, the most frequent and the most important in predicting interest in conservation easements are those undertaken for recreational and subsistence, rather than economic, purposes. This suggests that while easements might be appropriate for working lands, their role in reconciling land use with conservation requires a flexible definition of work.

Breure, A., G. De Deyn, E. Dominati, T. Eglin, K. Hedlund, J. Van Orshoven and L. Posthuma (2012). "Ecosystem services: a useful concept for soil policy making!" Current Opinion in Environmental Sustainability **4**(5): 578-585.

Category: Policy

Keywords: *Ecosystem services, policy making, soil, benefits*

Abstract: This paper is based on the session 'Ecosystem services: a useful concept for soil policy making?' at the Wageningen Applied Soil Conference in September 2011. In that session it was shown from different angles that policy awareness of the dependence of humankind on ecosystem services has resulted in the development of tools for optimal allocation and quantification of ecosystem services and raising

awareness to stakeholders and decision makers. A number of case studies provided practical applications of developed tools that show how an ecosystem services approach can work as a way to value ecosystems. The use of ecosystem services may lead to mitigation of soil degradation and at the same time increase production of services both to private land owners as well as to the society as common goods. In our opinion the results available to date show that quantifying the benefits of ecosystems is a way to support the positive view stated in the title and we encourage the development of decision support tools based on more extensive yet user friendly integrated approaches of resource management, sector planning, and priority setting in the near future.

Brittain, C., R. Bommarco, M. Vighi, J. Settele and S. Potts (2010). "Organic farming in isolated landscapes does not benefit flower-visiting insects and pollination." Biological Conservation **143**(8): 1860-1867.

Category: Ecosystem services

Keywords: *Agriculture, bee, biodiversity, ecosystem service, insecticide, pollinator, pollination*

Abstract: Organic farming has often been found to provide benefits for biodiversity, but the benefits can depend on the species considered and characteristics of the surrounding landscape. In an intensively farmed area of Northeast Italy we investigated whether isolated organic farms, in a conventionally farmed landscape, provided local benefits for insect pollinators and pollination services. We quantified the relative effects of local management (i.e. the farm system), landscape management (proportion of surrounding uncultivated land) and interactions between them. We compared six organic and six conventional vine fields. The proportion of surrounding uncultivated land was calculated for each site at radii of 200, 500, 1000 and 2000 m. The organic fields did not differ from the conventional in their floral resources or proportion of surrounding uncultivated land. Data were collected on pollinator abundance and species richness, visitation rates to, and pollination of experimental potted plants. None of these factors were significantly affected by the farming system. The abundance of visits to the potted plants in the conventional fields tended to be negatively affected by the proportion of surrounding uncultivated land. The proportion fruit set, weight of seeds per plant and seed weight in conventional and organic fields were all negatively affected by the proportion of surrounding uncultivated land. In vine fields the impact of the surrounding landscape was stronger than the local management. Enhancement of biodiversity through organic farming should not be assumed to be ubiquitous, as potential benefits may be offset by the crop type, organic-management practices and the specific habitat requirements in the surrounding landscape.

Brittain, C. and S. G. Potts (2011). "The potential impacts of insecticides on the life-history traits of bees and the consequences for pollination." Basic and Applied Ecology **12**(4): 321-331.

Category: Ecosystem services

Keywords: *biodiversity, disturbance, ecosystem service,; environmental chemicals, pesticide*

pressure, pollination, insecticide

Abstract: Maintaining the relationships between plants and pollinators is vital to ecosystem stability. Insecticides may disturb these interactions with poorly understood consequences for pollination. Community level research is essential, if we are to understand the wider effects of insecticides on a variety of pollinating taxa and the impacts on the plants they pollinate. In this article we discuss the potential effects of both the lethal and sub-lethal impacts of insecticide use in agro-ecosystems on pollination services by bees. In particular, we consider how particular life-history traits of pollinators, such as sociality and floral specialisation may be differentially affected by insecticides. We discuss how this might translate through to pollination services. We propose that a trait-based approach can give insight into the potential impacts of insecticides on plant–pollinator communities.

Brooks, D., J. Storkey, S. Clark, L. Firbank, S. Petit and I. Woiwod (2011). "Trophic links between functional groups of arable plants and beetles are stable at a national scale." Journal of Animal Ecology **81**(1): 4-13.

Category: Ecosystem services

Keywords: *Agro-ecosystem, biodiversity, community dynamics, Farm Scale Evaluations, granivory, plant–insect interactions, pest regulation*

Summary

1. There is an urgent need to accurately model how environmental change affects the wide-scale functioning of ecosystems, but advances are hindered by a lack of knowledge of how trophic levels are linked across space. It is unclear which theoretical approach to take to improve modelling of such interactions, but evidence is gathering that linking species responses to their functional traits can increase understanding of ecosystem dynamics. Currently, there are no quantitative studies testing how this approach might improve models of multiple, trophically interacting species, at wide spatial scales.
2. Arable weeds play a foundational role in linking food webs, providing resources for many taxa, including carabid beetles that feed on their seeds and weed-associated invertebrate prey. Here, we model associations between weeds and carabids across farmland in Great Britain (GB), to test the hypothesis that wide-scale trophic links between these groups are structured by their species functional traits.
3. A network of c. 250 arable fields, covering four crops and most lowland areas of GB, was sampled for weed, carabid and invertebrate taxa over 3 years. Data sets of these groups were closely matched in time and space, and each contained numerous species with a range of eco-physiological traits. The consistency of trophic linkages between multiple taxa sharing functional traits was tested within multivariate and log-linear models.
4. Robust links were established between the functional traits of taxa and their trophic interactions. Autumn-germinating, small-seeded weeds were associated with smaller, spring-breeding carabids, more specialised in seed feeding, whereas spring-germinating, large-seeded weeds were associated with a range of larger, autumn-breeding omnivorous carabids. These relationships were strong and dynamic, being independent of changes in invertebrate food resources and consistent across sample dates, crops and regions of GB.

5. We conclude that, in at least one system of interacting taxa, functional traits can be used to predict consistent, wide-scale trophic links. This conceptual approach is useful for assessing how perturbations affecting lower trophic levels are ramified throughout ecosystems and could be used to assess how environmental change affects a wider range of secondary consumers.

Brussaard, L. (1997). "Biodiversity and ecosystem functioning in soil." Ambio: 563-570.
Category: Ecosystem services
Keywords: *Ecosystem services, soil biota, bacteria and archaea, fungi, protozoa, nematodes, enchytraeids, mites, insects, earthworms, soil nutrients/cycling*

Abstract: We review the current knowledge on biodiversity in soils, its role in ecosystem processes, its importance for human purposes, and its resilience against stress and disturbanc. The number of existing species is vastly higher than the number described, even in the macroscopically visible taxa, and biogeogrpahical syntheses are largely lacking. A major effort in tazonomy and the training of a new generation of systematists is imperative. This effort has to be focussed on the groups of soil organisms that, to the best of our knowledge, play key roles in ecosystem functioning. To identify such groups, spheres of influence (SOI) of soil biota - such as the root biota, the shredders of organic matter and the soil bioturbators- are recognised that presumably control ecosystem processes, for example, through interactions with plants. Within those SOI, functional groups of soil organisms are recognised. Research questions of the highest urgency are the assignment of species to functional groups and determining the redundancy of species within functional groups. These priorities follow from the need to addresss the extent of any loss of functioning in soils, associated with intensive agriculture, forest disturbance, pollution of the environment, and global environmental change. The soil biota considered at present to be most ar riask are species-poor functional groups among macrofaunal shrdders of organic matter, bioturbators of soil, specialized bacteria like nitrifiers and nitrogen fixers, and fungiform mycorrhizas. An experimental approach in addressing these research priorities is needed, using long-term and large-scale field experiments and modern methods of geostatistics and geographic information systems.

Brussaard, L., T. Kuyper and W. Didden (2004). Biological soil quality from biomass to biodiversity-importance and resilience. Managing soil quality: challenges in modern agriculture**:** 139.
Category: Ecosystem services
Keywords: *Biological indicators, soil quality, soil biodiversity, soil nutrients/cycling*

Summary
We think of the soil as a living system, where many, if not most, physical and chemical properties and processes are mediated by the soil biota, affecting soil quality. Various aspects of the soil biota react sensitively to changes in the environment, including agricultural management. We conclude that changes in soil biodiversity, measured in terms of community structure of microbes and nematodes, give early warnings of long-term changes in organic matter, nutrient status and soil

structure, which cannot be easily observed directly. These parameters are easy to measure and they are responsive to agricultural management.

We also conclude that diversity confers stability/resilience on the ecosystem if (mananagment) stress and disturbance reduce the number of species. However, at the level of the entire (soil) community, i.e. beyond the level of diversity within taxonomic groups (such as nematodes), a causal relationship between soil biodiversity and ecosystem functioning and stability does not seem to exist, and the existing knowledge at this level is not yet sufficiently complete and quantitative to be of practical value for management. Nevertheless, reductions of the soil biota result in loss of stability of the soil community with possible loss of ecosystem functioning.

Finally we provide scientific knowledge that can contribute to the process of establishment of reference vallues of indicators of soil quality and to agricultural management recommendations, but the assessment of values for management is something to be subjectively agreed upon in practical situations, rather than objectively assessed.

Cadotte, M., K. Carscadden and N. Mirotchnick (2011). "Beyond species: functional diversity and the maintenance of ecological processes and services." Journal of applied ecology **48**(5): 1079-1087.

Category: Ecosystem services

Keywords: *Biodiversity conservation, community assembly, ecosystem function, ecosystem services, functional diversity, restoration, species richness*

Summary

1. The goal of conservation and restoration activities is to maintain biological diversity and the ecosystem services that this diversity provides. These activities traditionally focus on the measures of species diversity that include only information on the presence and abundance of species. Yet how diversity influences ecosystem function depends on the traits and niches filled by species.

2. Biological diversity can be quantified in ways that account for functional and phenotypic differences. A number of such measures of functional diversity (FD) have been created, quantifying the distribution of traits in a community or the relative magnitude of species similarities and differences. We review FD measures and why they are intuitively useful for understanding ecological patterns and are important for management.

3. In order for FD to be meaningful and worth measuring, it must be correlated with ecosystem function, and it should provide information above and beyond what species richness or diversity can explain. We review these two propositions, examining whether the strength of the correlation between FD and species richness varies across differing environmental gradients and whether FD offers greater explanatory power of ecosystem function than species richness.

4. Previous research shows that the relationship between FD and richness is complex and context dependent. Different functional traits can show individual responses to different gradients, meaning that important changes in diversity can occur with minimal change in richness. Further, FD can explain variation in ecosystem function even when richness does not.

5. Synthesis and applications. FD measures those aspects of diversity that potentially affect community assembly and function. Given this explanatory power, FD should be incorporated into conservation and restoration decision-making, especially for those efforts attempting to reconstruct or preserve healthy, functioning ecosystems.

Carbonell-Bojollo, R., E. J. Gonzalez-Sanchez, O. Veroz-Gonzalez and R. Ordoñez-Fernandez (2011). "Soil management systems and short term CO2 emissions in a clayey soil in southern Spain." Science of The Total Environment **409**(15): 2929-2935.

Category: Agroecology and agroecological practices

Keywords: *Conventional tillage, no tillage, conservation agriculture, CO2 emissions, soil management, Spain*

Abstract: The soil in general and that destined for agricultural use, more specifically, can act as a source or sink of carbon, hence its direct involvement in strategies for mitigating climate change. A large proportion of this mitigation potential is produced by the sequestration of carbon by soils and, to a lesser extent, by a reduction in emissions from the soil. The most effective practices for increasing the organic carbon in the soils are generally those linked to conservation agriculture, which includes practices of no tillage or minimum tillage and the use of cover crops. During the farming seasons of 2006/07, 2007/08, 2008/09 and 2009/10, a trial was conducted in which the carbon dioxide emissions in soil with a high percentage of clay in the Vega de Carmona (Seville) were estimated, and it was determined how climate conditions and the adoption of conservation agriculture practices vs. the use of traditional tillage influenced the flux of gas into the atmosphere.

Cardinale, B., J. Emmett Duffy, A. Gonzalez, D. Hooper, C. Perrings, P. Venail, A. Narwani, G. Mace, D. Tilman and D. Wardle (2012). "Biodiversity loss and its impact on humanity." Nature **486**(7401): 59-67.

Category: Agriculture-induced impacts

Keywords: *Ecology, environmental science, Earth sciences, plant sciences*

Abstract: The most unique feature of Earth is the existence of life, and the most extraordinary feature of life is its diversity. Approximately 9 million types of plants, animals, protists and fungi inhabit the earth. So, too, do 7 billion people. Two decades ago, at the first Earth Summit, the vast majority of the world's nations declared that human actions were dismantling Earth's ecosystems, eliminating genes, species, and biological traits at an alarming rate. This observation led to a daunting question: How will loss of biological diversity alter the functioning of ecosystems and their ability to provide society with the goods and services needed to prosper?

Carpenter, S., H. Mooney, J. Agard, D. Capistrano, R. DeFries, S. Diaz, T. Dietz, A. Duraiappah, A. Oteng-Yeboah, H. Pereira, C. Perrings, W. Reid, J. Sarukhan, R. Scholes and A. Whyte (2009). "Science for managing ecosystem services: Beyond the Millennium Ecosystem

Assessment." Proceedings of the National Academy of Sciences **106**(5): 1305-1312.
Category: Ecosystem services
Keywords: *Millennium Ecosystem Assessment, social and ecological systems, human well-being, effects*

Abstract: The Millennium Ecosystem Assessment (MA) introduced a new framework for analyzing social–ecological systems that has had wide influence in the policy and scientific communities. Studies after the MA are taking up new challenges in the basic science needed to assess, project, and manage flows of ecosystem services and effects on human well-being. Yet, our ability to draw general conclusions remains limited by focus on discipline-bound sectors of the full social–ecological system. At the same time, some polices and practices intended to improve ecosystem services and human well-being are based on untested assumptions and sparse information. The people who are affected and those who provide resources are increasingly asking for evidence that interventions improve ecosystem services and human well-being. New research is needed that considers the full ensemble of processes and feedbacks, for a range of biophysical and social systems, to better understand and manage the dynamics of the relationship between humans and the ecosystems on which they rely. Such research will expand the capacity to address fundamental questions about complex social–ecological systems while evaluating assumptions of policies and practices intended to advance human well-being through improved ecosystem services.

Carrière, S., E. Rodary, P. Méral, G. Serpantié, V. Boisvert, C. Kull, G. Lestrelin, L. Lhoutellier, B. Moizo, G. Smektala and J.-C. Vandevelde (2013). "Rio+20, biodiversity marginalized." Conservation Letters **6**(1): 6-11.
Category: Policy
Keywords: *Agroecosystems, biodiversity conservation, biodiversity governance, market-based instruments, standardization*

Abstract: At the Rio+20 Conference (June 2012), the biodiversity conservation agenda was subsumed into broader environmental issues like sustainable development, “green economy,” and climate change. This shoehorning of biodiversity issues is concomitant with a trend toward market-based instruments and toward standardized biodiversity assessment and monitoring. This article raises concern that these trends can marginalize important and specific aspects of biodiversity governance, including other policy tools and region-specific socio-ecological environments. Among other trends, this contributes to the marginalization of agroecosystems as habitat and matrix for biodiversity. Such agroecosystems, however, can have a major impact on conservation outcomes as they comprise a major part of terrestrial lands. If the biodiversity crisis is to be curbed, special attention must be drawn to societies, institutional approaches, and environments that are currently marginalized in conservation policies.

Carvalheiro, L. G., W. E. Kunin, P. Keil, J. Aguirre-Gutiérrez, W. N. Ellis, R. Fox, Q. Groom, S. Hennekens, W. Van Landuyt, D. Maes, F. Van de Meutter, D. Michez, P. Rasmont, B. Ode, S. G. Potts, M. Reemer, S. P. M. Roberts, J. Schaminée, M. F. WallisDeVries and J. C. Biesmeijer

(2013). "Species richness declines and biotic homogenisation have slowed down for NW-European pollinators and plants." Ecology Letters **16**(7): 870-878.

Category: Agriculture-induced impacts

Keywords: *accumulation curves, biodiversity loss, community ecology, plant–flower visitor communities, pollination, similarity, spatial homogenization, species richness estimations, temporal and spatial patterns*

Abstract: Concern about biodiversity loss has led to increased public investment in conservation. Whereas there is a widespread perception that such initiatives have been unsuccessful, there are few quantitative tests of this perception. Here, we evaluate whether rates of biodiversity change have altered in recent decades in three European countries (Great Britain, Netherlands and Belgium) for plants and flower visiting insects. We compared four 20-year periods, comparing periods of rapid land-use intensification and natural habitat loss (1930–1990) with a period of increased conservation investment (post-1990). We found that extensive species richness loss and biotic homogenisation occurred before 1990, whereas these negative trends became substantially less accentuated during recent decades, being partially reversed for certain taxa (e.g. bees in Great Britain and Netherlands). These results highlight the potential to maintain or even restore current species assemblages (which despite past extinctions are still of great conservation value), at least in regions where large-scale land-use intensification and natural habitat loss has ceased.

Carvell, C., J. L. Osborne, A. F. G. Bourke, S. N. Freeman, R. F. Pywell and M. S. Heard (2011). "Bumble bee species' responses to a targeted conservation measure depend on landscape context and habitat quality." Ecological applications **21**(5): 1760-1771.

Category: Ecosystem services

Keywords: *Agri-environment schemes, bee conservation, Bombus spp., forage plants, habitat quality, land use, pollinators, United Kingdom, pollination*

Abstract: The global decline of insect pollinators, especially bees, is cause for concern, and there is an urgent need for cost-effective conservation measures in agricultural landscapes. While landscape context and habitat quality are known to influence species richness and abundance of bees, there is a lack of evidence from manipulative field experiments on bees' responses to adaptive management across differently structured landscapes. We present the results of a large-scale study that investigated the effects of a targeted agri-environment scheme (AES) on bumble bees (Bombus spp.) over three years in the United Kingdom. Forage patches of different sizes were sown with a conservation flower mixture across eight sites covering a broad range of agricultural land use types. Species richness and worker densities (especially of the longer-tongued Bombus species for which the mixture was targeted) were significantly higher on sown forage patches than on existing non-crop control habitats throughout the three-year study, but the strength of this response depended on both the proportions of arable land and abundance of herbaceous forb species in the surrounding landscape. The size of sown patches also affected worker density, with smaller patches (0.25 ha) attracting higher densities of some species than larger patches (1.0 ha). Our models show that a targeted AES can deliver greater net benefits in more intensively farmed areas, in terms of the

number and species richness of bumble bees supported, than in heterogeneous landscapes where other foraging habitats exist. These findings serve to strengthen the evidence base for extending agri-environment schemes to boost declining pollinator populations to a larger number of agricultural landscapes across the globe.

Cassman, K., P. Grassini and J. van Wart (2010). "Crop yield potential, yield trends, and global food security in a changing climate." Handbook of Climate Change and Agroecosystems: Impacts, Adaptation, and Mitigation.

Category: Climate change

Keywords: *Land, water, climate change, yield trends, yield potential, yield plateaus*

Abstract: Even without climate change the current trajectory in yields of the major food crops is not sufficient to meet demand from population and income growth without an enormous expansion of cropped area. Such an expansion would come at the expense of the remaining rainforest, wetlands, and grassland savannahs. Conversion of these C-rich ecosystems would hasten the rise in greenhouse gas (GHG) emissions and greatly reduce habitat for biodiversity. To avoid this conversion will require a rapid acceleration in the rate of gain in crop yields on existing farmland, and these higher yields must be achieved while also reducing GHG emissions from crop production and preserving soil and water quality. The process of increasing yields while reducing the environmental footprint of crop production is called "ecological intensification." Achieving ecological intensification in all of the world's most productive cropping systems represents the single greatest scientific challenge facing humankind. Climate change adds another dimension to this challenge because there remains substantial uncertainty about the impact of increasing temperatures and [CO2] on crop yields and rainfall distribution. Ultimately, global food production capacity is determined by crop yield potential, the amount of arable land suitable to support crop production, and water supply. Lack of agreement between estimates of yield response to increased temperature derived from simulation models versus estimates obtained from the relationship between growing season temperature and crop yields is cause for concern. Either models are not capturing the full impact of temperature, or the empirical relationships are confounded by other factors. In either case, there is an urgent need to better understand the fundamental basis of crop yield potential and the impact of climate change on it.

Cassman, K. G. (1999). "Ecological intensification of cereal production systems: Yield potential, soil quality, and precision agriculture." Proceedings of the National Academy of Sciences **96**(11): 5952-5959.

Category: Ecosystem services

Keywords: *ecological intensification, cereal, wheat, rice, maize, yield potential, soil quality, precision agriculture*

Abstract: Wheat (Triticum aestivum L.), rice (Oryza sativa L.), and maize (Zea mays L.) provide about two-thirds of all energy in human diets, and four major cropping systems in which these cereals are grown represent the foundation of human food supply. Yield per unit time and land has increased markedly during the past 30 years

in these systems, a result of intensified crop management involving improved germplasm, greater inputs of fertilizer, production of two or more crops per year on the same piece of land, and irrigation. Meeting future food demand while minimizing expansion of cultivated area primarily will depend on continued intensification of these same four systems. The manner in which further intensification is achieved, however, will differ markedly from the past because the exploitable gap between average farm yields and genetic yield potential is closing. At present, the rate of increase in yield potential is much less than the expected increase in demand. Hence, average farm yields must reach 70–80% of the yield potential ceiling within 30 years in each of these major cereal systems. Achieving consistent production at these high levels without causing environmental damage requires improvements in soil quality and precise management of all production factors in time and space. The scope of the scientific challenge related to these objectives is discussed. It is concluded that major scientific breakthroughs must occur in basic plant physiology, ecophysiology, agroecology, and soil science to achieve the ecological intensification that is needed to meet the expected increase in food demand.

Chan, K., L. Hoshizaki and B. Klinkenberg (2011). "Ecosystem services in conservation planning: targeted benefits vs. co-benefits or costs?" PloS one **6**(9): e24378.

Category: Farmer and societal benefits

Keywords: *Ecosystem service, human well-being, intrinsically-important targeted benefits, substitutable co-benefits, British Columbia*

Abstract: There is growing support for characterizing ecosystem services in order to link conservation and human well-being. However, few studies have explicitly included ecosystem services within systematic conservation planning, and those that have follow two fundamentally different approaches: ecosystem services as intrinsically-important targeted benefits vs. substitutable co-benefits. We present a first comparison of these two approaches in a case study in the Central Interior of British Columbia. We calculated and mapped economic values for carbon storage, timber production, and recreational angling using a geographical information system (GIS). These 'marginal' values represent the difference in service-provision between conservation and managed forestry as land uses. We compared two approaches to including ecosystem services in the site-selection software Marxan: as Targeted Benefits, and as Co-Benefits/Costs (in Marxan's cost function); we also compared these approaches with a Hybrid approach (carbon and angling as targeted benefits, timber as an opportunity cost). For this analysis, the Co-Benefit/Cost approach yielded a less costly reserve network than the Hybrid approach (1.6% cheaper). Including timber harvest as an opportunity cost in the cost function resulted in a reserve network that achieved targets equivalently, but at 15% lower total cost. We found counter-intuitive results for conservation: conservation-compatible services (carbon, angling) were positively correlated with each other and biodiversity, whereas the conservation-incompatible service (timber) was negatively correlated with all other networks. Our findings suggest that including ecosystem services within a conservation plan may be most cost-effective when they are represented as substitutable co-benefits/costs, rather than as targeted benefits. By explicitly valuing the costs and benefits associated with services, we may be able to achieve

meaningful biodiversity conservation at lower cost and with greater co-benefits.

Chappell, M. J. and L. LaValle (2011). "Food security and biodiversity: can we have both? An agroecological analysis." Agriculture and Human Values **28**(1): 3-26.
Category: Policy
Keywords: *agroecology, alternative agriculture, biodiversity conservation, food security, organic agriculture, political ecology*

Abstract: We present an extensive literature review exploring the relationships between food insecurity and rapid biodiversity loss, and the competing methods proposed to address each of these serious problems. Given a large and growing human population, the persistence of widespread malnutrition, and the direct and significant threats the expanding agricultural system poses to biodiversity, the goals of providing universal food security and protecting biodiversity seem incompatible. Examining the literature shows that the current agricultural system already provides sufficient food on a worldwide basis, but in doing so methodically undermines the capacity of agroecosystems to preserve biodiversity. However, the available evidence emphasizes the interdependence of biodiversity and agriculture, and the important role each plays in the maintenance of the other. Thus, our review supports the claim that the solutions to the problems of widespread food insecurity and biodiversity loss need not be mutually exclusive, and that it may be possible to address both using appropriate alternative agricultural practices.

Chee, Y. (2004). "An ecological perspective on the valuation of ecosystem services." Biological Conservation **120**(4): 549-565.
Category: Farmer and societal benefits
Keywords: *Ecosystem services, valuation, ecological economics, contingent valuation, cost-benefit analysis, decision-making under uncertainty*

Abstract: Ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfil human life. Ecosystem service valuation is being developed as a vehicle to integrate ecological understanding and economic considerations to redress the traditional neglect of ecosystem services in policy decisions. This paper presents a critical review on the neoclassical economic framework, tools used for economic valuation of ecosystem services and the economic welfare approach to collective decision-making, from an ecological perspective. The applicability of the framework and techniques for valuing ecosystem services are evaluated in light of the challenges posed by the complex, non-linear nature of many ecosystem services. Decisions concerning ecosystem management are often complex, socially contentious and fraught with uncertainty. Although judicious application of economic valuation techniques to ecosystem services can provide valuable information for conceptualizing decision choices and evaluating management options, there are serious limitations in the economic welfare approach to decision-making. These shortcomings and their implications for ecosystem management are elucidated and alternative approaches that emphasize participation, explicit treatment of uncertainty and transparent decision-making processes are discussed.

Christie, M., I. Fazey, R. Cooper, T. Hyde and J. Kenter (2012). "An evaluation of monetary and non-monetary techniques for assessing the importance of biodiversity and ecosystem services to people in countries with developing economies." Ecological Economics **83**(0): 67-78.

Category: Farmer and societal benefits

Keywords: *Environmental valuation, biodiversity, ecosystem services, developing countries, participatory approaches, deliberative valuation, poverty alleviation*

Abstract: Biodiversity supports a range of ecosystems services that are of fundamental importance to people in poor countries. Economic valuation of biodiversity is important for the development of policies that protect biodiversity and alleviate poverty. This paper provides an evaluation of monetary and non-monetary techniques for assessing the value of biodiversity to people in least developed countries (LDCs). Specifically, research questions include:

1) To what extent have monetary and non-monetary techniques been used to assess the value of biodiversity and ecosystem services in LDCs?

2) What are the key methodological, practical, epistemological and policy challenges to assessing the value of biodiversity and ecosystem services in LDCs?

3) How can valuation methods be improved to allow more accurate valuation in LDCs?

Clough, Y., J. Barkmann, J. Juhrbandt, M. Kessler, T. C. Wanger, A. Anshary, D. Buchori, D. Cicuzza, K. Darras, D. Putra, S. Erasmi, R. Pitopang, C. Schmidt, C. Schulze, D. Seidel, I. Steffan-Dewenter, K. Stenchly, S. Vidal, M. Weist, A. Wielgoss and T. Tscharntke (2011). "Combining high biodiversity with high yields in tropical agroforests." Proceedings of the National Academy of Sciences **108**(20): 8311-8316.

Category: Ecosystem services

Keywords: *Agroecosystems, ecosystem services, ecology-economy, trade-offs, endemic species richness, shade trees*

Abstract: Local and landscape-scale agricultural intensification is a major driver of global biodiversity loss. Controversially discussed solutions include wildlife-friendly farming or combining high-intensity farming with land-sparing for nature. Here, we integrate biodiversity and crop productivity data for smallholder cacao in Indonesia to exemplify for tropical agroforests that there is little relationship between yield and biodiversity under current management, opening substantial opportunities for wildlife-friendly management. Species richness of trees, fungi, invertebrates, and vertebrates did not decrease with yield. Moderate shade, adequate labor, and input level can be combined with a complex habitat structure to provide high biodiversity as well as high yields. Although livelihood impacts are held up as a major obstacle for wildlife-friendly farming in the tropics, our results suggest that in some situations, agroforests can be designed to optimize both biodiversity and crop production benefits without adding pressure to convert natural habitat to farmland.

Concepción, E. D., M. Díaz, D. Kleijn, A. Báldi, P. Batáry, Y. Clough, D. Gabriel, F. Herzog, A. Holzschuh, E. Knop, E. J. P. Marshall, T. Tscharntke and J. Verhulst (2012). "Interactive effects of landscape context constrain the effectiveness of local agri-environmental management." Journal of applied ecology **49**(3): 695-705.

Category: Ecosystem services

Keywords: *bees, birds, field-scale management, landscape complexity, model testing, nonlinear effects, plants, species richness, spiders*

Abstract:

1. Ecological theory predicts that the effectiveness of local agri-environmental management to enhance species richness at field scales will be the highest at intermediate levels of landscape complexity because of nonlinear effects of landscape context on field-scale diversity.

2. We examined how landscape complexity determined effectiveness of local agri-environmental management in terms of effects on species richness of birds, plants, spiders and bees in 232 extensive and intensive paired fields (112 arable fields and 120 grasslands) from 18 regions located in six European countries.

3. As predicted, landscape complexity enhanced field-scale species richness in a mostly nonlinear (sigmoidal) way, with earlier species richness increases in extensive than in intensive fields along landscape complexity gradients. Length of semi-natural boundaries (for arable fields) and propor- tion of unfarmed habitat (for grasslands) were the landscape features influencing species richness.

4. The relationships between effectiveness of local management and landscape complexity for all taxa were best described with hump-shaped curves, indicating the highest effectiveness at intermediate landscape complexities.

5. Synthesis and applications. We used models to investigate how and why effects of local management intensity on species richness vary along wide gradients of landscape complexity. We conclude that landscape-scale management options should take priority over local extensification measures within agri-environmental programmes. These programmes should follow a hierarchical multi-scale approach directed to address landscape-scale constraints on local diversity.

Conway, G. R. (1987). "The properties of agroecosystems." Agricultural Systems **24**(2): 95-117.

Category: Farmer and societal benefits

Keywords: *Agroecosystem*

Abstract: Agroecosystems may be regarded as true cybernetic systems whose goal is increased social value. This is achieved through a variety of strategies that combine different levels of productivity, stability, sustainability and equitability. Agricultural development thus involves making trade-offs between these properties. The point is illustrated by selected examples from agricultural history, including the origins of agriculture, manorial and modern western agriculture, and the Green Revolution in Indonesia. It is suggested that these properties may be used normatively as combined criteria for evaluating the performance of agricultural development programmes and projects.

Cook, S. M., Z. R. Khan and J. A. Pickett (2007). "The use of push-pull strategies in integrated pest management." Annu. Rev. Entomol. **52**: 375-400.

Category: Ecosystem services

Keywords: *Pest control, attractant, repellent, semiochemicals, behavioral manipulation, stimulo-deterrent diversionary strategy, pest regulation*

Abstract: Push-pull strategies involve the behavioral manipulation of insect pests and their natural enemies via the integration of stimuli that act to make the protected resource unattractive or unsuitable to the pests (push) while luring them toward an attractive source (pull) from where the pests are subsequently removed. The push and pull components are generally nontoxic. Therefore, the strategies are usually integrated with methods for population reduction, preferably biological control. Push-pull strategies maximize efficacy of behavior-manipulating stimuli through the additive and synergistic effects of integrating their use. By orchestrating a predictable distribution of pests, efficiency of population-reducing components can also be increased. The strategy is a useful tool for integrated pest management programs reducing pesticide input. We describe the principles of the strategy, list the potential components, and present case studies reviewing work on the development and use of push-pull strategies in each of the major areas of pest control.

Cooke, I., S. Queenborough, E. Mattison, A. Bailey, D. Sandars, A. R. Graves, J. Morris, P. Atkinson, P. Trawick, R. Freckleton, A. Watkinson and W. Sutherland (2009). "Integrating socio-economics and ecology: a taxonomy of quantitative methods and a review of their use in agro-ecology." Journal of applied ecology **46**(2): 269-277.

Category: Agroecology and agroecological practices

Keywords: *Agriculture, ecological model, interdisciplinary, socio-economic model*

Summary

1. Answering many of the critical questions in conservation, development and environmental management requires integrating the social and natural sciences. However, understanding the array of available quantitative methods and their associated terminology presents a major barrier to successful collaboration.

2. We provide an overview of quantitative socio-economic methods that distils their complexity into a simple taxonomy. We outline how each has been used in conjunction with ecological models to address questions relating to the management of socio-ecological systems.

3. We review the application of social and ecological quantitative concepts to agro-ecology and classify the approaches used to integrate the two disciplines. Our review included all published integrated models from 2003 to 2008 in 27 journals that publish agricultural modelling research. Although our focus is on agro-ecology, many of the results are broadly applicable to other fields involving an interaction between human activities and ecology.

4. We found 36 papers that integrated social and ecological concepts in a quantitative model. Four different approaches to integration were used, depending on the scale at which human welfare was quantified. Most models viewed humans as pure profit maximizers, both when calculating welfare and predicting behaviour.

5. Synthesis and applications. We reached two main conclusions based on our

taxonomy and review. The first is that quantitative methods that extend predictions of behaviour and measurements of welfare beyond a simple market value basis are underutilized by integrated models. The second is that the accuracy of prediction for integrated models remains largely unquantified. Addressing both problems requires researchers to reach a common understanding of modelling goals and data requirements during the early stages of a project.

Cooper, T., K. Hart and D. Baldock (2009). The Provision of Public Goods through Agriculture in the European Union. London, Institute for European Environmental Policy**:** 396.

Category: Farmer and societal benefits; Policy

Keywords: *EU, Public Goods, allocation mechanisms, economic incentives, agriculture, agricultural practices, public support, policy measures*

Abstract: The purpose of this report is to examine the concept of public goods as it applies to agriculture in Europe and to assess how far there is a case for policy measures to encourage the provision of public goods by agriculture. The evidence draws on a wide range of secondary sources, including the literature, evaluation studies, an in-depth analysis of the policy framework, along with detailed information collected from eight regional case studies conducted in the Czech Republic, France, Germany, Italy, Romania, Spain, Sweden, and the UK between April and July 2009.

The Public Goods Concept

In Europe, agriculture has received a sustained level of public support over the last 50 years. Other productive sectors are not subject to public intervention on this scale, which raises the question as to why it continues to be required given the sector's increasing competitiveness and market orientation. In certain respects, agriculture is like other economic sectors, with a large number of producers participating in a range of markets for food, fibre, and raw materials for energy and industrial products. In other respects, it has specific characteristics which mean that the potential for the provision of public goods in the field of the environment is particularly prevalent in this sector. It is widely argued that securing the provision of public goods provides a valid reason for public intervention in a market economy.

The public goods concept is well established in economic theory which defines public goods by the following characteristics:

- Non-excludable – if the good is available to one person, others cannot be excluded from the benefits it confers.
- Non-rival – if the good is consumed by one person it does not reduce the amount available to others.

In reality, these characteristics of non-excludability and non-rivalry may be exhibited to almost any degree, and indeed pure public goods are rare. This is because the potential sometimes exists to exclude - often at considerable cost - people who do not contribute to covering the costs associated with the provision of a particular public good, and certain public goods, such as popular cultural landscapes, can become congested, leading to a loss of enjoyment. As such, any given public good can be situated along what may be described as a continuum of 'publicness'.

Given the defining characteristics of public goods, their supply cannot be secured through markets. This is because non-excludability and non-rivalry in consumption

imply that users have no incentive to pay for public goods, often leading to over-exploitation. On the supply side, farmers have little incentive to provide public goods because they are not being paid to do so. In combination, these two factors explain the undersupply of public goods, and therefore, in the absence of functioning markets, public intervention is needed to achieve a desirable level of provision in line with societal demand. That said, public intervention is not always needed to secure the supply of public goods provided by agriculture. Certain quantities of public goods may be provided incidentally, as a side-effect of economically viable activities, or as a result of farmer altruism or self-interest.

To achieve a desirable level of public goods, policy actions are needed, unless demand is satisfied by incidental delivery. Where such actions go beyond the requirements set out in the legislative baseline, as enshrined in EU Directives, national legislation and in standards of good practice, they require payments to farmers for the delivery of public goods. Because a farmer holds the property rights and controls the factors of production, the most important of which is privately owned land, economic incentives are needed to encourage farmers to divert their means of production from the efficient production of farm commodities to the provision of public goods, which implies extra costs and / or income forgone. Thus, farmers need to be incentivised to pursue certain farming practices in order to maintain landscape features, restore and maintain specific habitats, or to manage natural resources such as water and soils, for example. In other words, society has to purchase what amounts to a reallocation of resources to underpin the provision of public goods.

Cordell, D., J.-O. Drangert and S. White (2009). "The story of phosphorus: Global food security and food for thought." Global Environmental Change **19**(2): 292-305.

Category: Agriculture-induced impacts

Keywords: *Phosphorus, phosphate rock, global food security, fertilizer, peak phosphorus, reuse, scarcity, soil nutrients/cycling*

Abstract: Food production requires application of fertilizers containing phosphorus, nitrogen and potassium on agricultural fields in order to sustain crop yields. However modern agriculture is dependent on phosphorus derived from phosphate rock, which is a non-renewable resource and current global reserves may be depleted in 50–100 years. While phosphorus demand is projected to increase, the expected global peak in phosphorus production is predicted to occur around 2030. The exact timing of peak phosphorus production might be disputed, however it is widely acknowledged within the fertilizer industry that the quality of remaining phosphate rock is decreasing and production costs are increasing. Yet future access to phosphorus receives little or no international attention. This paper puts forward the case for including long-term phosphorus scarcity on the priority agenda for global food security. Opportunities for recovering phosphorus and reducing demand are also addressed together with institutional challenges.

Cornia, G. (1985). "Farm size, land yields and the agricultural production function: An analysis for fifteen developing countries." World Development **13**(4): 513-534.

Category: Ecosystem services; Policy

Keywords: *Farm size, yield, agricultural production*

Abstract: The paper analyzes the relationship between factor inputs, land yields and labor productivity for farms of different size on the basis of FAO farm management data for 15 developing countries. For all but three countries a strong negative correlation is found between farm size on the one side, and factor inputs and yields per hectare on the other. The fitting of unconstrained production functions to the above data suggests that in only few cases the decline in yields for increasing farm size can be attributed to decreasing returns to scale. The higher yields observed in small farms are mainly to be ascribed to higher factor inputs and to a more intensive use of land. Therefore, where conspicuous labor surpluses exist, the superiority of small farming provides solid arguments in favor of land redistribution. Such an agrarian reform would determine higher output, higher labor absorption and a more equitable income distribution, thus contributing in a decisive manner to the alleviation of rural poverty. The paper also provides estimates of cross-sectional production functions for the 15 countries analyzed. Empirical relations are found between the output elasticities of land, labor and intermediate inputs and physical indicators of their scarcity. The paper concludes by proposing a simple method for deriving a long-term production function for agriculture.

Costanza, R. (2000). "Social goals and the valuation of ecosystem services." Ecosystems **3**(1): 4-10.

Category: Farmer and societal benefits; Ecosystem services

Keywords: *Ecosystem services, valuation, social goals, uncertainty, sustainability*

Introduction: Ecosystem services are obviously important in sustaining human life on earth (Daily 1997; Costanza and others 1997a). The big questions include; how important Over what temporal and spatial scales? What are the limits of humanity's ability to substitute for them? At what levels of stress to they flip to some other (less desirable) state? All of these questions require the ability to understand and model the interconnected, coevolving system of humans and nature (Costanza and others 1993, 1997b). In addition, the answers to these questions are not purely academic. We humans have to make choices and trade-offs concerning ecosystem services, and this imples and requires "valuation" because any choice between competing alternatives imples that the one chosen was more highly "valued." That the alternatives are "competing" is important, because if we can find a "win-win" solution then no real choice is required, and we can avoid valuation. But environmental decisions involve the problem of having to weigh and aggregate the myriad different kinds of "benefits" of a proposed action against its "costs". In most cases, these benefits and costs are both poorly understood and poorly quantified. In addition, the future vision and social goals that define the degree to which something is a benefit or a cost are themselves evolving and changing. In doing valuation of ecosystem services, we need to consider a broad set of goals that include ecological sustainability and social fairness, along with the traditional economic goal of efficiency.

Costanza, R., R. d'Arge, R. De Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. O'neill and J. Paruelo (1997). "The value of the world's ecosystem services and natural capital." Nature **387**(6630): 253-260.

Category: Ecosystem services

Keywords: *Ecosystem services, valuation methods, natural capital, marktes, GNP*

Abstract: The services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the Earth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent part of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services for 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion (1012) per year, with an average of US$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global gross national product total is around US$18 trillion per year.

Cox, S. and B. Bob Searle (2009). The state of ecosystem services. The Bridgespan Group.

Category: Ecosystem services

Keywords: *Ecosystem services, conservation, governance, knowledge*

Summary: The idea of taking an ecosystem services approach to conservation—that is, engaging in conservation efforts that address the sustainability of natural assets in the context of how people use those assets—has gained significant momentum in the past decade.

Consider: Since the seminal book, Nature's Services, was published in 1997, the number of publications focused on ecosystem services across academic fields has grown 1,108 percent, from 255 publications in 1997 to 3,080 in 2007. A major milestone occurred in 2001, with the launch of Millennium Ecosystem Assessment (MA), an international effort chartered by the UN involving more than 1,300 scientists. Another milestone occurred in 2005, when MA published its initial findings.

More recently, multinational gatherings, including the Conventions on Biological Diversity, the Ramsar Convention on Wetlands and Migratory Species, and the Convention to Combat Desertification, have incorporated the concept of ecosystem services into their discussions and convenings. And major nongovernmental organizations (NGOs) including The Nature Conservancy, the World Wildlife Fund, and the World Resources Institute (WRI) have begun piloting ecosystem services programs, as have major intergovernmental agencies the United Nations Development Program (UNDP) and the World Bank. (Of the World Bank's environmental projects, the proportion of biodiversity-focused projects has increased four-fold since the 1980s.) (Tallis et al, 2008)

With so many diverse efforts underway, it has been difficult, if not impossible, for many of those involved in the field to get a sense of what the ecosystem services landscape looks like as a whole, much less learn from one another's experiences. To help provide a map of the field, and to facilitate learning, researchers at Bridgespan, funded by the Gordon and Betty Moore Foundation, undertook a project to provide a comprehensive overview of the current state of ecosystem services and its

potential for impact in environmental conservation.
This report synthesizes:
☐ Thirty-six interviews with experts from academia, NGOs, government agencies, and corporations;
☐ A literature review of over 60 white papers and reports (a list detailing these resources is included at the
end of this document); and
☐ Impact results from 194 case studies from the Nature Valuation and Financing Network (NV&F) CaseBase database and 46 from the WRI's Corporate Ecosystem Services Review project database.

Curran, M., L. de Baan, A. M. De Schryver, R. van Zelm, S. Hellweg, T. Koellner, G. Sonnemann and M. A. J. Huijbregts (2011). "Toward meaningful end points of biodiversity in life cycle assessment." Environmental Science & Technology **45**(1): 70-79.
Category: Policy
Keywords: *Biodiversity; life cycle assessment*

Abstract: Halting current rates of biodiversity loss will be a defining challenge of the 21st century. To assess the effectiveness of strategies to achieve this goal, indicators and tools are required that monitor the driving forces of biodiversity loss, the changing state of biodiversity, and evaluate the effectiveness of policy responses. Here, we review the use of indicators and approaches to model biodiversity loss in Life Cycle Assessment (LCA), a methodology used to evaluate the cradle-to-grave environmental impacts of products. We find serious conceptual shortcomings in the way models are constructed, with scale considerations largely absent. Further, there is a disproportionate focus on indicators that reflect changes in compositional aspects of biodiversity, mainly changes in species richness. Functional and structural attributes of biodiversity are largely neglected. Taxonomic and geographic coverage remains problematic, with the majority of models restricted to one or a few taxonomic groups and geographic regions. On a more general level, three of the five drivers of biodiversity loss as identified by the Millennium Ecosystem Assessment are represented in current impact categories (habitat change, climate change and pollution), while two are missing (invasive species and overexploitation). However, methods across all drivers can be greatly improved. We discuss these issues and make recommendations for future research to better reflect biodiversity loss in LCA.

Czucz, B., A. Csecserits, Z. Botta-Dukat, G. Kroel-Dulay, R. Szabo, F. Horvath and Z. Molnar (2011). "An indicator framework for the climatic adaptive capacity of natural ecosystems." Journal of Vegetation Science **22**(4): 711-725.
Category: Climate change
Keywords: *Climate change, climatic refugia, dispersal capacity, landscape ecology, landscape index, migration, old-field regeneration, species distribution models, vulnerability assessment*

Abstract:
Questions: Can the climatic adaptive capacity of natural ecosystems be estimated with using landscape indicators based on vegetation or land-cover data? Can species

distribution model (SDM) outputs be enhanced using such indicators? What are the data requirements and optimal parameter values of potential indicators?
Location: Indicator framework: unspecified. Case study: Kiskunság, Hungary.
Methods: (1) We define a general framework for handling adaptation in ecological climate change impact assessments based on IPCC definitions. (2) As a part of this general framework, we propose an indicator framework consisting of two specific indicators (landscape connectivity and landscape diversity index) to estimate adaptive capacity of ecosystems to climate change. (3) Using old-field regeneration as a proxy process, we test the proposed indicators, perform sensitivity analysis to optimize them and detect limits of their applicability.
Results: Landscape metrics could provide significant information on regeneration success of old-fields. A combination of large-scale connectivity and local diversity had the highest explanatory power, with connectivity being clearly superior. The tested indicator framework can be applied on the basis of commonly available land-cover data sets. Ecological factors (like dispersal distances) are more important determinants of indicator performance than technical parameters or data resolution, provided minimum data quality is given. The dispersal distance of characteristic species of the Kiskunság forest–steppe region was 1 to 8 km during the last one to four decades.
Conclusions: The results convincingly show that relatively simple and tractable metrics can effectively indicate the landscape-specific capacity of ecosystems to adjust to climatic changes. We argue that the use of adaptive capacity indicator frameworks consisting of simple but ecologically meaningful indicators should accompany every policy-oriented SDM study.

Czucz, B., J. Gathman and G. McPherson (2010). "The impending peak and decline of petroleum production: an underestimated challenge for conservation of ecological integrity." Conservation Biology **24**(4): 948-956.
Category: Ecosystem services; Policy
Keywords: *Ecosystem services, EROI, fossil fuels, global change, impact assessment, maximum empower, peak oil, vulnerability assessment*

Abstract: In the last few decades petroleum has been consumed at a much faster pace than new reserves have been discovered. The point at which global oil extraction will attain a peak ("peak oil") and begin a period of unavoidable decline is approaching. This eventuality will drive fundamental changes in the quantity and nature of energy flows through the human economic system, which probably will be accompanied by economic turmoil, political conflicts, and a high level of social tension. Besides being a geological and economic issue, peak oil is also a fundamental concern as it pertains to ecological systems and conservation because economics is a subsystem of the global ecosystem and changes in human energy-related behaviors can lead to a broad range of effects on natural ecosystems, ranging from overuse to abandonment. As it becomes more difficult to meet energy demands, environmental considerations may be easily superseded. Given the vital importance of ecosystems and ecosystem services in a postpetroleum era, it is crucially important to wisely manage our ecosystems during the transition period to an economy based on little or no use of fossil fuels. Good policies can be formulated

through awareness and understanding gained from scenario-based assessments. Presently, most widely used global scenarios of environmental change do not incorporate resource limitation, including those of the Millennium Ecosystem Assessment and the Intergovernmental Panel on Climate Change. Considering the potential magnitude of the effects of peak oil on society and nature, the development of resource-constrained scenarios should be addressed immediately. Ecologists and conservation biologists are in an important position to analyze the situation and provide guidance, yet the topic is noticeably absent from ecological discussions. We urge politicians, corporate chief executives, thought leaders, and citizens to consider this problem seriously because it is likely to develop into one of the key environmental issues of the 21st century.

Daily, G. (1997). Nature's services: societal dependence on natural ecosystems, Island Press.
Category: Ecosystem services
Keywords: *Earth natural systems, ecosystem services, climate regulation, soil nutrients/cycling, pollination, pest regulation*

Book description from Amazon.com; Life itself as well as the entire human economy depends on goods and services provided by earth's natural systems. The processes of cleansing, recycling, and renewal, along with goods such as seafood, forage, and timber, are worth many trillions of dollars annually, and nothing could live without them. Yet growing human impacts on the environment are profoundly disrupting the functioning of natural systems and imperiling the delivery of these services.Nature's Services brings together world-renowned scientists from a variety of disciplines to examine the character and value of ecosystem services, the damage that has been done to them, and the consequent implications for human society. Contributors including Paul R. Ehrlich, Donald Kennedy, Pamela A. Matson, Robert Costanza, Gary Paul Nabhan, Jane Lubchenco, Sandra Postel, and Norman Myers present a detailed synthesis of our current understanding of a suite of ecosystem services and a preliminary assessment of their economic value. Chapters consider: major services including climate regulation, soil fertility, pollination, and pest control philosophical and economic issues of valuation case studies of specific ecosystems and services implication of recent findings and steps that must be taken to address the most pressing concerns Nature's Services represents one of the first efforts by scientists to provide an overview of the many benefits and services that nature offers to people and the extent to which we are all vitally dependent on those services. The book enhances our understanding of the value of the natural systems that surround us and can play an essential role in encouraging greater efforts to protect the earth's basic life-support systems before it is too late.

Daily, G. and P. Matson (2008). "Ecosystem services: From theory to implementation." Proceedings of the National Academy of Sciences **105**(28): 9455-9456.
Category: Policy
Keywords: *Ecosystem services, natural capital, mapping, finance, policy, governance, decision making*

Abstract: Around the world, leaders are increasingly recognizing ecosystems as

natural capital assets that supply life-support services of tremendous value. The challenge is to turn this recognition into incentives and institutions that will guide wise investments in natural capital, on a large scale. Advances are required on three key fronts, each featured here: the science of ecosystem production functions and service mapping; the design of appropriate finance, policy, and governance systems; and the art of implementing these in diverse biophysical and social contexts. Scientific understanding of ecosystem production functions is improving rapidly but remains a limiting factor in incorporating natural capital into decisions, via systems of national accounting and other mechanisms. Novel institutional structures are being established for a broad array of services and places, creating a need and opportunity for systematic assessment of their scope and limitations. Finally, it is clear that formal sharing of experience, and defining of priorities for future work, could greatly accelerate the rate of innovation and uptake of new approaches.

Daily, G., S. Polasky, J. Goldstein, P. Kareiva, H. Mooney, L. Pejchar, T. Ricketts, J. Salzman and R. Shallenberger (2009). "Ecosystem services in decision making: time to deliver." Frontiers in Ecology and the Environment **7**(1): 21-28.

Category: Farmer and societal benefits; Policy

Keywords: *Ecosystem services, conservation, natural capital, decision making, Hawai´i*

Abstract: Over the past decade, efforts to value and protect ecosystem services have been promoted by many as the last, best hope for making conservation mainstream – attractive and commonplace worldwide. In theory, if we can help individuals and institutions to recognize the value of nature, then this should greatly increase investments in conservation, while at the same time fostering human well-being. In practice, however, we have not yet developed the scientific basis, nor the policy and finance mechanisms, for incorporating natural capital into resource- and land-use decisions on a large scale. Here, we propose a conceptual framework and sketch out a strategic plan for delivering on the promise of ecosystem services, drawing on emerging examples from Hawai‘i. We describe key advances in the science and practice of accounting for natural capital in the decisions of individuals, communities, corporations, and governments.

Dallimer, M., L. Marini, A. M. J. Skinner, N. Hanley, P. R. Armsworth and K. J. Gaston (2010). "Agricultural land-use in the surrounding landscape affects moorland bird diversity." Agriculture, Ecosystems & Environment **139**(4): 578-583.

Category: Agriculture-induced impacts

Keywords: *agri-environment scheme, biodiversity conservation, grassland, landscape*

Abstract: A multi-scale approach was used to investigate the response of the moorland bird community to agricultural land-use in the surrounding matrix and local-scale vegetation characteristics. For the assemblage of upland specialist species, there was a negative association with the extent of intensively managed grassland at the 750 m spatial scale. This had a greater influence on richness than the local vegetation characteristic of the moorland itself. Similarly, for species of conservation concern, richness was enhanced by increased landscape-level woodland cover at the 750 m scale. Such assemblage-level associations can mask the

responses of individual species. For example, some upland specialists, such as the red grouse and golden plover, were negatively associated with intensive grassland in the landscape, while other species of conservation concern, notably curlew, lapwing and snipe all showed positive relationships. These results indicate that upland agriculture at the landscape-scale is integral to maintaining the richness and composition of UK moorland birds and hence land management actions for moorland should not be limited to that habitat alone.

Dänhardt, J., M. Green, Å. Lindström, M. Rundlöf and H. G. Smith (2010). "Farmland as stopover habitat for migrating birds – effects of organic farming and landscape structure." Oikos **119**(7): 1114-1125.

Category: Agriculture-induced impacts

Keywords: *agricultural intensification, migrating birds, landscape, organic farming*

Abstract: Agricultural intensification in Europe has affected farmland bird populations negatively, both during summer and winter. Although the migratory period poses separate challenges on birds than breeding and wintering, the consequences of farming practices for birds during migration remain poorly investigated. We monitored abundance and species richness of migratory birds in autumn at matched pairs of organic and conventional farms situated either in intensively farmed open plains (homogeneous landscapes) or in small-scale farming landscapes (heterogeneous landscapes) in southern Sweden. Total bird density did not differ between landscape types but was marginally higher on organic compared to conventional farms. When including taxonomic status in the model (passerines vs non-passerines), we found significantly more birds on organic farms, and more non-passerines in the homogeneous landscapes. The effect of farming practice and landscape type on density differed between functional groups. Omnivore density was higher in the homogeneous landscapes, and invertebrate feeders were marginally more abundant on organic farms. The effects of farming practice on the overall species richness and on the density of granivorous birds were landscape dependent. In the homogeneous landscapes, organic farms held a higher number of species and density of granivorous birds than conventional farms, but there was no such difference in the heterogeneous landscapes. Thus, organic farming can enhance abundance and species richness of farmland birds during migration, but the effect differs between landscape types and species. The effectiveness of organic farming was highest in the homogeneous landscape making it important to promote organic farming there. However, for some species during migration, increased heterogeneity in homogeneous landscapes may have negative effects. We propose that migratory bird diversity in homogeneous landscapes may be best preserved by keeping the landscape open, but that a reduced agricultural intensity, such as organic farming, should be encouraged.

Darling, E. and I. Côté (2008). "Quantifying the evidence for ecological synergies." Ecology Letters **11**(12): 1278-1286.

Category: Ecosystem services

Keywords: *Meta-analysis, mortality, multiple stressors, non-additive effects, synergy*

Abstract: There is increasing concern that multiple drivers of ecological change will interact synergistically to accelerate biodiversity loss. However, the prevalence and magnitude of these interactions remain one of the largest uncertainties in projections of future ecological change. We address this uncertainty by performing a meta-analysis of 112 published factorial experiments that evaluated the impacts of multiple stressors on animal mortality in freshwater, marine and terrestrial communities. We found that, on average, mortalities from the combined action of two stressors were not synergistic and this result was consistent across studies investigating different stressors, study organisms and life-history stages. Furthermore, only one-third of relevant experiments displayed truly synergistic effects, which does not support the prevailing ecological paradigm that synergies are rampant. However, in more than three-quarters of relevant experiments, the outcome of multiple stressor interactions was non-additive (i.e. synergies or antagonisms), suggesting that ecological surprises may be more common than simple additive effects.

De Deyn, G. and W. Van der Putten (2005). "Linking aboveground and belowground diversity." Trends in ecology & evolution **20**(11): 625-633.

Category: Ecosystem services

Keywords: *Trophic group, functional group, below ground plant part, above ground plant part, terrestrial environment, subterranean medium, plant community, ecosystem functioning, trophic relation, biodiversity, soil nutrient/cycling*

Abstract: Aboveground and belowground species interactions drive ecosystem properties at the local scale, but it is unclear how these relationships scale-up to regional and global scales. Here, we discuss our current knowledge of aboveground and belowground diversity links from a global to a local scale. Global diversity peaks towards the Equator for large, aboveground organisms, but not for small (mainly belowground) organisms, suggesting that there are size-related biodiversity gradients in global aboveground–belowground linkages. The generalization of aboveground–belowground diversity relationships, and their role in ecosystem functioning, requires surveys at scales that are relevant to the organisms and ecosystem properties. Habitat sizes and diversity gradients can differ significantly between aboveground and belowground organisms and between ecosystems. These gradients in biodiversity and plant community trait perception need to be acknowledged when studying aboveground–belowground biodiversity linkages.

De Deyn, G. B., C. E. Raaijmakers, H. R. Zoomer, M. P. Berg, P. C. de Ruiter, H. A. Verhoef, T. M. Bezemer and W. H. van der Putten (2003). "Soil invertebrate fauna enhances grassland succession and diversity." Nature **422**(6933): 711-713.

Category: Ecosystem services

Keywords: *invertebrata, grassland, species diversity, soil functionality, vegetation succession, animal plant relation, soil fauna, animal community, soil nutrients/cycling*

Abstract: One of the most important areas in ecology is to elucidate the factors that drive succession in ecosystems and thus influence the diversity of species in natural vegetation. Significant mechanisms in this process are known to be resource

limitation and the effects of aboveground vertebrate herbivores. More recently, symbiotic and pathogenic soil microbes have been shown to exert a profound effect on the composition of vegetation and changes therein. However, the influence of invertebrate soil fauna on succession has so far received little attention. Here we report that invertebrate soil fauna might enhance both secondary succession and local plant species diversity. Soil fauna from a series of secondary grassland succession stages selectively suppress early successional dominant plant species, thereby enhancing the relative abundance of subordinate species and also that of species from later succession stages. Soil fauna from the mid-succession stage had the strongest effect. Our results clearly show that soil fauna strongly affects the composition of natural vegetation and we suggest that this knowledge might improve the restoration and conservation of plant species diversity.

De Schutter, O. (2011). Agroecology and the Right to Food: Report presented at the 16th Session of the United Nations Human Rights Council. Geneva, Switzerland, United Nations Human Rights Council.
Category: Policy; Agroecology and agroecological practices
Keywords: *Right to food, agroecology*

De Schutter, O. (2012). Contribution of the Special Rapporteur, Mr. Olivier De Schutter, to the inquiry launched by the International Development Committee of the Parliament of the United Kingdom in advance of the June 2013 G8 Summit. Mandate of the Special Rapporteur on the right to food. Geneva, Office of the High Commissioner of Human Rights**:** 6.
Category: Policy; Agroecology and agroecological practices
Keywords: *Right to food, UK, International Law, policy, Right to Food Guidelines, gender equality, empowerment of women, poverty, climate change, Global Fund for Social Protection, food reserves, agrofuels, accountability*

De Vries, F., R. Rabbinge and J. Groot (1997). "Potential and attainable food production and food security in different regions." Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences **352**(1356): 917-928.
Category: Policy; Agroecology and agroecological practices
Keywords: *Food production, food supply, sustainability, resource management, population growth*
Abstract: Growing prosperity in the South is accompanied by human diets that will claim more natural resources per capita. This reality, combined with growing populations, may raise the global demand for food crops two– to four–fold within two generations. Considering the large volume of natural resources and potential crop yields, it seems that this demand can be met smoothly. However, this is a fallacy for the following reasons. (i) Geographic regions differ widely in their potential food security: policy choices for agricultural use of natural resources are limited in Asia. For example, to ensure national self–sufficiency and food security, most of the suitable land (China) and nearly all of the surface water (India) are

needed. Degradation restricts options further. (ii) The attainable level of agricultural production depends also on socio–economic conditions. Extensive poverty keeps the attainable food production too low to achieve food security, even when the yield gap is wide, as in Africa. (iii) Bio–energy, non–food crops and nature 'compete' with food crops for natural resources.

Debaeke, P., N. Munier-Jolain, M. Bertrand, L. Guichard, J.-M. Nolot, V. Faloya and P. Saulas (2009). Iterative Design and Evaluation of Rule-Based Cropping Systems: Methodology and Case Studies - A Review. Sustainable Agriculture, Springer Netherlands**:** 707-724.

Category: Agriculture-induced impacts

Keywords: *Agronomic evaluation, decision rules, integrated cropping systems, long-term experiment*

Abstract: The economic and regulatory context of crop production changes rapidly, but concerns about agricultural sustainability, including environmental impacts, are increasing steadily. To cope with complexity and uncertainty, innovative methodologies are required for designing, managing and evaluating prototype cropping systems. A generic approach combining iteratively design of cropping systems and evaluation of their performances is presented in this review article. It includes five main steps: (1) defining the set of goals and constraints for each cropping system, (2) identifying a suitable agronomic strategy, (3) formulating the consistent set of technical decision rules, (4) applying and evaluating the rule-based system, and (5) validating or refining the strategy and the rules. This methodology was applied to a range of environmental and production contexts, in a perspective of integrated crop production (ICP) prototyping. Three cropping system experiments conducted in France were brought together to demonstrate the potentialities of this system approach and discuss the methodological bottlenecks to address. The three case studies differed by the context of crop production and resource use: adaptation to limited irrigation water (Toulouse), introduction of innovative cropping systems (Versailles), and substitution of herbicides by non-chemical methods (Dijon). The consequences of the specific objectives in each case study on the experimental design and the evaluation process were discussed. Special attention was paid to the time step of the evaluation process, the duration of the improvement loops when prototyping cropping systems, the global evaluation of the systems and the evaluation of individual decision rules.

DeFries, R. S., J. A. Foley and G. P. Asner (2004). "Land-use choices: balancing human needs and ecosystem function." Frontiers in ecology and the environment **2**(5): 249-257.

Category: Ecosystem services; policy

Keywords: *Ecosystem functions, land use, human needs*

Abstract: Conversion of land to grow crops, raise animals, obtain timber, and build cities is one of the foundations of human civilization. While land use provides these essential ecosystem goods, it alters a range of other ecosystem functions, such as the provisioning of freshwater, regulation of climate and biogeochemical cycles, and maintenance of soil fertility. It also alters habitat for biological diversity. Balancing the inherent trade-offs between satisfying immediate human needs and maintaining

other ecosystem functions requires quantitative knowledge about ecosystem responses to land use. These responses vary according to the type of land-use change and the ecological setting, and have local, short-term as well as global, long-term effects. Land-use decisions ultimately weigh the need to satisfy human demands and the unintended ecosystem responses based on societal values, but ecological knowledge can provide a basis for assessing the trade-offs.

Delaplane, K. and D. Mayer (2000). Crop pollination by bees, Cabi.
Category: Ecosystem services
Keywords: *Pollinators, bees, ecosystem services, crop production, pollination*

Description from Amazon.com: The collapse of the ubiquitous honey bee population during the past 20 years has caused a pollination vacuum for many crops. Surveys and grower experience indicate that a crisis exists in pollinator populations. This book is an accessible, practical and authoritative research-based guide to using bees for crop pollination. It emphasizes conserving feral bee populations as well as more traditional methods of culturing honey bees and other bees. It addresses the biology of pollination, culturing and managing bees for optimum crop pollination. Individual pollination requirements and recommendations for the worlds main crops are covered in 36 short chapters that make up the second part of the book.

Delettre, Y. (2005). "Short-range spatial patterning of terrestrial Chironomidae (Insecta: Diptera) and farmland heterogeneity." Pedobiologia **49**(1): 15-27.
Category: Ecosystem services
Keywords: *Agriculture, biodiversity, disturbance, hedgerow, field margin, landscape heterogeneity, soil fauna, soil nutrients/cycling*

Abstract: Most work considering the effects of landscape structure and heterogeneity on biodiversity in farmland has been devoted to mammals or birds. Despite their worldwide distribution in many different soil types, the ecology of terrestrial Chironomidae is still poorly known. The influence of landscape heterogeneity on the short-range spatial distribution of adult terrestrial Chironomidae within three agricultural landscapes was investigated in Brittany (France). One hundred and twenty-eight yellow pan traps collecting flying individuals emerging from surrounding habitats were set in pairs on the soil surface of crop fields at the bottom of bordering hedges throughout the three sites. Chironomids abundance data were related to nine environmental factors using co-inertia analyses. The terrestrial chironomid community, which included 11 species, was dominated numerically by a semi-terrestrial species, Limnophyes minimus (Mg.), and a true terrestrial species, Smittia pratorum (G.). Amongst environmental factors, disturbance level, land cover, soil hydromorphy, and vegetation height had a significant influence on the distribution of species at all sites. Hedge quality and soil flooding were also significant factors at two of the three sites. Specific life-history traits (including larval and adult ecological requirements) interact with landscape heterogeneity to determine the short-range spatial patterning of species. This work, which provides the first detailed study of adult terrestrial chironomids in farmland, shows that management of crop fields and hedges by farmers has a strong influence

on landscape heterogeneity and, consequently, on the spatial distribution of species.

Diaz, S., J. Fargione, F. Chapin III and D. Tilman (2006). "Biodiversity loss threatens human well-being." PLoS biology **4**(8): e277.
Category: Agriculture-induced impacts
Keywords: *Megadiversity hot spots, vulnerable people*

From introduction: The diversity of life on Earth is dramatically affected by human alterations of ecosystems [1]. Compelling evidence now shows that the reverse is also true: biodiversity in the broad sense affects the properties of ecosystems and, therefore, the benefits that humans obtain from them. In this article, we provide a synthesis of the most crucial messages emerging from the latest scientific literature and international assessments of the role of biodiversity in ecosystem services and human well-being.

Human societies have been built on biodiversity. Many activities indispensable for human subsistence lead to biodiversity loss, and this trend is likely to continue in the future. We clearly benefit from the diversity of organisms that we have learned to use for medicines, food, fibers, and other renewable resources. In addition, biodiversity has always been an integral part of the human experience, and there are many moral reasons to preserve it for its own sake. What has been less recognized is that biodiversity also influences human well-being, including the access to water and basic materials for a satisfactory life, and security in the face of environmental change, through its effects on the ecosystem processes that lie at the core of the Earth's most vital life support systems.

Diaz, S., F. Quetier, D. Caceres, S. Trainor, N. Perez-Harguindeguy, M. Bret-Harte, B. Finegan, M. Peña-Claros and L. Poorter (2011). "Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society." Proceedings of the National Academy of Sciences **108**(3): 895-902.
Category: Farmer and societal benefits
Keywords: *Ecosystem services, diversity, interdisciplinary analysis, society*

Abstract: The crucial role of biodiversity in the links between ecosystems and societies has been repeatedly highlighted both as source of wellbeing and as a target of human actions, but not all aspects of biodiversity are equally important to different ecosystem services. Similarly, different social actors have different perceptions of and access to ecosystem services, and therefore, they have different wants and capacities to select directly or indirectly for particular biodiversity and ecosystem characteristics. Their choices feed back onto the ecosystem services provided to all parties involved and in turn, affect future decisions. Despite this recognition, the research communities addressing biodiversity, ecosystem services, and human outcomes have yet to develop frameworks that adequately treat the multiple dimensions and interactions in the relationship. Here, we present an interdisciplinary framework for the analysis of relationships between functional diversity, ecosystem services, and human actions that is applicable to specific social environmental systems at local scales. We connect the mechanistic understanding of the ecological role of diversity with its social relevance: ecosystem services. The

framework permits connections between functional diversity components and priorities of social actors using land use decisions and ecosystem services as the main links between these ecological and social components. We propose a matrix-based method that provides a transparent and flexible platform for quantifying and integrating social and ecological information and negotiating potentially conflicting land uses among multiple social actors. We illustrate the applicability of our framework by way of land use examples from temperate to subtropical South America, an area of rapid social and ecological change.

Doré, T., D. Makowski, E. Malézieux, N. Munier-Jolain, M. Tchamitchian and P. Tittonell (2011). "Facing up to the paradigm of ecological intensification in agronomy: revisiting methods, concepts and knowledge." European Journal of Agronomy(34): 197-210.

Category: ecosystem services

Keywords: *agroecology, agroecosystem, plant science, farmers´ knowledge, meta-analysis, comparative analysis, ecological intensification*

Abstract: Agriculture is facing up to an increasing number of challenges, including the need to ensure various ecosystem services and to resolve apparent conflicts between them. One of the ways forward for agriculture currently being debated is a set of principles grouped together under the umbrella term “ecological intensification”. In published studies, ecological intensification has generally been considered to be based essentially on the use of biological regulation to manage agroecosystems, at field, farm and landscape scales. We propose here five additional avenues that agronomic research could follow to strengthen the ecological intensification of current farming systems. We begin by assuming that progress in plant sciences over the last two decades provides new insight of potential use to agronomists. Potentially useful new developments in plant science include advances in the fields of energy conversion by plants, nitrogen use efficiency and defence mechanisms against pests. We then suggest that natural ecosystems may also provide sources of inspiration for cropping system design, in terms of their structure and function on the one hand, and farmers’ knowledge on the other. Natural ecosystems display a number of interesting properties that could be incorporated into agroecosystems. We discuss the value and limitations of attempting to ‘mimic’ their structure and function, while considering the differences in objectives and constraints between these two types of system. Farmers develop extensive knowledge of the systems they manage. We discuss ways in which this knowledge could be combined with, or fed into scientific knowledge and innovation, and the extent to which this is likely to be possible. The two remaining avenues concern methods. We suggest that agronomists make more use of meta-analysis and comparative system studies, these two types of methods being commonly used in other disciplines but barely used in agronomy. Meta-analysis would make it possible to quantify variations of cropping system performances in interaction with soil and climate conditions more accurately across environments and socio-economic contexts. Comparative analysis would help to identify the structural characteristics of cropping and farming systems underlying properties of interest. Such analysis can be performed with sets of performance indicators and methods borrowed from ecology for analyses of the structure and organisation of these systems. These five

approaches should make it possible to deepen our knowledge of agroecosystems for action.

Drechsler, M., F. Watzold, K. Johst and J. Shogren (2010). "An agglomeration payment for cost-effective biodiversity conservation in spatially structured landscapes." Resource and Energy Economics **32**(2): 261-275.

Category: Ecosystem services

Keywords: *Agglomeration bonus, biodiversity conservation, cost-effectiveness, ecological-economic modelling, metapopulation, spatial heterogeneity*

Abstract: Connected habitats are ecologically more valuable than isolated habitats for many species. A key challenge when designing payments for biodiversity in fragmented landscapes is to increase the spatial connectivity of habitats. Based on the idea of an agglomeration bonus we consider a scheme in which land-owners only receive payments if habitats are arranged in an ecologically favourable configuration. We compare the cost-effectiveness of agglomeration payments to spatially homogeneous payments on a conceptual level. Our results suggest that positive efficiency gains exist for agglomeration payments. We use Large Blue butterfly habitat in Germany as a specific case study, and find the agglomeration payments may lead to cost-savings of nearly 70% relative to homogenous payments.

Dutton, A., G. Edwards-Jones and D. Macdonald (2010). "Estimating the value of non-use benefits from small changes in the provision of ecosystem services." Conservation Biology **24**(6): 1479-1487.

Category: Farmer and societal benefits

Keywords: *Biodiversity offsets, habitat restoration, land-use change, marginal values, non-use values, stated preference*

Abstract: The unit of trade in ecosystem services is usually the use of a proportion of the parcels of land associated with a given service. Valuing small changes in the provision of an ecosystem service presents obstacles, particularly when the service provides non-use benefits, as is the case with conservation of most plants and animals. Quantifying non-use values requires stated-preference valuations. Stated-preference valuations can provide estimates of the public's willingness to pay for a broad conservation goal. Nevertheless, stated-preference valuations can be expensive and do not produce consistent measures for varying levels of provision of a service. Additionally, the unit of trade, land use, is not always linearly related to the level of ecosystem services the land might provide. To overcome these obstacles, we developed a method to estimate the value of a marginal change in the provision of a non-use ecosystem service—in this case conservation of plants or animals associated with a given land-cover type. Our method serves as a tool for calculating transferable valuations of small changes in the provision of ecosystem services relative to the existing provision. Valuation is achieved through stated-preference investigations, calculation of a unit value for a parcel of land, and the weighting of this parcel by its ability to provide the desired ecosystem service and its effect on the ability of the surrounding land parcels to provide the desired service. We used the water vole (Arvicola terrestris) as a case study to illustrate the method. The average

present value of a meter of water vole habitat was estimated at UK£12, but the marginal value of a meter (based on our methods) could range between £0 and £40 or more.

Egger, K. (1986). "Ecological intensification. Soil conservation and improvement of tropical soils by pastoral agroforestry systems." Collection Documents Systèmes Agraires(6): 129-135.

Category: Ecosystem services

Keywords: *ecological intensificaiton; agroforestry, choice of species, fodder plants, green manures, multipurpose trees, pigeon peas, Silvopastoral systems, soil conservation, trees, woody plants*

Abstract: An agropastoral project in Rwanda is used to illustrate the ecological intensification approach to soil conservation. Trees and shrubs such as Grevillea robusta, Albizia versicolor, Croton macrostachys, Acrocarpus fraxinifolius, Cassia spectabilis, Cedrela odorata, Casuarina equisetifolia, Millettia dura and Maesopsis eminii at an optimum density of 200-400 trees/ha with multiple age composition were recommended for reinforcing banks and establishing terraces. Use of Eucalyptus, cypresses and pines was to be avoided. Replacement of the grasses Tripsacum laxum, and Setaria and Pennisetum by the shrubs Leucaena, Calliandra calothyrsus and Cajanus cajan and increased planting of legumes in drainage ditches was also recommended. The increased use of green manures to increase soil OM levels was discussed and the need to make use of some of the biomass produced for bedding or fodder to prevent the accumulation of undecomposed OM was stressed. A mixture of Tephrosia vogelii, C. cajan and a Crotalaria sp. from the Cameroons planted 10 cm apart gave satisfactory results. An ideal pastoral agroforestry system for the central highlands of Rwanda is presented in diagrammatic form.

Eigenbrod, F., P. Armsworth, B. Anderson, A. Heinemeyer, S. Gillings, D. Roy, C. Thomas and K. Gaston (2010). "Error propagation associated with benefits transfer-based mapping of ecosystem services." Biological Conservation **143**(11): 2487-2493.

Category: Farmer and societal benefits

Keywords: *Biodiversity, carbon, natural capital, sustainability, spatial value transfer, Britain*

Abstract: An increasing number of studies are taking the important first step in global efforts to conserve key ecosystem services by mapping their spatial distributions. However, a lack of primary data for most services in most places has largely forced such mapping exercises to be based on proxies. The common way of producing these proxies is through benefits transfer-based mapping, in which estimates of the values of services are obtained from a small region for particular land cover types, and then extrapolated to a larger area for these same types. However, the errors that may result from such extrapolations are poorly understood. Here, we separate the generalization errors associated with benefits transfer mapping into three constituent components – uniformity, sampling, and regionalization error – and evaluate their effects using primary data for four ecosystem services in England. Variation in ecosystem services within a particular land cover type (uniformity error) alone led to a poor fit to primary data for most

services; sampling effects (sampling error) and extrapolating from a small region to a larger area (regionalization error) led to substantial, but highly variable, additional reductions in the fit to primary data. We also show that combining multiple ecosystem services into a single layer is likely to be even more problematic as it contains the errors in each of the constituent layers. These errors are sufficiently large to undermine decisions that might be based on such extrapolated maps. Greatly improved mapping of the actual distributions of ecosystem services is therefore needed to achieve the goal of conserving these vital assets.

Eilers, E., C. Kremen, S. Greenleaf, A. Garber and A. Klein (2011). "Contribution of pollinator-mediated crops to nutrients in the human food supply." PloS one **6**(6): e21363.

Category: Ecosystem services

Keywords: *Animal-pollinated world crops, nutritional composition, pollinator dependency, pollinator decline, pollination*

Abstract: The contribution of nutrients from animal pollinated world crops has not previously been evaluated as a biophysical measure for the value of pollination services. This study evaluates the nutritional composition of animal-pollinated world crops. We calculated pollinator dependent and independent proportions of different nutrients of world crops, employing FAO data for crop production, USDA data for nutritional composition, and pollinator dependency data according to Klein et al. (2007). Crop plants that depend fully or partially on animal pollinators contain more than 90% of vitamin C, the whole quantity of Lycopene and almost the full quantity of the antioxidants β-cryptoxanthin and β-tocopherol, the majority of the lipid, vitamin A and related carotenoids, calcium and fluoride, and a large portion of folic acid. Ongoing pollinator decline may thus exacerbate current difficulties of providing a nutritionally adequate diet for the global human population.

Eisenbeis, G., R. Lenz and T. Heiber (1999). "Organic residue decomposition: The minicontainer-system a multifunctional tool in decomposition studies." Environmental Science and Pollution Research **6**(4): 220-224.

Category: Agroecology and agroecological practices

Keywords: *Biological activity, decomposition, litter, minicontainer-system, organic residue decomposition, soil monitoring, soil nutrients/cycling*

Abstract: The Minicontainer-test, first described by Eisenbeis (1993), was designed to study the kinetics of organic residue decomposition at a microsite level. It is derived from the litterbag technique and consists of polyethylene minicontainers (volume about 1.5 cm3) filled with a test substrate (litter, straw, cellulose, etc.). The minicontainers (MCs) are closed at either end with plastic gauze discs of variable mesh size (e.g. 20 µm, 250 µm, 500 µm or 2 mm). A definite number of such units are inserted into PVC-bars, which can be implanted into the soil horizontally or vertically, or be exposed on the soil surface horizontally. The bars are very stable and can be exposed in different environments for months to years. If required, the bars can be removed temporarily and stored, e.g. during soil cultivation. Should fresh litter be used, two phases of decomposition can be distinguished: a fast initial phase, which can be mainly related to the effect of leaching, and a second slow phase

depending mainly on the activity of soil organisms and litter quality. Several questions can be addressed to investigations using MCs, e.g. 1) parts of the soil fauna which are involved in decomposition (nematodes, microarthropods, and smaller specimens of the macrofauna, e.g. enchytraeidae, diplopods and dipteran larvae) can be extracted from the litter substrate using a miniscale high gradient extractor, 2) the organic mass loss of litter can be determined, 3) microbial biomass (Cmic, Nmic) can be assessed by fumigation extraction and 4) microbial activity (respiration) in the test substrate can also be assessed by use of standardised methods. Compared to litterbag studies, the larger number of small replicate units improves the statistical evaluation. Until today the Minicontainer-test has been applied in forestry and agriculture, e.g. studying the effects of liming, soil restoration and the application of insecticides, e.g. Diflubenzuron (Dimilin) and Btk (Bacillus thuringiensis var.kurstaki).

Eitzel, M., S. Diver, H. Sardiñas, L. Hallett, J. Olson, A. Romero, G. Oliveira, A. Schuknecht, R. Tidmore and K. Suding (2012). "Insights from a Cross-Disciplinary Seminar: 10 Pivotal Papers for Ecological Restoration." Restoration Ecology **20**(2): 147-152.

Category: Ecosystem services; Agroecology and agroecological practices

Keywords: *Climate modeling, coupled social and ecological systems, ecological monitoring, ecosystem services markets, global change, novel ecosystems, restoration practice, Traditional Ecological Knowledge*

Abstract: Restoration ecology is a deepening and diversifying field with current research incorporating multiple disciplines and infusing long-standing ideas with fresh perspectives. We present a list of 10 recent pivotal papers exemplifying new directions in ecological restoration that were selected by students in a cross-disciplinary graduate seminar at the University of California, Berkeley. We highlight research that applies ecological theory to improve restoration practice in the context of global change (e.g. climate modeling, evaluation of novel ecosystems) and discuss remaining knowledge gaps. We also discuss papers that recognize the social context of restoration and the coupled nature of social and ecological systems, ranging from the incorporation of cultural values and Traditional Ecological Knowledge into restoration, to the consideration of the broader impacts of markets on restoration practices. In addition, we include perspectives that focus on improving communication between social and natural scientists as well as between scientists and practitioners, developing effective ecological monitoring, and applying more integrated, whole-landscape approaches to restoration. We conclude with insights on recurrent themes in the papers regarding planning restoration in human-modified landscapes, application of ecological theory, improvements to restoration practice, and the social contexts of restoration. We share lessons from our cross-disciplinary endeavor, and invite further discussion on the future directions of restoration ecology through contributions to our seminar blog site http://restecology.blogspot.com.

Ekstrom, G. and B. Ekbom (2011). "Pest control in agro-ecosystems: An ecological approach." Critical Reviews in Plant Sciences **30**(1-2): 74-94.

Category: Ecosystem services

Keywords: *Adaptive pest control, agricultural performance indicators, climate field schools, continuous improvement, environmental impact quotients, impact reduction, rational pesticide use, resilience, pest regulation*

Abstract: This text combines two basically different views on pest control namely the scientific researcher's view on pest control and the pesticide regulator's views on pesticide control aiming at a common and pragmatic ecological approach. A set of practicable 'tools' are discussed that can be used to monitor and reduce environmental impact on agro-ecosystems where the ultimate goal is to move towards a more environmentally sustainable agriculture. General principles governing farming systems and pest control strategies are illustrated with pesticide use and pesticide risk reduction measures in coffee and rice cultivations. Adaptive pest control based on Integrated Pest Management with a rational use of pesticides as a last resort is suggested to be the most viable way forward.

Elmqvist, T., C. Folke, M. Nystrom, G. Peterson, J. Bengtsson, B. Walker and J. Norberg (2003). "Response diversity, ecosystem change, and resilience." Frontiers in Ecology and the Environment **1**(9): 488-494.

Category: Ecosystem services

Keywords: *Diversity, ecosystem change, resilience, ecosystem services, environmental change*

Abstract: Biological diversity appears to enhance the resilience of desirable ecosystem states, which is required to secure the production of essential ecosystem services. The diversity of responses to environmental change among species contributing to the same ecosystem function, which we call response diversity, is critical to resilience. Response diversity is particularly important for ecosystem renewal and reorganization following change. Here we present examples of response diversity from both terrestrial and aquatic ecosystems and across temporal and spatial scales. Response diversity provides adaptive capacity in a world of complex systems, uncertainty, and human-dominated environments. We should pay special attention to response diversity when planning ecosystem management and restoration, since it may contribute considerably to the resilience of desired ecosystem states against disturbance, mismanagement, and degradation.

Engel, S., S. Pagiola and S. Wunder (2008). "Designing payments for environmental services in theory and practice: An overview of the issues." Ecological Economics **65**(4): 663-674.

Category: Farmer and societal benefits

Keywords: *Payments for environmental services, incentive mechanisms, conservation, ecosystem services*

Abstract: Payments for environmental services (PES) have attracted increasing interest as a mechanism to translate external, non-market values of the environment into real financial incentives for local actors to provide environmental services (ES). In this introductory paper, we set the stage for the rest of this Special Issue of Ecological Economics by reviewing the main issues arising in PES design and implementation and discussing these in the light of environmental economics. We

start with a discussion of PES definition and scope. We proceed to review some of the principal dimensions and design characteristics of PES programs and then analyze how PES compares to alternative policy instruments. Finally, we examine in detail two important aspects of PES programs: their effectiveness and their distributional implications.

PES is not a silver bullet that can be used to address any environmental problem, but a tool tailored to address a specific set of problems: those in which ecosystems are mismanaged because many of their benefits are externalities from the perspective of ecosystem managers. PES is based on the beneficiary-pays rather than the polluter-pays principle, and as such is attractive in settings where ES providers are poor, marginalized landholders or powerful groups of actors. An important distinction within PES is between user-financed PES in which the buyers are the users of the ES, and government-financed PES in which the buyers are others (typically the government) acting on behalf of ES users. In practice, PES programs differ in the type and scale of ES demand, the payment source, the type of activity paid for, the performance measure used, as well as the payment mode and amount. The effectiveness and efficiency of PES depends crucially on program design.

Engelkes, T., E. Morrien, K. Verhoeven, T. Bezemer, A. Biere, J. Harvey, L. McIntyre, W. Tamis and W. van der Putten (2008). "Successful range-expanding plants experience less above-ground and below-ground enemy impact." Nature **456**(7224): 946-948.

Category: Ecosystem services

Keywords: *Dynamical climatology, geographic distribution, animal plant relation, warming, climate change, altitudinal distribution, latitudinal distribution, biomass, native species, comparative study, phytophagous, insect resistance, distribution range, expansion, plant, pest regulation, invasive species, belowground biodiversity*

Abstract: Many species are currently moving to higher latitudes and altitudes1–3. However, little is known about the factors that influence the future performance of range-expanding species in their new habitats. Here we show that range-expanding plant species from a riverine area were better defended against shoot and root enemies than were related native plant species growing in the same area. We grew fifteen plant species with and without non-coevolved poly- phagous locusts and cosmopolitan, polyphagous aphids. Contrary to our expectations, the locusts performed more poorly on the range-expanding plant species than on the congeneric native plant species, whereas the aphids showed no difference. The shoot herbi- vores reduced the biomass of the native plants more than they did that of the congeneric range expanders. Also, the range-expanding plants developed fewer pathogenic effects4,5 in their root-zone soil than did the related native species. Current predictions forecast biodiversity loss due to limitations in the ability of species to adjust to climate warming conditions in their range6–8. Our results strongly suggest that the plants that shift ranges towards higher latitudes and altitudes may include potential invaders, as the successful range expanders may experience less control by above-ground or below- ground enemies than the natives.

European Commission (2005). Agri-environment Measures. Overview on general principles,

types of measures, and application**:** 24.
Category: Policy
Keywords: *Agri-environmental measures, (non) productive land management, impacts, biodiversity, landscape*

Aim of the report: This report is based on the agri-environment sections of a selection of mid-term Rural Development reports by Member States/regions1, a selection of literature in the field, and informal contacts with experts. It aims to give an early overview on agri-environmental measures applied in the 2000-2006 Rural Development programming period. There were limitations on what could be achieved, not least because the information contained in many of the mid-term reports on uptake and impacts is limited. A comprehensive picture of the effectiveness and efficiency of agri-environmental measures will be available from the evaluation study on agri-environmental measures for which work has started in the beginning of 2005.

The report starts by providing some background on agri-environment measures, describes the sort of commitments they involve, examines some obstacles to effective measures, and then gives an account of the information available on environmental impacts of measures. It then looks briefly at the question of efficiency of measures. Finally, it enumerates key points arising out of past experience which were taken into account in preparing the Rural Development reform package of July 2004.

European Commission (2011). Our life insurance, our natural capital: an EU biodiversity strategy to 2020. Communication from the Commission to the European Parliament, The Council, The economic and social committe and the committe of the regions. COM (2011). **244**.
Category: Policy
Keywords: *Biodiversity, natural capital, EU*

Abstract: Biodiversity — the extraordinary variety of ecosystems, species and genes that surround us — is our life insurance, giving us food, fresh water and clean air, shelter and medicine, mitigating natural disasters, pests and diseases and contributes to regulating the climate. Biodiversity is also our natural capital, delivering ecosystem services that underpin our economy. Its deterioration and loss jeopardises the provision of these services: we lose species and habitats and the wealth and employment we derive from nature, and endanger our own wellbeing. This makes biodiversity loss the most critical global environmental threat alongside climate change — and the two are inextricably linked. While biodiversity makes a key contribution to climate change mitigation and adaptation, achieving the '2 degrees' target coupled with adequate adaptation measures to reduce the impacts of unavoidable effects of climate change are also essential to avert biodiversity loss.

Current rates of species extinction are unparalleled. Driven mainly by human activities, species are currently being lost 100 to 1,000 times faster than the natural rate: according to the FAO, 60% of the world's ecosystems are degraded or used unsustainably; 75% of fish stocks are over-exploited or significantly depleted and 75% of the genetic diversity of agricultural crops has been lost worldwide since 1990. An estimated 13 million hectares of tropical forests are cleared each year1 and 20%

of the world's tropical coral reefs have already disappeared, while 95% will be at risk of destruction or extreme damage by 2050 if climate change continues unabated2.
In the EU, only 17 % of habitats and species and 11 % of key ecosystems protected under EU legislation are in a favourable state3. This is in spite of action taken to combat biodiversity loss, particularly since the EU 2010 biodiversity target was set in 2001. The benefits of these actions have been outweighed by continued and growing pressures on Europe's biodiversity: land-use change, over-exploitation of biodiversity and its components, the spread of invasive alien species, pollution and climate change have either remained constant or are increasing. Indirect drivers, such as population growth, limited awareness about biodiversity and the fact that biodiversity's economic value is not reflected in decision making are also taking a heavy toll on biodiversity.
This strategy is aimed at reversing biodiversity loss and speeding up the EU's transition towards a resource efficient and green economy. It is an integral part of the Europe 2020 Strategy4, and in particular the resource efficient Europe flagship initiative5.

European Commission (2012). "Agri-environment measures." Policy areas: agriculture and environment. Retrieved 03/07/2013, 2013, from http://ec.europa.eu/agriculture/envir/measures/.
Category: Policy
Keywords: *Agri-environment measures*

Abstract: Biodiversity — the extraordinary variety of ecosystems, species and genes that surround us — is our life insurance, giving us food, fresh water and clean air, shelter and medicine, mitigating natural disasters, pests and diseases and contributes to regulating the climate. Biodiversity is also our natural capital, delivering ecosystem services that underpin our economy. Its deterioration and loss jeopardises the provision of these services: we lose species and habitats and the wealth and employment we derive from nature, and endanger our own wellbeing. This makes biodiversity loss the most critical global environmental threat alongside climate change — and the two are inextricably linked. While biodiversity makes a key contribution to climate change mitigation and adaptation, achieving the '2 degrees' target coupled with adequate adaptation measures to reduce the impacts of unavoidable effects of climate change are also essential to avert biodiversity loss.
Current rates of species extinction are unparalleled. Driven mainly by human activities, species are currently being lost 100 to 1,000 times faster than the natural rate: according to the FAO, 60% of the world's ecosystems are degraded or used unsustainably; 75% of fish stocks are over-exploited or significantly depleted and 75% of the genetic diversity of agricultural crops has been lost worldwide since 1990. An estimated 13 million hectares of tropical forests are cleared each year and 20% of the world's tropical coral reefs have already disappeared, while 95% will be at risk of destruction or extreme damage by 2050 if climate change continues unabated.
In the EU, only 17 % of habitats and species and 11 % of key ecosystems protected under EU legislation are in a favourable state. This is in spite of action taken to combat biodiversity loss, particularly since the EU 2010 biodiversity target was set in 2001. The benefits of these actions have been outweighed by continued and growing

pressures on Europe's biodiversity: land-use change, over-exploitation of biodiversity and its components, the spread of invasive alien species, pollution and climate change have either remained constant or are increasing. Indirect drivers, such as population growth, limited awareness about biodiversity and the fact that biodiversity's economic value is not reflected in decision making are also taking a heavy toll on biodiversity.

This strategy is aimed at reversing biodiversity loss and speeding up the EU's transition towards a resource efficient and green economy. It is an integral part of the Europe 2020 Strategy, and in particular the resource efficient Europe flagship initiative5.

Evans, N. (2013). "Strawberry fields forever? Conflict over neo-productivist Spanish polytunnel technology in British agriculture." Land Use Policy **35**(0): 61-72.

Category: Agriculture-induced impacts

Keywords: *Spanish polytunnels, neo-productivism, new agricultural technologies, rural protest, planning regulation, conflict resolution*

Highlights

- Plastic Spanish polytunnels are a technology of neo-productivist British agriculture.
- UK growers can now compete on the supermarket-driven global strawberry market.
- The appearance of polytunnels in rural communities has caused bitter conflict.
- Planners are identified as the 'strawberry tools' for exercising weak regulation.
- Polytunnels allow glimpses of likely future conflicts from agricultural technologies.

Abstract: This paper uses the example of Spanish polytunnels to demonstrate how the deployment of 'neo-productivist' agricultural technologies to meet the demands of food security and sustainability within a globalised food chain is likely to precipitate greater countryside conflict. Field-scale 'Spanish polytunnels' for strawberry growing have become a new feature of the British agricultural landscape. This has been driven primarily by supermarkets searching for high quality and quantity supplies of soft fruit. With production becoming industrialised, conflict has ensued in some rural communities where polytunnels have appeared. Interviews with prominent strawberry growers and protestors against polytunnels illuminate a vociferous and embittered wrangle. Within it, land use planners are labelled as 'strawberry fools' by both sides for failing, until recently, to provide decisive regulation to prevent conflict and effect its resolution. The paper concludes by drawing attention to the future characteristics of conflicts precipitated as new agricultural technologies are implemented rapidly, impact unevenly and are received acrimoniously.

Ewel, J. (1999). "Natural systems as models for the design of sustainable systems of land use." Agroforestry Systems **45**(1-3): 1-21.

Category: Agroecology and agroecological practices

Keywords: *Agriculture, climate, fertility, humid tropics life zones, succession, grazing systems*

Abstract: Natural ecosystems, whose components are the results of natural

selection, are sustainable; most are productive, responsive to pests, and retentive of nutrients. Thus, they are appropriate models on which to base the design of new systems of land use. Abiotic and biotic stressors are related non-linearly; the nadir of total stress being mid-way along a gradient of environmental harshness. Superimposing the stress functions on Holdridge's life zone chart yields four broad categories of environments for agriculture: climates where annual rainfall is similar to potential evapotranspiration, plus three other categories that are either too cold, too arid, or too wet. Extremely cold lands have no potential for agriculture. Lands that are arid or infertile can be used successfully, although the cost of compensating for environmental limitations increases exponentially with increasing abiotic stress. Grazing animals (which act as trophic buffers between people and environment) have proven successful in dry and infertile environments. The humid tropical lowlands epitomise environments of low abiotic stress but overwhelming biotic intricacy. Here it pays to imitate natural systems rather than struggle to impose simplicity on ecosystems that are inherently complex. The keys to success are to (i) channel productivity into outputs of nutritional and economic importance, (ii) maintain adequate diversity to compensate for losses in a system simple enough to be horticulturally manageable, (iii) manage plants and herbivores to facilitate associational resistance and not associational susceptibility, and (iv) use perennial plants to maintain soil fertility, guard against erosion, and make full use of resources.

Ewers, R., J. Scharlemann, A. Balmford and R. Green (2009). "Do increases in agricultural yield spare land for nature?" Global Change Biology **15**(7): 1716-1726.

Category: Ecosystem services

Keywords: *Agricultural intensification, deforestation, food availability, global analysis, land use change*

Abstract: Feeding a rapidly expanding human population will require a large increase in the supply of agricultural products during the coming decades. This may lead to the transformation of many landscapes from natural vegetation cover to agricultural land use, unless increases in crop yields reduce the need for new farmland. Here, we assess the evidence that past increases in agricultural yield have spared land for wild nature. We investigated the relationship between the change in the combined energy yield of the 23 most energetically important food crops over the period 1979–1999 and the change in per capita cropland area for 124 countries over the same period. Per capita area of the 23 staple crops tended to decrease in developing countries where large yield increases occurred. However, this was counteracted by a tendency for the area used to grow crops other than staples to increase in the countries where staple crop yields increased. There remained a weak tendency in developing countries for the per capita area of all cropland to decline as staple crop yield increased, a pattern that was most evident in developing countries with the highest per capita food supplies. In developed countries, there was no evidence that higher staple crop yields were associated with decreases in per capita cropland area. This may be because high agricultural subsidies in developed countries override any land-sparing pattern that might otherwise occur. Declines in the area of natural forest were smaller in countries where the yield of staple crops increased most, when the negative effects of human population increases on forest area were

controlled for. Our results show that land-sparing is a weak process that occurs under a limited set of circumstances, but that it can have positive outcomes for the conservation of wild nature.

Ewert, F., M. D. A. Rounsevell, I. Reginster, M. J. Metzger and R. Leemans (2005). "Future scenarios of European agricultural land use: I. Estimating changes in crop productivity." Agriculture, Ecosystems & Environment **107**(2-3): 101-116.

Category: Climate change

Keywords: *Crop productivity, modelling, technology development, climate change, increasing CO2, land use change*

The future of agricultural land use in Europe is unknown but is likely to be influenced by the productivity of crops. Changes in crop productivity are difficult to predict but can be explored by scenarios that represent alternative economic and environmental pathways of future development. We developed a simple static approach to estimate future changes in the productivity of food crops in Europe (EU15 member countries, Norway and Switzerland) as part of a larger approach of land use change assessment for four scenarios of the IPCC Special Report on Emission Scenarios (SRES) representing alternative future developments of the world that may be global or regional, economic or environmental. Estimations were performed for wheat (Triticum aestivum) as a reference crop for the time period from 2000 until 2080 with particular emphasis on the time slices 2020, 2050 and 2080. Productivity changes were modelled depending on changes in climatic conditions, atmospheric CO2 concentration and technology development. Regional yield statistics were related to an environmental stratification (EnS) with 84 environmental strata for Europe to estimate productivity changes depending on climate change as projected by the global climate model HadCM3. A simple empirical relationship was used to estimate crop productivity as affected by increasing CO2 concentration simulated by the global environment model IMAGE 2.2. Technology was modelled to affect potential yield and the gap between actual and potential yield. We estimated increases in crop productivity that ranged between 25 and 163% depending on the time slice and scenario compared to the baseline year (2000). The increases were the smallest for the regional environmental scenario and the largest for the global economic scenario. Technology development was identified as the most important driver but relationships that determine technology development remain unclear and deserve further attention. Estimated productivity changes beyond 2020 were consistent with changes in the world-wide demand for food crops projected by IMAGE. However, estimated increases in productivity exceeded expected demand changes in Europe for most scenarios, which is consistent with the observed present oversupply in Europe. The developed scenarios enable exploration of future land use changes within the IPCC SRES scenario framework.

Fahrig, L. (2003). "Effects of habitat fragmentation on biodiversity." Annual review of ecology, evolution, and systematics: 487-515.

Category: Ecosystem services

Keywords: *Habitat loss, landscape scale, habitat configuration, patch size, patch isolation,*

extinction threshold, landscape complementation

Abstract: The literature on effects of habitat fragmentation on biodiversity is huge. It is also very diverse, with different authors measuring fragmentation in differen tways and as a consequence drawing different conclusions regarding both the magnitude and direction of its effects.Habitat fragmentation is usually defined as a landscape scale process involving both habitat loss and the breaking apart of habitat. Resultsof empirical studies of habitat fragmentation are often difficult to interpret because(a) many researchers measure fragmentation at the patch scale, not the landscape scale and (b) most researchers measure fragmentation in ways that do not distinguish between habitat loss and habitat fragmentation per se, i.e., the breakingapart of habitat after controlling for habitat loss.

Empirical studies to date suggest that habitat loss has large, consistently negative effects on biodiversity. Habitat fragmentation per se has much weaker effects on biodiversit ythatare at least as likely to be positiveas negative.Therefore,to correctly interpret the influence of habitat fragmentation on biodiversity, the effects of these two components of fragmentation must be measured independently. More studies of the independent effects of habitat loss and fragmentation per se are needed to determine the factors that lead to positive versus negative effects of fragmentationper se. I suggest that the term "fragmentation" should be reservedfor the breaking apart of habitat, independent of habitat loss.

Fahrig, L., J. Baudry, L. Brotons, F. Burel, T. O. Crist, R. Fuller, C. Sirami, G. Siriwardena and J.-L. Martin (2011). "Functional landscape heterogeneity and animal biodiversity in agricultural landscapes." Ecology Letters **14**(2): 101-112.

Category: Ecosystem services

Keywords: *Agri-environment scheme, crop diversity, field margins, field size, habitat fragmentation, intermediate heterogeneity hypothesis, landscape complementation, landscape composition, landscape configuration, spatial heterogeneity, wild biodiversity*

Abstract: Biodiversity in agricultural landscapes can be increased with conversion of some production lands into 'more-natural'– unmanaged or extensively managed – lands. However, it remains unknown to what extent biodiversity can be enhanced by altering landscape pattern without reducing agricultural production. We propose a framework for this problem, considering separately compositional heterogeneity (the number and proportions of different cover types) and configurational heterogeneity (the spatial arrangement of cover types). Cover type classification and mapping is based on species requirements, such as feeding and nesting, resulting in measures of 'functional landscape heterogeneity'. We then identify three important questions: does biodiversity increase with (1) increasing heterogeneity of the more-natural areas, (2) increasing compositional heterogeneity of production cover types and (3) increasing configurational heterogeneity of production cover types? We discuss approaches for addressing these questions. Such studies should have high priority because biodiversity protection globally depends increasingly on maintaining biodiversity in human-dominated landscapes.

FAO (2008). Climate change adaptation and mitigation in the food and agriculture sector. Technical background document from the expert consultation held on 5 to 7 March 2008. Climate Change, Energy and Food, 3-5 June 2008. Rome.

Category: Climate change

Keywords: *Climate change, food, adaptation, mitigation*

Abstract: Many countries worldwide are facing food crises due to conflict and disasters, while food security is being adversely affected by unprecedented price hikes for basic food, driven by historically low food stocks, high oil prices and growing demand for agro-fuels, and droughts and floods linked to climate change. High international cereal prices have already sparked food riots in several countries. In addition, rural people (who feed the cities) are now, for the first time, less numerous than city dwellers and developing countries are becoming major emitters of greenhouse gases. Many traditional equilibriums are changing, such as those between food crops and energy crops and cultivated lands and rangelands, as is the nature of conflicts in general. These changing equilibriums are, and will be, affected by changing climate, resulting in changed and additional vulnerability patterns.

The Intergovernmental Panel on Climate Change (IPCC) predicts that during the next decades, billions of people, particularly those in developing countries, will face changes in rainfall patterns that will contribute to severe water shortages or flooding, and rising temperatures that will cause shifts in crop growing seasons. This will increase food shortages and distribution of disease vectors, putting populations at greater health and life risks. The predicted temperature rise of 1 to 2.5o C by 2030 will have serious effects, including reduced crop yield in tropical areas. The impact of a single climate-, water- or weather-related disaster can wipe out years of gains in economic development.

Climate change will result in additional food insecurities, particularly for the resource poor in developing countries who cannot meet their food requirements through market access. Communities must protect themselves against the possibility of food-shortage emergencies through appropriate use of resources in order to preserve livelihoods as well as lives and property. It is imperative to identify and institutionalize mechanisms that enable the most vulnerable to cope with climate change impacts. This requires collaborative thinking and responses to the issues generated by the interaction of food security, climate change and sustainable development.

FAO (2011). Save and grow: A policymaker's guide to sustainable intensification of smallholder crop production, Food and Agriculture Organization of the United Nations.

Category: Ecosystem services; Policy

Keywords: *Agriculture, crop production, ecosystems, food security, sustainability*

Abstract: The present paradigm of intensive crop production cannot meet the challenges of the new millennium. In order to gorw, agriculture must learn to save. This book presents a new paradigm: sustainable crop production intensification, which produces more from the same area of land while conserving resources, reducing negative impacts on the environment and enhancing natural capital and the flow of ecosystem services.

Farber, S., R. Costanza and M. Wilson (2002). "Economic and ecological concepts for valuing ecosystem services." Ecological Economics **41**(3): 375-392.
Category: Farmer and societal benefits
Keywords: *Economic valuation, ecological valuation, ecogical services, valuation*

Abstract: The purpose of this special issue is to elucidate concepts of value and methods of valuation that will assist in guiding human decisions vis-à-vis ecosystems. The concept of ecosystem service value can be a useful guide when distinguishing and measuring where trade-offs between society and the rest of nature are possible and where they can be made to enhance human welfare in a sustainable manner. While win-win opportunities for human activities within the environment may exist, they also appear to be increasingly scarce in a 'full' global ecological–economic system. This makes valuation all the more essential for guiding future human activity. This paper provides some history, background, and context for many of the issues addressed by the remaining papers in this special issue. Its purpose is to place both economic and ecological meanings of value, and their respective valuation methods, in a comparative context, highlighting strengths, weakness and addressing questions that arise from their integration.

Fierer, N., K. Carney, M. Horner-Devine and J. Megonigal (2009). "The biogeography of ammonia-oxidizing bacterial communities in soil." Microbial Ecology **58**(2): 435-445.
Category: Ecosystem services
Keywords: *Environmental factor, biogeochemical cycle, America, nitrobacteraceae, temperature, environment, availability, harbor, community structure, clone, 16S-RNA, geographic distribution, North America, ecosystem, composition, nitrogen cycle, soils, microbial community, ammonia, biogeography, nitrosospira, bacteria, soil nutrinets/cycling*

Abstract: Although ammonia-oxidizing bacteria (AOB) are likely to play a key role in the soil nitrogen cycle, we have only a limited understanding of how the diversity and composition of soil AOB communities change across ecosystem types. We examined 23 soils collected from across North America and used sequence-based analyses to compare the AOB communities in each of the distinct soils. Using 97% 16S rRNA sequence similarity groups, we identified only 24 unique AOB phylotypes across all of the soils sampled. The majority of the sequences collected were in the Nitrosospira lineages (representing 80% of all the sequences collected), and AOB belonging to Nitrosospira cluster 3 were particularly common in our clone libraries and ubiquitous across the soil types. Community composition was highly variable across the collected soils, and similar ecosystem types did not always harbor similar AOB communities. We did not find any significant correlations between AOB community composition and measures of N availability. From the suite of environmental variables measured, we found the strongest correlation between temperature and AOB community composition; soils exposed to similar mean annual temperatures tended to have similar AOB communities. This finding is consistent with previous studies and suggests that temperature selects for specific AOB lineages. Given that distinct AOB taxa are likely to have unique functional attributes,

the biogeographical patterns exhibited by soil AOB may be directly relevant to understanding soil nitrogen dynamics under changing environmental conditions.

Finke, D. and R. Denno (2005). "Predator diversity and the functioning of ecosystems: the role of intraguild predation in dampening trophic cascades." Ecology Letters **8**(12): 1299-1306.

Category: Ecosystem services

Keywords: *Biocontrol, biodiversity, food webs, herbivore suppression, indirect interactions, omnivory, predator–predator interactions, predator–prey interactions, salt marsh trophic dynamics, pest control, pest regulation*

Abstract: Single trophic-level studies of the relationship between biodiversity and ecosystem functioning highlight the importance of mechanisms such as resource partitioning, facilitation, and sampling effect. In a multi-trophic context, trophic interactions such as intraguild predation may also be an important mediator of this relationship. Using a salt-marsh food web, we investigated the interactive effects of predator species richness (one to three species) and trophic composition (strict predators, intraguild predators, or a mixture of the two) on ecosystem functions such as prey suppression and primary production via trophic cascades. We found that the trophic composition of the predator assemblage determined the impact of increasing predator species richness on the occurrence of trophic cascades. In addition, increasing the proportion of intraguild predator species present diminished herbivore suppression and reduced primary productivity. Therefore, trophic composition of the predator assemblage can play an important role in determining the nature of the relationship between predator diversity and ecosystem function.

Firbank, L., J. Elliott, B. Drake, Y. Cao and R. Gooday (2013). "Evidence of sustainable intensification among British farms." Agriculture, Ecosystems & Environment **173**(0): 58-65.

Category: Ecosystem services

Keywords: *Ecosystem services, biodiversity, GHG emissions, diffuse pollution, ammonia emissions, land sparing, agro-ecological indicators, sustainable agriculture, organic farming, sustainable intensification*

Abstract: Several influential reports have suggested that one of the most appropriate responses to expected food shortages and ongoing environmental degradation is sustainable intensification, i.e. the increase of food production with at worst no increase in environmental harm, and ideally environmental benefit. Here we sought evidence of sustainable intensification among British farmers by selecting innovative arable, dairy, mixed and upland farms and analysing their own data on yields, inputs and land use and management for 2006 and 2011. The evidence was obtained by interview, and was interpreted in terms of the ecosystem services of food production (GJ ha−1, where area took into account estimated area to grow any imported animal feeds), regulation of climate, air and water quality (modelled emissions of GHGs (CO2e ha−1), ammonia (kg ha−1) and nitrate loss (kg ha−1)) and biodiversity (using an index based on the presence of habitats and management).

Several farms have increased both food production and other ecosystem services over this time by increasing yields, using resources more efficiently and/or

enhancing biodiversity, and sometimes by reducing livestock numbers and increasing cropping. The motivation has been to improve farm profitability through increasing food production, reducing input costs and accessing public payments through agri-environment schemes and generating renewable energy. Such sustainable intensification was not achieved by farmers who increased meat or milk yields. Sustainable intensification can be achieved when the correct drivers are in place to influence the actions of individual farmers. Also, it is possible to indicate sustainable intensification by using a small number of high-level indicators derived from data that farmers already hold, though such an approach may not capture the impacts of farmer innovative practices.

Fischer, J., B. Brosi, G. Daily, P. Ehrlich, R. Goldman, J. Goldstein, D. Lindenmayer, A. Manning, H. Mooney and L. Pejchar (2008). "Should agricultural policies encourage land sparing or wildlife-friendly farming?" Frontiers in Ecology and the Environment **6**(7): 380-385.

Category: Ecosystem services; Policy

Keywords: *Land sharing, land sparing, wildlife-friendly farming, agricultural landscape, policy guidelines, theory of island biogeography, wild diversity*

Abstract: As the demands on agricultural lands to produce food, fuel, and fiber continue to expand, effective strate- gies are urgently needed to balance biodiversity conservation and agricultural production. “Land sparing” and “wildlife-friendly farming” have been proposed as seemingly opposing strategies to achieve this bal- ance. In land sparing, homogeneous areas of farmland are managed to maximize yields, while separate reserves target biodiversity conservation. Wildlife-friendly farming, in contrast, integrates conservation and production within more heterogeneous landscapes. Different scientific traditions underpin the two approaches. Land sparing is associated with an island model of modified landscapes, where islands of nature are seen as separate from human activities. This simple dichotomy makes land sparing easily com- patible with optimization methods that attempt to allocate land uses in the most efficient way. In contrast, wildlife-friendly farming emphasizes heterogeneity, resilience, and ecological interactions between farmed and unfarmed areas. Both social and biophysical factors influence which approach is feasible or appropriate in a given landscape. Drawing upon the strengths of each approach, we outline broad policy guidelines for conservation in agricultural landscapes.

Fischer, J. and D. Lindenmayer (2007). "Landscape modification and habitat fragmentation: a synthesis." Global Ecology and Biogeography **16**(3): 265-280.

Category: Agriculture-induced impacts

Keywords: *Connectivity, countryside biogeography, edge effects, extinction proneness, habitat loss, habitat fragmentation, keystone, species, landscape heterogeneity, matrix, threatening processes*

Abstract: Landscape modification and habitat fragmentation are key drivers of global species loss. Their effects may be understood by focusing on: (1) individual species and the processes threatening them, and (2) human-perceived landscape patterns

and their correlation with species and assemblages. Individual species may decline as a result of interacting exogenous and endogenous threats, including habitat loss, habitat degradation, habitat isolation, changes in the biology, behaviour, and interactions of species, as well as additional, stochastic threats. Human-perceived landscape patterns that are frequently correlated with species assemblages include the amount and structure of native vegetation, the prevalence of anthropogenic edges, the degree of landscape connectivity, and the structure and heterogeneity of modified areas. Extinction cascades are particularly likely to occur in landscapes with low native vegetation cover, low landscape connectivity, degraded native vegetation and intensive land use in modified areas, especially if keystone species or entire functional groups of species are lost. This review (1) demonstrates that species-oriented and pattern-oriented approaches to understanding the ecology of modified landscapes are highly complementary, (2) clarifies the links between a wide range of interconnected themes, and (3) provides clear and consistent terminology. Tangible research and management priorities are outlined that are likely to benefit the conservation of native species in modified landscapes around the world.

Fisher, B., R. Turner and P. Morling (2009). "Defining and classifying ecosystem services for decision making." Ecological Economics **68**(3): 643-653.
Category: Ecosystem services
Keywords: *Ecosystem services, ecosystem benefits, human welfare, environmental decision making, Millennium Assessment*
Abstract: The concept of ecosystems services has become an important model for linking the functioning of ecosystems to human welfare. Understanding this link is critical for a wide-range of decision-making contexts. While there have been several attempts to come up with a classification scheme for ecosystem services, there has not been an agreed upon, meaningful and consistent definition for ecosystem services. In this paper we offer a definition of ecosystem services that is likely to be operational for ecosystem service research and several classification schemes. We argue that any attempt at classifying ecosystem services should be based on both the characteristics of the ecosystems of interest and a decision context for which the concept of ecosystem services is being mobilized. Because of this there is not one classification scheme that will be adequate for the many contexts in which ecosystem service research may be utilized. We discuss several examples of how classification schemes will be a function of both ecosystem and ecosystem service characteristics and the decision-making context.

Flohre, A., M. Rudnick, G. Traser, T. Tscharntke and T. Eggers (2011). "Does soil biota benefit from organic farming in complex vs. simple landscapes?" Agriculture, Ecosystems & Environment **141**(1â€“2): 210-214.
Category: Agroecology and agroecological practices; Ecosystem services
Keywords: *Agri-environmental schemes, soil biodiversity, landscape complexity, organic farming, earthworms, microbial biomass, soil nutrients/cycling, pest regulation*
Abstract: Organic farming can counteract detrimental effects of agricultural intensification on farmland biodiversity. Enhancing biodiversity with agri-

environmental schemes is hypothesized to be more efficient in simple than complex landscapes, a pattern confirmed for many aboveground taxa. Although belowground biodiversity is an important part of the agroecosystem, studies on the interacting effects of local and landscape intensification on the belowground detritivore community, including bacteria, fungi, collembolans and earthworms are lacking. We sampled diversity and abundance of arable weeds, earthworms and collembolans, soil respiration rate and microbial biomass in 12 pairs of organically and conventionally managed fields in landscapes differing in structural complexity. Organic farming significantly enhanced species richness of arable weeds, while conventional farming enhanced soil respiration and abundance of Collembola with furca. This research shows that the landscape context plays a significant role in shaping effects of organic vs. conventional farming on soil biota. Earthworm species richness in simple landscapes, where predation pressure is reduced, was enhanced by organic farming, whereas in complex landscapes, conventional farming, which often causes reduced predation, fostered earthworm species richness. As the same pattern was found for microbial carbon biomass, earthworms may have enhanced microbial biomass. In contrast to earthworm and microbial diversity, aboveground biodiversity benefits most from organic farming in simple landscapes. In general, organic farming appears to be more efficient in conserving aboveground than belowground diversity.

Flynn, D., M. Gogol-Prokurat, T. Nogeire, N. Molinari, B. Richers, B. Lin, N. Simpson, M. Mayfield and F. DeClerck (2009). "Loss of functional diversity under land use intensification across multiple taxa." Ecology Letters **12**(1): 22-33.

Category: Ecosystem services

Keywords: *Biodiversity measurement, functional redundancy, functional traits, land use change, meta-analysis*

Abstract: Land use intensification can greatly reduce species richness and ecosystem functioning. However, species richness determines ecosystem functioning through the diversity and values of traits of species present. Here, we analyze changes in species richness and functional diversity (FD) at varying agricultural land use intensity levels. We test hypotheses of FD responses to land use intensification in plant, bird, and mammal communities using trait data compiled for 1600+ species. To isolate changes in FD from changes in species richness we compare the FD of communities to the null expectations of FD values. In over one-quarter of the bird and mammal communities impacted by agriculture, declines in FD were steeper than predicted by species number. In plant communities, changes in FD were indistinguishable from changes in species richness. Land use intensification can reduce the functional diversity of animal communities beyond changes in species richness alone, potentially imperiling provisioning of ecosystem services.

Foley, J. A., R. DeFries, G. Asner, C. Barford, G. Bonan, S. Carpenter, F. Chapin, M. Coe, G. Daily, H. Gibbs, J. Helkowski, T. Holloway, E. Howard, C. Kucharik, C. Monfreda, J. Patz, I. Prentice, N. Ramankutty and P. Snyder (2005). "Global consequences of land use." Science **309**(5734): 570-574.

Category: Policy; Agriculture-induced impacts

Keywords: *Resource management, natural biological resources, biosphere, sustainable use, ecosystem, carrying capacity, biodiversity, loss, land use*

Abstract: Land use has generally been considered a local environmental issue, but it is becoming a force of global importance. Worldwide changes to forests, farmlands, waterways, and air are being driven by the need to provide food, fiber, water, and shelter to more than six billion people. Global croplands, pastures, plantations, and urban areas have expanded in recent decades, accompanied by large increases in energy, water, and fertilizer consumption, along with considerable losses of biodiversity. Such changes in land use have enabled humans to appropriate an increasing share of the planet's resources, but they also potentially undermine the capacity of ecosystems to sustain food production, maintain freshwater and forest resources, regulate climate and air quality, and ameliorate infectious diseases. We face the challenge of managing trade-offs between immediate human needs and maintaining the capacity of the biosphere to provide goods and services in the long term.

Foresight (2011). The Future of Food and Farming. Executive Summary. London, The Government Office for Science.

Category: Policy; Ecosystem services

Keywords: *Food systems, demand, production, prices, challenges, sustainability, biodiversity, ecosystem services*

Project aim: to explore the pressures on the global food system between now and 2050 and identify the decisions that policy makers need to take today, and in the years ahead, to ensure that a global population rising to nine billion or more can be fed sustainably2 and equitably. The global food system will experience an unprecedented confluence of pressures over the next 40 years. On the demand side, global population size will increase from nearly seven billion today to eight billion by 2030, and probably to over nine billion by 2050; many people are likely to be wealthier, creating demand for a more varied, high-quality diet requiring additional resources to produce. On the production side, competition for land, water and energy will intensify, while the effects of climate change will become increasingly apparent.The need to reduce greenhouse gas emissions and adapt to a changing climate will become imperative. Over this period globalisation will continue, exposing the food system to novel economic and political pressures.

Any one of these pressures (‘drivers of change’) would present substantial challenges to food security; together they constitute a major threat that requires a strategic reappraisal of how the world is fed. Overall, the Project has identified and analysed five key challenges for the future. Addressing these in a pragmatic way that promotes resilience to shocks and future uncertainties will be vital if major stresses to the food system are to be anticipated and managed. The five challenges, outlined further in Sections 4 – 8, are:

A. Balancing future demand and supply sustainably – to ensure that food supplies are affordable.

B. Ensuring that there is adequate stability in food supplies – and protecting the most vulnerable from the volatility that does occur.

C. Achieving global access to food and ending hunger.This recognises that producing enough food in the world so that everyone can potentially be fed is not the same thing as ensuring food security for all.
D. Managing the contribution of the food system to the mitigation of climate change.
E. Maintaining biodiversity and ecosystem services while feeding the world.
These last two challenges recognise that food production already dominates much of the global land surface and water bodies, and has a major impact on all the Earth's environmental systems.

Franklin, A., B. Noon and T. George (2002). "What is habitat fragmentation?" Studies in Avian Biology **25**: 20-29.
Category: Agriculture-induced impacts
Keywords: *Forest fragmentation, habitat, habitat fragmentation, habitat heterogeneity*

Abstract: Habitat fragmentation is an issue of primary concern in conservation biology. However. both the concepts of habitat and fragmentation are ill-defined and often misused. We review the habitat concept and examine differences between habitat fragmentation and habitat heterogeneity, and we suggest that habitat fragmentation is both a state (or outcome) and a process. In addition, we attempt to distinguish between and provide guidelines for situations where habitat loss occurs without frag- mentation, habitat loss occurs with fragmentation, and fragmentation occurs with no habitat loss. We use two definitions for describing habitat fragmentation. a general definition and a situational definition (definitions related to specific studies or situations). Conceptually. we define the state of habitat fragmentation as the discontinuity, resulting from a given set of mechanisms. in the spatial distribution of resources and conditions present in an area at a given scale that affects occupancy, reproduction, or survival in a particular species. We define the process of habitat fragmentation as the set of mechanisms leading to that state of discontinuity. We identify four requisites that we believe should be described in situational definitions: what is being fragmented. what is the scale of fragmentation, what is the extent and pattern of fragmentation. and what is the mechanism causing fragmentation.

Free, J. (1970). Insect pollination of crops. London, Academic Press.
Category: Ecosystem services
Keywords: *Pollinators, crop production*

The second edition of this text on the significance of insect pollination of crops has been expanded to include new information on many crops, particularly tropical ones, and on the use of managed populations of bees, both colonial and solitary.

Frison, E. A., J. Cherfas and T. Hodgkin (2011). "Agricultural biodiversity is essential for a sustainable improvement in food and nutrition security." Sustainability **3**(1): 238-253.
Category: Farmer and societal benefits
Keywords: *Agricultural biodiversity, food security, sustainability, nutrition, hunger*

Abstract: Agricultural biodiversity has hitherto been valued almost exclusively as a

source of traits that can be used in scientific breeding programs to improve the productivity of crop varieties and livestock breeds. We argue that it can make a far greater contribution to increased productivity. In particular, a wider deployment of agricultural biodiversity is an essential component in the sustainable delivery of a more secure food supply. Diversity of kingdoms, species and genepools can increase the productivity of farming systems in a range of growing conditions, and more diverse farming systems are also generally more resilient in the face of perturbations, thus enhancing food security. Diversity can maintain and increase soil fertility and mitigate the impact of pests and diseases. Diversity of diet, founded on diverse farming systems, delivers better nutrition and greater health, with additional benefits for human productivity and livelihoods. Agricultural biodiversity will also be absolutely essential to cope with the predicted impacts of climate change, not simply as a source of traits but as the underpinnings of more resilient farm ecosystems. Many of the benefits of agricultural biodiversity are manifested at different ecological and human scales, and cut across political divisions, requiring a cross-sectoral approach to reassess the role of agricultural biodiversity in sustainable and secure food production.

Gabriel, D., S. M. Sait, J. Hodgson, U. Schmutz, W. Kunin and T. Benton (2010). "Scale matters: the impact of organic farming on biodiversity at different spatial scales." Ecology Letters **13**(7): 858-869.

Category: Agriculture-induced impacts; Ecosystem services

Keywords: *Agri-environment schemes, agro-ecology, conservation, diversity, landscape, spill-over*

Abstract: There is increasing recognition that ecosystems and their services need to be managed in the face of environmental change. However, there is little consensus as to the optimum scale for management. This is particularly acute in the agricultural environment given the level of public investment in agri-environment schemes (AES). Using a novel multiscale hierarchical sampling design, we assess the effect of land use at multiple spatial scales (from location-within-field to regions) on farmland biodiversity. We show that on-farm biodiversity components depend on farming practices (organic vs. conventional) at farm and landscape scales, but this strongly interacts with fine- and coarse-scale variables. Different taxa respond to agricultural practice at different spatial scales and often at multiple spatial scales. Hence, AES need to target multiple spatial scales to maximize effectiveness. Novel policy levers may be needed to encourage multiple land managers within a landscape to adopt schemes that create landscape-level benefits.

Gabriel, D., C. Thies and T. Tscharntke (2005). "Local diversity of arable weeds increases with landscape complexity." Perspectives in Plant Ecology, Evolution and Systematics **7**(2): 85-93.

Category: Ecosystem services

Keywords: *Annual plants, landscape, local species richness, soil conditions, spatial scales*

Abstract: Patterns of plant diversity are often related to local site conditions and to competitive interactions, but landscape context may also be important for local plant species richness. This is shown here by analysing the relationship between

landscape complexity and local species richness of arable weeds in wheat fields. The fields were located in 18 landscapes characterised by a gradient in landscape complexity from structurally complex to structurally simple (39–94% arable land). We quantified local site conditions, field management intensity and landscape characteristics, and used principle component analyses to ordinate the environmental variables. The percentage of arable land was negatively correlated with perimeter–area ratio, habitat-type diversity and topographical heterogeneity, but landscape characteristics did not correlate with local site conditions and field management intensity. The number of plant species was mainly related to landscape characteristics and to a lesser extent to field management intensity (nitrogen fertilisation), whereas local soil characteristics did not contribute to the explanation of arable weed richness. In a geographic scale analysis using circular landscape sectors ranging from 1 km up to 5 km diameter, the predictive power of landscape complexity for local plant species richness was strongest at 2 km indicating a scale-dependent relationship between landscape context and plant species richness. Our results support the hypothesis that local plant species richness in arable fields is greatly influenced by processes operating at the landscape scale. Seed rain from ruderal source habitats and disturbed edges may be the most important underlying process.

Gallai, N., J.-M. Salles, J. Settele and B. Vaissiere (2009). "Economic valuation of the vulnerability of world agriculture confronted with pollinator decline." Ecological Economics **68**(3): 810-821.

Category: Ecosystem services

Keywords: *Pollination, valuation, vulnerability, agriculture, ecosystem service, crop*

Abstract: There is mounting evidence of pollinator decline all over the world and consequences in many agricultural areas could be significant. We assessed these consequences by measuring 1) the contribution of insect pollination to the world agricultural output economic value, and 2) the vulnerability of world agriculture in the face of pollinator decline. We used a bioeconomic approach, which integrated the production dependence ratio on pollinators, for the 100 crops used directly for human food worldwide as listed by FAO. The total economic value of pollination worldwide amounted to €153 billion, which represented 9.5% of the value of the world agricultural production used for human food in 2005. In terms of welfare, the consumer surplus loss was estimated between €190 and €310 billion based upon average price elasticities of − 1.5 to − 0.8, respectively. Vegetables and fruits were the leading crop categories in value of insect pollination with about €50 billion each, followed by edible oil crops, stimulants, nuts and spices. The production value of a ton of the crop categories that do not depend on insect pollination averaged €151 while that of those that are pollinator-dependent averaged €761. The vulnerability ratio was calculated for each crop category at the regional and world scales as the ratio between the economic value of pollination and the current total crop value. This ratio varied considerably among crop categories and there was a positive correlation between the rate of vulnerability to pollinators decline of a crop category and its value per production unit. Looking at the capacity to nourish the world population after pollinator loss, the production of 3 crop categories – namely fruits,

vegetables, and stimulants - will clearly be below the current consumption level at the world scale and even more so for certain regions like Europe. Yet, although our valuation clearly demonstrates the economic importance of insect pollinators, it cannot be considered as a scenario since it does not take into account the strategic responses of the markets.

Gallai, N. and B. Vaissière (2009). Guidelines for the economic valuation of pollination services at a national scale. Rome, FAO**:** 20.
Category: Ecosystem services
Keywords: *Pollination services, crop selection, animal pollination*

Abstract: FAO has collaborated with INRA (l'institut national de recherche agronomique of the French government) to reconfigure the findings of a recent research paper published by scientists affiliated with the institute. the original findings (Gallai et al. 2009) made an economic valuation of the vulnerability of world agriculture to pollinator declines. in the present work, a tool for applying the same analysis on a national level was developed, and is presented in the format of an excel spreadsheet. the tool, and background documents, can be found on the web- site of Fao's Global action on pollination services for sustainable agriculture.

Gardi, C., L. Montanarella, D. Arrouays, A. Bispo, P. Lemanceau, C. Jolivet, C. Mulder, L. Ranjard, J. Römbke, M. Rutgers and C. Menta (2009). "Soil biodiversity monitoring in Europe: ongoing activities and challenges." European Journal of Soil Science **60**(5): 807-819.
Category: Ecosystem services
Keywords: *Soils, Europe, soil science, Earth science, activity, monitoring, species diversity, soil biodiversity, soil nutrients/cylcing*

Abstract: The increasing interest in soil biodiversity and its protection includes both the biodiversity conservation issues and the mostly unknown economic and ecological values of services provided by soil biodiversity. Inventory and monitoring are necessary tools for the achievement of an adequate level of knowledge regarding soil biodiversity status and for the detection of biodiversity hot spots as well as areas where current levels of biodiversity are under threat of decline. In this paper the main tools and methodological approaches for soil biodiversity measurement are presented. Technical aspects related to the inventory and monitoring activities at a large spatial scale are discussed. A short review of some current experiences of soil biodiversity monitoring at the European level is also presented.

Gardiner, M. M., D. A. Landis, C. Gratton, C. D. DiFonzo, M. O'Neal, J. M. Chacon, M. T. Wayo, N. P. Schmidt, E. E. Mueller and G. E. Heimpel (2009). "Landscape diversity enhances biological control of an introduced crop pest in the north-central USA." Ecological applications **19**(1): 143-154.
Category: Ecosystem services
Keywords: *Aphis glycines, biological control, ecosystem services, introduced crop pests, landscape, diversity, natural enemies, predators, soybean aphid, pest regulation*

Abstract: Arthropod predators and parasitoids provide valuable ecosystem services in agricultural crops by suppressing populations of insect herbivores. Many natural enemies are influenced by non-crop habitat surrounding agricultural fields, and understanding if, and at what scales, land use patterns influence natural enemies is essential to predicting how landscape alters biological control services. Here we focus on biological control of soybean aphid, Aphis glycines Matumura, a specialist crop pest recently introduced to the north-central United States. We measured the amount of biological control service supplied to soybean in 26 replicate fields across Michigan, Wisconsin, Iowa, and Minnesota across two years (2005–2006). We measured the impact of natural enemies by experimentally excluding or allowing access to soybean aphid infested plants and comparing aphid population growth over 14 days. We also monitored aphid and natural enemy populations at large in each field. Predators, principally coccinellid beetles, dominated the natural enemy community of soybean in both years. In the absence of aphid predators, A. glycines increased significantly, with 5.3-fold higher aphid populations on plants in exclusion cages vs. the open field after 14 days. We calculated a biological control services index (BSI) based on relative suppression of aphid populations and related it to landscape diversity and composition at multiple spatial scales surrounding each site. We found that BSI values increased with landscape diversity, measured as Simpson's D. Landscapes dominated by corn and soybean fields provided less biocontrol service to soybean compared with landscapes with an abundance of crop and non-crop habitats. The abundance of Coccinellidae was related to landscape composition, with beetles being more abundant in landscapes with an abundance of forest and grassland compared with landscapes dominated by agricultural crops. Landscape diversity and composition at a scale of 1.5 km surrounding the focal field explained the greatest proportion of the variation in BSI and Coccinellidae abundance. This study indicates that natural enemies provide a regionally important ecosystem service by suppressing a key soybean pest, reducing the need for insecticide applications. Furthermore, it suggests that management to maintain or enhance landscape diversity has the potential to stabilize or increase biocontrol services.

Garibaldi, L., I. Steffan-Dewenter, R. Winfree, M. Aizen, R. Bommarco, S. Cunningham, C. Kremen, L. Carvalheiro, L. Harder, O. Afik, I. Bartomeus, F. Benjamin, V. Boreux, D. Cariveau, N. Chacoff, J. Dudenhoffer, B. Freitas, J. Ghazoul, S. Greenleaf, J. Hipolito, A. Holzschuh, B. Howlett, R. Isaacs, S. Javorek, C. Kennedy, K. Krewenka, S. Krishnan, Y. Mandelik, M. Mayfield, I. Motzke, T. Munyuli, B. A. Nault, M. Otieno, J. Petersen, G. Pisanty, S. Potts, R. Rader, T. Ricketts, M. Rundlof, C. Seymour, C. Schuepp, H. Szentgyorgyi, H. Taki, T. Tscharntke, C. Vergara, B. Viana, T. Wanger, C. Westphal, N. Williams and A. Klein (2013). "Wild pollinators enhance fruit set of crops regardless of honey bee abundance." Science **339**(6127): 1608-1611.

Category: Ecosystem services

Keywords: *Insect pollination, fructification, domestic animal, wild animal, pollination efficiency, comparative study, pollinator, wild diversity, pollination*

Abstract: The diversity and abundance of wild insect pollinators have declined in many agricultural landscapes. Whether such declines reduce crop yields, or are mitigated by managed pollinators such as honey bees, is unclear. We found

universally positive associations of fruit set with flower visitation by wild insects in 41 crop systems worldwide. In contrast, fruit set increased significantly with flower visitation by honey bees in only 14% of the systems surveyed. Overall, wild insects pollinated crops more effectively; an increase in wild insect visitation enhanced fruit set by twice as much as an equivalent increase in honey bee visitation. Visitation by wild insects and honey bees promoted fruit set independently, so pollination by managed honey bees supplemented, rather than substituted for, pollination by wild insects. Our results suggest that new practices for integrated management of both honey bees and diverse wild insect assemblages will enhance global crop yields.

Garibaldi, L. A., M. Aizen, A. Klein, S. Cunningham and L. Harder (2011). "Global growth and stability of agricultural yield decrease with pollinator dependence." Proceedings of the National Academy of Sciences **108**(14): 5909-5914.

Category: Ecosystem services

Keywords: *Diminishing returns, environmental degradation, global pollination, crisis, food security, land use change, pollination*

Abstract: Human welfare depends on the amount and stability of agricultural production, as determined by crop yield and cultivated area. Yield increases asymptotically with the resources provided by farmers' inputs and environmentally sensitive ecosystem services. Declining yield growth with increased inputs prompts conversion of more land to cultivation, but at the risk of eroding ecosystem services. To explore the interdependence of agricultural production and its stability on ecosystem services, we present and test a general graphical model, based on Jensen's inequality, of yield–resource relations and consider implications for land conversion. For the case of animal pollination as a resource influencing crop yield, this model predicts that incomplete and variable pollen delivery reduces yield mean and stability (inverse of variability) more for crops with greater dependence on pollinators. Data collected by the Food and Agriculture Organization of the United Nations during 1961–2008 support these predictions. Specifically, crops with greater pollinator dependence had lower mean and stability in relative yield and yield growth, despite global yield increases for most crops. Lower yield growth was compensated by increased land cultivation to enhance production of pollinator-dependent crops. Area stability also decreased with pollinator dependence, as it correlated positively with yield stability among crops. These results reveal that pollen limitation hinders yield growth of pollinator-dependent crops, decreasing temporal stability of global agricultural production, while promoting compensatory land conversion to agriculture. Although we examined crop pollination, our model applies to other ecosystem services for which the benefits to human welfare decelerate as the maximum is approached.

Garibaldi, L. A., I. Steffan-Dewenter, C. Kremen, J. Morales, R. Bommarco, S. Cunningham, L. Carvalheiro, N. P. Chacoff, J. Dudenhöffer, S. Greenleaf, A. Holzschuh, R. Isaacs, K. M. Krewenka, Y. Mandelik, M. M. Mayfield, L. A. Morandin, S. Potts, T. Ricketts, H. Szentgyörgyi, B. Viana, C. Westphal, R. Winfree and A. Klein (2011). "Stability of pollination services decreases with isolation from natural areas despite honey bee visits." Ecology

Letters **14**(10): 1062-1072.
Category: Ecosystem services
Keywords: *Apis mellifera, Bombus spp., ecosystem services, flower visitors, landscape management, pollinator services, richness, spatial stability, sustainable agricultural landscapes, temporal stability, pollination*

Abstract: Sustainable agricultural landscapes by definition provide high magnitude and stability of ecosystem services, biodiversity and crop productivity. However, few studies have considered landscape effects on the stability of ecosystem services. We tested whether isolation from florally diverse natural and semi-natural areas reduces the spatial and temporal stability of flower-visitor richness and pollination services in crop fields. We synthesised data from 29 studies with contrasting biomes, crop species and pollinator communities. Stability of flower-visitor richness, visitation rate (all insects except honey bees) and fruit set all decreased with distance from natural areas. At 1 km from adjacent natural areas, spatial stability decreased by 25, 16 and 9% for richness, visitation and fruit set, respectively, while temporal stability decreased by 39% for richness and 13% for visitation. Mean richness, visitation and fruit set also decreased with isolation, by 34, 27 and 16% at 1 km respectively. In contrast, honey bee visitation did not change with isolation and represented > 25% of crop visits in 21 studies. Therefore, wild pollinators are relevant for crop productivity and stability even when honey bees are abundant. Policies to preserve and restore natural areas in agricultural landscapes should enhance levels and reliability of pollination services.

Garnett, T. and C. Godfray (2012). Sustainable intensification in agriculture. Navigating a course through competing food system priorities. Oxford, Food Climate Research Network and the Oxford Martin Programme on the Future of Food, University of Oxford**:** 51.
Category: Ecosystem services
Keywords: *Sustainable intensification*

From Forward:

This report is based on discussions held at a two day workshop held in January 2012, co-organised by the Food Climate Research Network and the Oxford Martin Programme on the Future of Food. The workshop was facilitated by Kath Dalmeny of Sustain and funded by the Foresight Programme and the Oxford Martin Programme on the Future of Food.

The purpose of the workshop was to bring together key thinkers from the academic and policy community, and from diverse disciplines, to consider the meanings, issues and challenges around sustainable intensification in general, and particularly in relation to three areas of concern: environmental sustainability; animal welfare and human wellbeing (specifically nutrition). A list of workshop participants is provided on the next page.

This report draws upon these discussions and upon further analysis and exploration subsequent to the workshop. It was written by Tara Garnett and Charles Godfray with valuable input from all the workshop participants, most of whom provided comments on a draft version. However, it is emphasised that this report is by no means a consensus document. It should not be seen as representing the unanimous views of everyone present or endorsed by the organisations to which they belong.

The role of this document, rather, is to map out some of the conceptual territory that was explored, to stimulate discussion, and to identify areas where further work is needed.

The report is aimed at policy makers, both in the UK and elsewhere, working in areas relevant to food security. While clearly 'food security' is about far more than agricultural policy alone, our intention here is to take a small part of the food security puzzle – agricultural policy – and to consider how it intersects with environmental, animal welfare and health policies. Our argument is that agricultural policy, if it is to help rather than hinder the ultimate goal of food security, needs to operate in an integrated manner with these other policy areas.

Ultimately, this report argues the case for a more 'systems' oriented approach to decision making. While it does not go so far as to define a research agenda or make policy recommendations – this would require more work than has been possible in the time available – it urges the need for a substantial programme of future activity in order to:

(a) deepen and extend understanding of systems interactions;

(b) consider and define what specific goals societies wish agricultural production to achieve;

(c) develop metrics that will enable societies to measure progress in achieving them; and

(d) implement successful policies.

Gasparatos, A., P. Stromberg and K. Takeuchi (2011). "Biofuels, ecosystem services and human wellbeing: Putting biofuels in the ecosystem services narrative." Agriculture, Ecosystems & Environment **142**(3-4): 111-128.

Category: Ecosystem services

Keywords: *Biofuels, ecosystem services, biodiversity, human wellbeing, Millennium Ecosystem Assessment*

Abstract: First generation biofuels provide a number of ecosystem services (e.g., fuel, climate regulation) but they also compromise other ecosystem services (e.g., food, freshwater services) which are of paramount value to human wellbeing. However, this knowledge is fragmented and little is known about how the ecosystem services provided and/or compromised by biofuels link to human wellbeing. In fact, whether biofuels production and use can have a negative or positive impact on the environment and society depends on several interconnected factors. This paper provides a critical review of the drivers, impacts and tradeoffs of biofuel production and use. In particular, it rationalizes the evidence coming from diverse academic disciplines and puts it into perspective by employing the ecosystem services framework popularized by the Millennium Ecosystem Assessment (MA). An outcome of this systematic review is a simplified conceptual framework that illustrates the main trade-offs of biofuel production and use by employing a consistent language grounded on the concepts of ecosystem services. Given the almost complete lack of literature explicitly linking biofuels and ecosystem services, our review concludes by identifying priority research areas on the interface of biofuels, ecosystem services and human wellbeing.

Gasson, R. (1973). "Goals and values of farmers." Journal of Agricultural Economics **24**(3): 521-542.
Category: Farmer and societal benefits
Keywords: *Goals, values, farming styles, planning*

Abstract: Economic theory treats motivation as a parameter, explaining variation in economic behaviour in terms of availability of resources. This theory does not provide a wholly convincing account of farmers' actions. It is suggested that a better understanding of motivation, taken in conjunction with information already available on material resources and constraints, could lead to a more adequate explanation and prediction of farmers' economic behaviour. This paper explores the subject of goals and values in the farming occupation as one facet of motivation. Values may refer to instrumental, social, expressive or intrinsic aspects of farming and it is their ordering relative to one another which influences farmers' decisions in situations of choice. Pilot studies suggest that farmers have a predominantly intrinsic orientation to work, valuing the way of life, independence and performance of work tasks above expressive, instrumental or social aspects of their occupation. Comparing value orientations of larger with smaller farmers illustrates some implications and possible uses of this approach.

Gatzweiler, F. and K. Hagedorn (2013). Biodiversity and Cultural Ecosystem Services. Encyclopedia of Biodiversity (Second Edition). A. Simon. Waltham, Academic Press**:** 332-340.
Category: Farmer and societal benefits
Keywords: *Biodiversity, brain, coevolution, cognitive map, collective construction, cultural ecosystem services, institutions of sustainability, structural coupling, valuation languages, value articulating institutions, values*

Abstract: In the relationship between biodiversity and cultural ecosystem services, biodiversity enables the provision of "cultural ecosystem services" which are beneficial for human use and culture and its institutions provide a social lens through which ecosystem services are perceived and valued.
The article explores the linkages between biodiversity and cultural ecosystem services by describing what types of cultural ecosystem services are provided, explaining how culture shapes the way nature is perceived and valued and how these values are expressed. The particular role which languages of valuation, value articulating institutions, and institutions of sustainability (IoS) play within cultures are analyzed.

Geiger, F., J. Bengtsson, F. Berendse, W. Weisser, M. Emmerson, M. Morales, P. Ceryngier, J. Liira, T. Tscharntke and C. Winqvist (2010). "Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland." Basic and Applied Ecology **11**(2): 97-105.
Category: Agriculture-induced impacts
Keywords: *Agricultural intensification, organic farming, agri-environment schemes, vascular plants, carabids, birds, Europe, pest regulation*

Abstract: During the last 50 years, agricultural intensification has caused many wild

plant and animal species to go extinct regionally or nationally and has profoundly changed the functioning of agro-ecosystems. Agricultural intensification has many components, such as loss of landscape elements, enlarged farm and field sizes and larger inputs of fertilizer and pesticides. However, very little is known about the relative contribution of these variables to the large-scale negative effects on biodiversity. In this study, we disentangled the impacts of various components of agricultural intensification on species diversity of wild plants, carabids and ground-nesting farmland birds and on the biological control of aphids.

In a Europe-wide study in eight West and East European countries, we found important negative effects of agricultural intensification on wild plant, carabid and bird species diversity and on the potential for biological pest control, as estimated from the number of aphids taken by predators. Of the 13 components of intensification we measured, use of insecticides and fungicides had consistent negative effects on biodiversity. Insecticides also reduced the biological control potential. Organic farming and other agri-environment schemes aiming to mitigate the negative effects of intensive farming on biodiversity did increase the diversity of wild plant and carabid species, but – contrary to our expectations – not the diversity of breeding birds.

We conclude that despite decades of European policy to ban harmful pesticides, the negative effects of pesticides on wild plant and animal species persist, at the same time reducing the opportunities for biological pest control. If biodiversity is to be restored in Europe and opportunities are to be created for crop production utilizing biodiversity-based ecosystem services such as biological pest control, there must be a Europe-wide shift towards farming with minimal use of pesticides over large areas.

Geiger, F., G. R. de Snoo, F. Berendse, I. Guerrero, M. Morales, J. Onate, S. Eggers, T. Part, R. Bommarco and J. Bengtsson (2010). "Landscape composition influences farm management effects on farmland birds in winter: a pan-European approach." Agriculture, Ecosystems & Environment **139**(4): 571-577.

Category: Agriculture-induced impacts

Keywords: *Effects of agricultural intensity, farming practices, landscape composition, vegetation cover, abundance, richness, farmland birds, Europe*

Abstract: This study examined the effects of agricultural intensity, various farming practices, landscape composition and vegetation cover on the abundance and species richness of wintering farmland birds, assessed simultaneously across seven European regions.

The abundance and species richness of wintering farmland birds were negatively affected by agricul- tural intensity. The effects of yield and farm type were interlinked. Of the 10 farming practices assessed, mechanical weeding and the amount of organic fertilizer applied negatively affected farmland birds, presumably due to reduced food availability on arable fields. Positive effects of organic farming on farmland birds proved to be limited to simplified landscapes. More farmland birds were observed in areas with more stubble, pasture and green manure crops. Species richness was higher in areas with more pasture.

The results of this study show that farm management, vegetation cover and landscape composition all influence wintering farmland birds. Heterogeneous

landscapes comprising arable crops as well as grasslands support most species of farmland birds in winter. The effectiveness of organic farming and agri-environment schemes depends on landscape composition. Therefore, different agri-environment schemes should be designed for different landscape types.

Gemmill-Herren, B. (2009). Fruitful liaisons. Chapter on pollination. The wealth of nations: Ecosystem services, biodiversity and human well-being. J. McNeely, R. Mittermeie, T. Brooks and B. F., International Union for Conservation of Nature (IUCN), Conservation International (CI) and the International League of Conservation Photographers (ILCP).
Category: Ecosystem services
Keywords: *Pollination*
(no abstract)

Gemmill-Herren, B. (2011). Challenges and solutions to implement PES in smallholder farming systems in developing countries. Payments for Ecosystems Services and Food Security. D. Ottaviani and N. El-Hage Scialabba. Rome, FAO**:** 30-35.
Category: Ecosystem services
Keywords: *Payments for Ecosystems Services, ecosystem services, smallholder farming, agroecosystems, sustainability, agricultural production*
(no abstract)

Gemmill-Herren, B. and A. Ochieng (2008). "Role of native bees and natural habitats in eggplant (Solanum melongena) pollination in Kenya." Agriculture, Ecosystems & Environment **127**(1-2): 31-36.
Category: Ecosystem services
Keywords: *Eggplant, pollination, ecosystem services, wild habitat, agroecosystems, landscape ecology*
Abstract: The pollination requirements of eggplant (Solanum melongena) were investigated. One variety of eggplant exhibited a significantly reduced seed set in absence of pollinators, and two varieties significantly increased seed numbers when pollen deposition was enhanced. Two solitary bee species, Xylocopa caffra and Macronomia rufipes, were identified as effective pollinators of the crop. The visitation rates of these pollinators to eggplant flowers declined significantly with distance from the wild habitat. The importance of wild plants as alternative forage source for pollinators was assessed by a survey of the flowering plants in different habitats surrounding eggplant fields. While ruderal farm weeds provide much of these resources, the Acacia tortilis riverine forest experienced high visitation rates in one critical period of the dry season. The spatio-temporal foraging behaviour of eggplant pollinators highlights the role of the agricultural matrix in conserving ecosystem services. Interspersion of wild habitats with cultivated land promoted increased pollination services.

Gianinazzi, S., A. Gollotte, M.-N. Binet, D. Tuinen, D. Redecker and D. Wipf (2010).

"Agroecology: the key role of arbuscular mycorrhizas in ecosystem services." Mycorrhiza **20**(8): 519-530.

Category: Agroecology and agroecological practices

Keywords: *Arbuscular mycorrhiza, ecosystem services, agroecology, ecosystem sustainability, soil nutrient/cycling*

Abstract: The beneficial effects of arbuscular mycorrhizal (AM) fungi on plant performance and soil health are essential for the sustainable management of agricultural ecosystems. Nevertheless, since the 'first green revolution', less attention has been given to beneficial soil microorganisms in general and to AM fungi in particular. Human society benefits from a multitude of resources and processes from natural and managed ecosystems, to which AM make a crucial contribution. These resources and processes, which are called ecosystem services, include products like food and processes like nutrient transfer. Many people have been under the illusion that these ecosystem services are free, invulnerable and infinitely available; taken for granted as public benefits, they lack a formal market and are traditionally absent from society's balance sheet. In 1997, a team of researchers from the USA, Argentina and the Netherlands put an average price tag of US $33 trillion a year on these fundamental ecosystem services. The present review highlights the key role that the AM symbiosis can play as an ecosystem service provider to guarantee plant productivity and quality in emerging systems of sustainable agriculture. The appropriate management of ecosystem services rendered by AM will impact on natural resource conservation and utilisation with an obvious net gain for human society.

GIZ (2010). Eco-functional intensification of agricultural production seeds and fertiliser - contribution to food security. t. O. Documentation of the Workshop, GTZ (/GIZ)1, Eschborn. Eschborn, GIZ Dep. 45 "Agriculture, fisheries and food"**:** 17.

Category: Ecosystem services

Keywords: *Seeds, fertilizer, eco-intensification, food security, sustainable agriculture, developing countries, farmer-led seed markets*

Abstract: Global cereal production has almost tripled since 1950. This 'green revolution' has been made possible by enormous progress in plant breeding and the large-scale use of synthetic nitrogen. However, this intensification has also resulted in a decrease in biodiversity and an increase in greenhouse gas emissions, while food security remains an unsolved problem. Against this backdrop, the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD 2009)2 has postulated that sustainable intensification of small-scale agriculture on marginal lands holds significant potential for improving food security.

In this context, the workshop focused on the question of whether eco-functional intensifica- tion could be a new paradigm for food security. Representatives from the research community, FAO, the private sector and NGOs were invited to present their perspectives on the future of agricultural intensification. After a comprehensive introduction to the topic, sessions on seeds and fertilizers identified lessons learned and key challenges. Questions and concerns expressed by the audience were noted for the final panel discussion that dealt with policy implications and steps ahead.

In view of the breadth of the topic and the highly technical insights delivered by the

partici- pants, this documentation aims to concentrate solely on the key outcomes of the workshop. It therefore documents only the key points of each presentation. The final section summarizes the conclusions that can be drawn from the discussions and seeks to provide an outlook on how to move forward on the issue of eco-functional intensification in the context of international cooperation.

Gliessman, S. R. (1998). Agroecology: ecological process in sustainable agriculture. Michigan, Ann Arbor Press.
Category: Agroecology and agroecological practices
Keywords: *Agricultural ecology, sustainable agriculture, agricultural systems, agricultural ecology, sustainable agriculture, agricultural systems, sustainable agriculture, agricultural systems, agricultural ecology*

Godfray, H., J. Beddington, I. Crute, L. Haddad, D. Lawrence, J. Muir, J. Pretty, S. Robinson, S. Thomas and C. Toulmin (2010). "Food Security: The challenge of feeding 9 billion people." Science **327**(5967): 812-818.
Category: Climate change
Keywords: *Dynamical climatology, climate change, World, overexploitation, competition, food production, population growth, food intake, food supply, food security*
Abstract: Continuing population and consumption growth will mean that the global demand for food will increase for at least another 40 years. Growing competition for land, water, and energy, in addition to the overexploitation of fisheries, will affect our ability to produce food, as will the urgent requirement to reduce the impact of the food system on the environment. The effects of climate change are a further threat. But the world can produce more food and can ensure that it is used more efficiently and equitably. A multifaceted and linked global strategy is needed to ensure sustainable and equitable food security, different components of which are explored here.

Goldman, R., B. Thompson and G. Daily (2007). "Institutional incentives for managing the landscape: Inducing cooperation for the production of ecosystem services." Ecological Economics **64**(2): 333-343.
Category: Ecosystem services
Keywords: *Landscape design, biodiversity, ecosystem services, economic incentives, agriculture*
Abstract: Agricultural landscapes hold tremendous potential for producing a diverse stream of ecosystem services. Yet, because the spatial configuration of particular ecosystems is critical to the supply of many services, realizing this potential requires that farms be managed in a coordinated way across landscapes rather than as independent units. Under existing incentive programs, this level of coordination is typically neither required nor encouraged.
Here we explore how to achieve such coordination from an institutional perspective using voluntary incentives rather than regulation. We focus on three services operating at contrasting scales, from local to global: pollination, hydrologic services,

and carbon sequestration. First, we briefly illustrate how agricultural practices can diminish or enhance their provision. Next, we show how all three services require coordinated, landscape-scale management because provision depends upon particular spatial configurations, of which we provide several stylized examples. Finally, based on these stylized configurations, we evaluate the relative merits of three incentive designs–the "cooperation bonus," the "entrepreneur," and the "ecosystem service district"–to promote cross-farm cooperation to enhance service provision.

All three incentive systems rely on rational self-interest, have cooperative configurations to promote ecosystem services across different scales, use tiered reward systems, and have a major voluntary element. They are distinct in certain key features. The cooperation bonus system rewards conservation even without cooperation but adds a bonus for cooperation. In the entrepreneur incentive, all tiers of reward are contingent upon cooperation. The ecosystem service district scheme is only partially voluntary and forces cooperation of all landowners once the district is formed. Our analysis of these heuristic alternatives integrates biophysical, economic, and institutional factors with the aim of addressing the suite of institutional barriers for landscape-scale management.

Gomez-Baggethun, E., R. de Groot, P. Lomas and C. Montes (2010). "The history of ecosystem services in economic theory and practice: From early notions to markets and payment schemes." Ecological Economics **69**(6): 1209-1218.

Category: Ecosystem services

Keywords: *Economic history, use value, exchange value, ecosystem services, market based instruments, commodification*

Abstract: This paper reviews the historic development of the conceptualization of ecosystem services and examines critical landmarks in economic theory and practice with regard to the incorporation of ecosystem services into markets and payment schemes. The review presented here suggests that the trend towards monetization and commodification of ecosystem services is partly the result of a slow move from the original economic conception of nature's benefits as use values in Classical economics to their conceptualization in terms of exchange values in Neoclassical economics. The theory and practice of current ecosystem services science are examined in the light of this historical development. From this review, we conclude that the focus on monetary valuation and payment schemes has contributed to attract political support for conservation, but also to commodify a growing number of ecosystem services and to reproduce the Neoclassical economics paradigm and the market logic to tackle environmental problems.

Gonzalez-Varo, J., J. Biesmeijer, R. Bommarco, S. Potts, O. Schweiger, H. Smith, I. Steffan-Dewenter, H. Szentgyorgyi, M. Woyciechowski and M. Vila (2013). "Combined effects of global change pressures on animal-mediated pollination." Trends in ecology & evolution(0).

Category: Ecosystem services; Agriculture-induced impacts; Climate change;

Keywords: *Global change, animal mediated pollination, ecosystem services, synergistic effects, antagonistic effects, pollination*

Abstract: Pollination is an essential process in the sexual reproduction of seed plants and a key ecosystem service to human welfare. Animal pollinators decline as a consequence of five major global change pressures: climate change, landscape alteration, agricultural intensification, non-native species, and spread of pathogens. These pressures, which differ in their biotic or abiotic nature and their spatiotemporal scales, can interact in nonadditive ways (synergistically or antagonistically), but are rarely considered together in studies of pollinator and/or pollination decline. Management actions aimed at buffering the impacts of a particular pressure could thereby prove ineffective if another pressure is present. Here, we focus on empirical evidence of the combined effects of global change pressures on pollination, highlighting gaps in current knowledge and future research needs.

Goulson, D. (1999). "Foraging strategies of insects for gathering nectar and pollen, and implications for plant ecology and evolution." Perspectives in Plant Ecology, Evolution and Systematics **2**(2): 185-209.

Category: Ecosystem services

Keywords: *Departure rules, flower constancy, ideal free distribution, marginal value theorem, optimal foraging, scent marks, systematic searching, pollination*

Abstract: The majority of species of flowering plants rely on pollination by insects, so that their reproductive success and in part their population structure are determined by insect behaviour. The foraging behaviour of insect pollinators is flexible and complex, because efficient collection of nectar or pollen is no simple matter. Each flower provides a variable but generally small reward that is often hidden, flowers are patchily distributed in time and space, and are erratically depleted of rewards by other foragers. Insects that specialise in visiting flowers have evolved an array of foraging strategies that act to improve their efficiency, which in turn determine the reproductive success of the plants that they visit. This review attempts a synthesis of the recent literature on selectivity in pollinator foraging behaviour, in terms of the species, patch and individual flowers that they choose to visit.

The variable nature of floral resources necessitate foraging behaviour based upon flexible learning, so that foragers can respond to the pattern of rewards that they encounter. Fidelity to particular species allows foragers to learn appropriate handling skills and so reduce handling times, but may also be favoured by use of a search image to detect flowers. The rewards received are also used to determine the spatial patterns of searches; distance and direction of flights are adjusted so that foragers tend to remain within rewarding patches and depart swiftly from unrewarding ones. The distribution of foragers among patchy resources generally conforms to the expectations of two simple optimal foraging models, the ideal free distribution and the marginal value theorem.

Insects are able to learn to discriminate among flowers of their preferred species on the basis of subtle differences in floral morphology. They may discriminate upon the basis of flower size, age, sex or symmetry and so choose the more rewarding flowers. Some insects are also able to distinguish and reject depleted flowers on the basis of ephemeral odours left by previous visitors. These odours have recently been implicated as a mechanism involved in interspecific interactions between foragers.

From the point of view of a plant reliant upon insect pollination, the behaviour of its pollinators (and hence its reproductive success) is likely to vary according to the rewards offered, the size and complexity of floral displays used to advertise their location, the distribution of conspecific and of rewards offered by other plant species, and the abundance and behaviour of other flower visitors.

Green, A. and J. Elmberg (2013). "Ecosystem services provided by waterbirds." Biological Reviews: n/a-n/a.

Category: Ecosystem services

Keywords: *Bioindicators, cultural services, economic value, ecosystem engineering, ecosystem services, nutrient fluxes, pest control, seed dispersal, waterfowl harvest, zoochory, pest regulation*

Abstract: Ecosystem services are ecosystem processes that directly or indirectly benefit human well-being. There has been much recent literature identifying different services and the communities and species that provide them. This is a vital first step towards management and maintenance of these services. In this review, we specifically address the waterbirds, which play key functional roles in many aquatic ecosystems, including as predators, herbivores and vectors of seeds, invertebrates and nutrients, although these roles have often been overlooked. Waterbirds can maintain the diversity of other organisms, control pests, be effective bioindicators of ecological conditions, and act as sentinels of potential disease outbreaks. They also provide important provisioning (meat, feathers, eggs, etc.) and cultural services to both indigenous and westernized societies. We identify key gaps in the understanding of ecosystem services provided by waterbirds and areas for future research required to clarify their functional role in ecosystems and the services they provide. We consider how the economic value of these services could be calculated, giving some examples. Such valuation will provide powerful arguments for waterbird conservation.

Green, R., S. Cornell, J. Scharlemann and A. Balmford (2005). "Farming and the fate of wild nature." Science **307**(5709): 550-555.

Category: Ecosystem services

Keywords: *Land sharing, land sparing, crop yield, biodiversity conservation, population density, trade-offs, farmland area, province, sustainable intensification*

Abstract: Ecosystem services are ecosystem processes that directly or indirectly benefit human well-being. There has been much recent literature identifying different services and the communities and species that provide them. This is a vital first step towards management and maintenance of these services. In this review, we specifically address the waterbirds, which play key functional roles in many aquatic ecosystems, including as predators, herbivores and vectors of seeds, invertebrates and nutrients, although these roles have often been overlooked. Waterbirds can maintain the diversity of other organisms, control pests, be effective bioindicators of ecological conditions, and act as sentinels of potential disease outbreaks. They also provide important provisioning (meat, feathers, eggs, etc.) and cultural services to both indigenous and westernized societies. We identify key gaps

in the understanding of ecosystem services provided by waterbirds and areas for future research required to clarify their functional role in ecosystems and the services they provide. We consider how the economic value of these services could be calculated, giving some examples. Such valuation will provide powerful arguments for waterbird conservation.

Gregory, P., S. Johnson, A. Newton and J. Ingram (2009). "Integrating pests and pathogens into the climate change/food security debate." Journal of Experimental Botany **60**(10): 2827-2838.

Category: Climate change

Keywords: *Dynamical climatology, botany, plant production, food security, food supply, climate change, pathogenic, pest and disease, pest regulation*

Abstract: While many studies have demonstrated the sensitivities of plants and of crop yield to a changing climate, a major challenge for the agricultural research community is to relate these findings to the broader societal concern with food security. This paper reviews the direct effects of climate on both crop growth and yield and on plant pests and pathogens and the interactions that may occur between crops, pests, and pathogens under changed climate. Finally, we consider the contribution that better understanding of the roles of pests and pathogens in crop production systems might make to enhanced food security. Evidence for the measured climate change on crops and their associated pests and pathogens is starting to be documented. Globally atmospheric [CO2] has increased, and in northern latitudes mean temperature at many locations has increased by about 1.0–1.4 °C with accompanying changes in pest and pathogen incidence and to farming practices. Many pests and pathogens exhibit considerable capacity for generating, recombining, and selecting fit combinations of variants in key pathogenicity, fitness, and aggressiveness traits that there is little doubt that any new opportunities resulting from climate change will be exploited by them. However, the interactions between crops and pests and pathogens are complex and poorly understood in the context of climate change. More mechanistic inclusion of pests and pathogen effects in crop models would lead to more realistic predictions of crop production on a regional scale and thereby assist in the development of more robust regional food security policies.

Group, I. E. (2012). Organic agriculture. A strategy for climate change adaptation. Dossier. Brussels**:** 24.

Category: Climate change

Keywords: *Organic agriculture, climate change adaptation, Northern Europe, Mediterranean Region, climate change adaptation policy*

Abstract: Changing climate patterns have already begun to have considerable impact on agricultural production in many regions. In the near future, shifts in local climatic conditions and the frequency of extreme weather events such as droughts and floods are expected to occur even more frequently, with potentially devastating effects for agricultural yields. Strategies need to be developed to make our food and farming systems more resilient to the effects of climate change. This dossier

presents the latest scientific findings to show how organic farming as a holistic sustainable production system can con- tribute to effective climate change adaptation strategies for the agriculture sector.

The first article by Adrian Müller and Andreas Gattinger demonstrates that farm systems need to become more resilient to climate change impacts such as water stress and increased pest pressure in order to avoid extensive losses in agricultural production. Organic farming practices are an investment in climate change resilience. Crop rotation and the use of organic fertilisers contribute to improved soil structures and therefore reduce water erosion due to heavy rain fall, and enhance water supply during dry periods. Furthermore crop and income diversification can help to reduce economic risks for the farmer.

With a focus on Northern Europe, Jørgen E. Olesen outlines how changing temperatures and precipitation patterns will impact on farming in the future. Increasing temperatures will lead to the expansion northwards of crops such as grain maize or sunflowers, on the other hand yields for some cereals are expected to decline. Olesen argues that farming systems will need to increase their resilience to climatic extremes. Diverse crop rotations and soils that provide good water supplies during droughts, and rapid water infiltration and drainage during periods of intense rainfall are major parts of any adaptation strategy – as well as characteristic of organic farming systems. Eduardo Aguilera, Gloria Guzmán and Livia Ortolani describe the impacts of climate change on agriculture in Mediterranean regions. A rise in temperatures and drought is expected in this region with many soils extremely vulnerable due to their low organic matter content. Moreover changing climate patterns might lead to the loss of important typical regional production as well as the market opportunities that geographical indications offer farmers. Practices that are common in organic agriculture such as the use of organic fertilisers, cover crops, robust traditional crops and good biodiversity management are the main elements that can help farmers to successfully cope with the changing climate.

In the final article, Antje Kölling and Teresa Elola-Calderón analyse the international and European legal context of climate change adaptation in agriculture, exploring how EU policy frameworks can support the development and expan- sion of organic systems as effective strategy and solutions to climate adaptation.

Gurr, G., S. Wratten and W. Snyder (2012). Soil fertility, biodiversity and pest management, Wiley-Blackwell.

Category: Ecosystem services

Keywords: *Soil fertility, biodiversity and pest management, agroecosystem health optimisation, synergism, soil fertility management and IPM,,above-ground and below-ground, of ecosystems, soil fertility, plant resistance to insect pests, soil nitrogen on crop damage, indirect effects, insect herbivore dynamics, organically fertilised systems, soil fertility practices, soil biological activity, and significance, pest regulation, pollination, soil nutrients/cycling*

Summary: Biodiversity offers great potential for managing insect pests. It provides resistance genes and anti-insect compounds; a huge range of predatory and parasitic natural enemies of pests; and community ecology-level effects operating at the local

and landscape scales to check pest build-up. This book brings together world leaders in theoretical, methodological and applied aspects to provide a comprehensive treatment of this fast-moving field.

Chapter authors from Europe, Asia, Africa, Australasia and the Americas ensure a truly international scope. Topics range from scientific principles, innovative research methods, ecological economics and effective communication to farmers, as well as case studies of successful use of biodiversity-based pest management some of which extend over millions of hectares or are enshrined as government policy.

Written to be accessible to advanced undergraduates whilst also stimulating the seasoned researcher, this work will help unlock the power of biodiversity to deliver sustainable insect pest management.

Hajjar, R., D. Jarvis and B. Gemmill-Herren (2008). "The utility of crop genetic diversity in maintaining ecosystem services." Agriculture, Ecosystems & Environment **123**(4): 261-270.

Category: Ecosystem services

Keywords: *Agroecosystem, carbon sequestration, crop genetic diversity, ecosystem services, pest and disease, pollination pest regulation, soil nutrients/cycling*

Abstract: Few studies have addressed the relationship between genetic diversity and provision of ecosystem services in agroecosystems. In this review, we argue that the contribution of biological diversity to ecosystem functioning in agricultural production systems is variable, but can be substantial, and occurs at the genetic, as well as species, level in arable systems. In particular, we look at the potential benefits of crop genetic diversity in enhancing agroecosystem functioning and the provision of services, both directly and indirectly. Increasing crop genetic diversity has shown to be useful in pest and disease management, and has the potential to enhance pollination services and soil processes in specific situations. By contributing to the long-term stability of agroecosystems and helping to provide continuous biomass cover, crop genetic diversity also aids the ecosystem to sequester carbon, and helps in preventing soil erosion.

Hallin, S., C. Jones, M. Schloter and L. Philippot (2009). "Relationship between N-cycling communities and ecosystem functioning in a 50-year-old fertilization experiment." ISME J. **3**: 597-605.

Category: Ecosystem services

Keywords: *Microbial communities, ecosystem functioning, nitrogen nitrification, denitrification, multivariate analysis, community size, community composition, long-term field experiments, fertilization regimes, soil nutrients/cycling*

Abstract: The relative importance of size and composition of microbial communities in ecosystem functioning is poorly understood. Here, we investigated how community composition and size of selected functional guilds in the nitrogen cycle correlated with agroecosystem functioning, which was defined as microbial process rates, total crop yield and nitrogen content in the crop. Soil was sampled from a 50-year fertilizer trial and the treatments comprised unfertilized bare fallow, unfertilized with crop, and plots with crop fertilized with calcium nitrate, ammonium sulfate, solid cattle manure or sewage sludge. The size of the functional guilds and

the total bacterial community were greatly affected by the fertilization regimes, especially by the sewage sludge and ammonium sulfate treatments. The community size results were combined with previously published data on the composition of the corresponding communities, potential ammonia oxidation, denitrification, basal and substrate-induced respiration rates, in addition to crop yield for an integrated analysis. It was found that differences in size, rather than composition, correlated with differences in process rates for the denitrifier and ammonia-oxidizing archaeal and total bacterial communities, whereas neither differences in size nor composition was correlated with differences in process rates for the ammonia-oxidizing bacterial community. In contrast, the composition of nitrate-reducing, denitrifying and total bacterial communities co-varied with primary production and both were strongly linked to soil properties.

Halpern, B., C. White, S. Lester, C. Costello and S. Gaines (2011). "Using portfolio theory to assess tradeoffs between return from natural capital and social equity across space." Biological Conservation **144**(5): 1499-1507.

Category: Ecosystem services

Keywords: *Ecosystem services, environmental justice, marine reserves, fisheries, channel Islands, portfolio theory*

Abstract: Spatial variance in returns from natural resources, driven by resource dynamics and regulations, can have strong consequences for equitable delivery of value to individuals and communities. Yet resource management models implicitly weight returns equally across space, even when space is explicitly included in model dynamics and policy. Here we translate financial portfolio theory from the temporal to spatial realm and use it to quantify the inherent tradeoff between resource returns and social equity, defined as a more uniform distribution of resource value across space. We illustrate this approach with a marine case study of the Channel Islands, California, USA. Depending on the spatial distribution of resources, increasing spatial equity requires nonlinear reductions in resource returns. Realistic management options, such as effort-based fisheries regulations or marine protected areas, increase or reduce this tradeoff, respectively. We also quantify two critical advantages of portfolio approaches to management: they improve outcomes by avoiding false expectations and increase either resource return or social equity while maintaining the other.

Hattenschwiler, S., A. Tiunov and S. Scheu (2005). "Biodiversity and litter decomposition in terrestrial ecosystems." Annual review of ecology, evolution, and systematics **36**(1): 191-218.

Category: Ecosystem services

Keywords: *Ecosystem functioning, microorganisms, nutrient cycling, soil food web, soil-animal diversity, soil nutrients/cycling*

Abstract: We explore empirical and theoretical evidence for the functional significance of plant-litter diversity and the extraordinary high diversity of decomposer organisms in the process of litter decomposition and the consequences for biogeochemical cycles. Potential mechanisms for the frequently observed litter-

diversity effects on mass loss and nitrogen dynamics include fungi-driven nutrient transfer among litter species, inhibition or stimulation of microorganisms by specific litter compounds, and positive feedback of soil fauna due to greater habitat and food diversity. Theory predicts positive effects of microbial diversity that result from functional niche complementarity, but the few existing experiments provide conflicting results. Microbial succession with shifting enzymatic capabilities enhances decomposition, whereas antagonistic interactions among fungi that compete for similar resources slow litter decay. Soil-fauna diversity manipulations indicate that the number of trophic levels, species identity, and the presence of keystone species have a strong impact on decomposition, whereas the importance of diversity within functional groups is not clear at present. In conclusion, litter species and decomposer diversity can significantly influence carbon and nutrient turnover rates; however, no general or predictable pattern has emerged. Proposed mechanisms for diversity effects need confirmation and a link to functional traits for a comprehensive understanding of how biodiversity interacts with decomposition processes and the consequences of ongoing biodiversity loss for ecosystem functioning.

Haynes, R., R. Swift and R. Stephen (1991). "Influence of mixed cropping rotations (pasture-arable) on organic matter content, water stable aggregation and clod porosity in a group of soils." Soil and Tillage Research **19**(1): 77-87.

Category: Ecosystem services

Keywords: *Mixed cropping, pastures, New Zealand, organic matter, soil chemicophysical properties, soil, soil nutrients/cycling*

Abstract: The effects of previous cropping history on soil organic matter content, aggregate stability and clod porosity were investigated on three soil types commonly used for mixed cropping in the Canterbury region of New Zealand. An index of previous cropping history (number of years under pasture or arable cropping immediately prior to sampling) and the hot water-extractable carbohydrate fraction were closely correlated with aggregate stability. Total N, organic C, acid-hydrolysable and cold water-extractable carbohydrate were moderately well correlated with aggregate stability whilst HCl- and NaOH-extractable carbohydrates were poorly correlated with aggregate stability. Aggregate stability was correlated with clod porosity when arable and pasture samples were analysed separately, but not when all soils were included.

In many of the typical short-term mixed cropping rotations used in the study area the total soil organic matter content remained relatively unchanged yet microbial biomass C, hot water-extractable carbohydrate and aggregate stability increased markedly during the pasture phase and declined during the arable period. It is suggested that the increase in aggregate stability during the short-term pasture is due principally to production of binding carbohydrates (which are hot water-extractable) by the large microbial biomass present in the pasture rhizosphere. When the pasture is ploughed under the microbial biomass declines as does aggregate stability. The increase in aggregate stability following pasture establishment is considerably more rapid than the increase in clod porosity. Thus, at a similar clod porosity, pasture aggregates had a higher aggregate stability than their

arable counterparts.

Heaton, E., L. Schulte, M. Berti, H. Langeveld, W. Zegada-Lizarazu, D. Parrish and A. Monti (2013). "Managing a second-generation crop portfolio through sustainable intensification: Examples from the USA and the EU." Biofuels, Bioproducts and Biorefining: n/a-n/a.

Category: Agroecology and agroecological practices; ecosystem services

Keywords: *Food vs. fuel, agroecology, landscape management, bioenergy, biomass, ecosystem services, sustainable intensification*

Abstract: Sustainable intensification of agricultural systems has been suggested – in addition to reducing waste and changing consumption habits – as a way to increase food, feed, fuel, and fiber security in the twenty-first century. Here we describe three primary strategies of agricultural intensification – conventional intensification, temporal intensification, and spatial intensification – and how they can be used to manage and integrate food and second-generation crop portfolios. While each strategy has individual merits, combining them to meet case-specific targets may achieve optimum results. Multiple experiments and examples from the USA and the EU illustrate the potential of combining these approaches for agroecological intensification that can provide ecosystem services while maintaining or increasing economic output, thus striking a balance between 'land sparing' and 'land sharing'. Management strategies will vary by the types of markets available, e.g., food, fuel and/or ecosystem services, and the scale of markets supplied, e.g., small heat and power vs. large cellulosic ethanol. Future research should holistically and methodologically evaluate the trade-offs between different management strategies

Hector, A., B. Schmid, C. Beierkuhnlein, M. Caldeira, M. Diemer, P. Dimitrakopoulos, J. Finn, H. Freitas, P. Giller, J. Good, R. Harris, P. Hogberg, K. Huss-Danell, J. Joshi, A. Jumpponen, C. Korner, P. Leadley, M. Loreau, A. Minns, C. Mulder, G. O'Donovan, S. Otway, J. Pereira, A. Prinz, D. Read, M. Scherer-Lorenzen, E.-D. Schulze, A.-S. Siamantziouras, E. Spehn, A. Terry, A. Troumbis, F. Woodward, S. Yachi and J. Lawton (1999). "Plant diversity and productivity experiments in European grasslands." Science **286**(5442): 1123-1127.

Category: Ecosystem services

Keywords: *Grassland, biodiversity, species richness, primary productivity, biomass, below ground plant part, above ground plant part, geographical variation, Europe*

Abstract: At eight European field sites, the impact of loss of plant diversity on primary productivity was simulated by synthesizing grassland communities with different numbers of plant species. Results differed in detail at each location, but there was an overall log-linear reduction of average aboveground biomass with loss of species. For a given number of species, communities with fewer functional groups were less productive. These diversity effects occurred along with differences associated with species composition and geographic location. Niche complementarity and positive species interactions appear to play a role in generating diversity-productivity relationships within sites in addition to sampling from the species pool.

Hedlund, K. (2002). "Soil microbial community structure in relation to vegetation management on former agricultural land." Soil Biology and Biochemistry **34**(9): 1299-1307.
Category: Ecosystem services
Keywords: *Changing land usage, fatty acid signatures, bacteria, arbuscular mycorrhiza, microbial biomass, soil inoculations, soil, soil nutrients/cycling*

Abstract: Agricultural overproduction has led the European Union to encourage long-term abandonment of agricultural land. To enhance the transition of agricultural land to natural grasslands or forests different management practices in relation to vegetation can be used. The aim of this study was to understand the interactions between plant and associated soil microbial communities during the succession of agricultural land. A field experiment was established on newly abandoned agricultural land where the development of the soil microbial community was studied in plots after sowing a mixture of 15 plant species and in plots that were left to be naturally colonized by plants. The plants sown contained five species each of grasses, legumes and forbs representing three functional groups. A subset of these plots were inoculated with soil cores from a later successional stage. Adjacent soils with ongoing agricultural practices and deciduous beech forest were also studied. The microbial community composition and biomass were studied by determining fatty acid signatures (PLFA, NFLA) of soil microorganisms. The microbial community had changed within 2 years from that of the agricultural field diverging into one type present in sown plots and another in plots that were naturally colonized by plants. Sowing plant seed mixtures promoted growth of the bacterial community and sarophytic fungi. Respiration measurements showed higher microbial activity and biomass in sown plots. Bait plants for arbuscular mycorrhizal (AM) fungi and NLFA 16:1ω5 showed that the biomass of AM-fungi was reduced when seed mixtures were sown, which also decreased the formation of mycorrhizal associations on plant roots.

Hedlund, K., B. Griffiths, S. Christensen, S. Scheu, H. Setala, T. Tscharntke and H. A. Verhoef (2004). "Trophic interactions in changing landscapes: responses of soil food webs." Basic and Applied Ecology **5**(6): 495-503.
Category: Ecosystem services
Keywords: *Land use change, dispersal, habitat fragmentation, trophic levels, soil fauna, fungi, bacteria, soil, soil nutrient/cycling*

Abstract: Soil communities in landscapes that are rapidly changing due to a range of anthropogenic processes can be regarded as highly transient systems where interactions between competing species or trophic levels may be seriously disrupted. In disturbed communities dispersal in space and time has a role in ensuring continuity of community function. Stable communities, in undisturbed systems, are more dependent on competition and other biotic interactions between species. We predicted how food web components would respond to disturbance, based on their dispersal and colonizing abilities. During decomposition, flows of energy and nutrients generally follow either a bacterial-based path, with bacteria as the primary decomposer and bacterial-feeding fauna and their predators forming the associated food web, or a fungal-based channel. Trophic links that were generally resistant to change were the organisms of the bacterial pathway that have high abilities to

disperse in time and passively disperse in space. Organisms in the fungal pathway were less resistant to disturbance. Resource inputs to the soil system are derived from plants, either through root exudation and root turnover during active growth or from dead plant material following senescence or agricultural tillage. Disturbances to the soil system can arise as a direct action on the soil, or indirectly from effects on the above-ground plant community. Disturbance-induced changes in plant community composition will change the soil food web composition. Organisms involved in direct interactions with plants (e.g. AM-mycorrhizal fungi) were also predicted to be vulnerable to disturbance.

Hedlund, K., I. Santa Regina, W. H. Van der Putten, J. Lepš, T. Díaz, G. W. Korthals, S. Lavorel, V. K. Brown, D. Gormsen, S. R. Mortimer, C. Rodríguez Barrueco, J. Roy, P. Smilauer, M. Smilauerová and C. Van Dijk (2003). "Plant species diversity, plant biomass and responses of the soil community on abandoned land across Europe: idiosyncracy or above-belowground time lags." Oikos **103**(1): 45-58.

Category: Ecosystem services

Keywords: *Animal plant relation, biodiversity, invertebrata, Europe, geographical variation, field experiment, arable land, idiosyncrasy, primary productivity, microbial biomass, soil fauna, soils, biomass, species diversity, vegetation structure, plant, soil, soil nutrients/cycling*

Abstract: Soil communities in landscapes that are rapidly changing due to a range of anthropogenic processes can be regarded as highly transient systems where interactions between competing species or trophic levels may be seriously disrupted. In disturbed communities dispersal in space and time has a role in ensuring continuity of community function. Stable communities, in undisturbed systems, are more dependent on competition and other biotic interactions between species. We predicted how food web components would respond to disturbance, based on their dispersal and colonizing abilities. During decomposition, flows of energy and nutrients generally follow either a bacterial-based path, with bacteria as the primary decomposer and bacterial-feeding fauna and their predators forming the associated food web, or a fungal-based channel. Trophic links that were generally resistant to change were the organisms of the bacterial pathway that have high abilities to disperse in time and passively disperse in space. Organisms in the fungal pathway were less resistant to disturbance. Resource inputs to the soil system are derived from plants, either through root exudation and root turnover during active growth or from dead plant material following senescence or agricultural tillage. Disturbances to the soil system can arise as a direct action on the soil, or indirectly from effects on the above-ground plant community. Disturbance-induced changes in plant community composition will change the soil food web composition. Organisms involved in direct interactions with plants (e.g. AM-mycorrhizal fungi) were also predicted to be vulnerable to disturbance.

Hein, L., K. van Koppen, R. de Groot and E. van Ierland (2006). "Spatial scales, stakeholders and the valuation of ecosystem services." Ecological Economics **57**(2): 209-228.

Category: Farmer and societal benefits

Keywords: *Ecosystem services, valuation, spatial scales, stakeholders, wetlands*

Abstract: Since the late 1960s, the valuation of ecosystem services has received ample attention in scientific literature. However, to date, there has been relatively little elaboration of the various spatial and temporal scales at which ecosystem services are supplied. This paper analyzes the spatial scales of ecosystem services, and it examines how stakeholders at different spatial scales attach different values to ecosystem services. The paper first establishes an enhanced framework for the valuation of ecosystem services, with specific attention for stakeholders. The framework includes a procedure to assess the value of regulation services that avoids double counting of these services. Subsequently, the paper analyses the spatial scales of ecosystem services: the ecological scales at which ecosystem services are generated, and the institutional scales at which stakeholders benefit from ecosystem services. On the basis of the proposed valuation framework, we value four selected ecosystem services supplied by the De Wieden wetlands in The Netherlands, and we analyze how these services accrue to stakeholders at different institutional scales. These services are the provision of reed for cutting, the provision of fish, recreation, and nature conservation. In the De Wieden wetland, reed cutting and fisheries are only important at the municipal scale, recreation is most relevant at the municipal and provincial scale, and nature conservation is important in particular at the national and international level. Our analysis shows that stakeholders at different spatial scales can have very different interests in ecosystem services, and we argue that it is highly important to consider the scales of ecosystem services when valuation of services is applied to support the formulation or implementation of ecosystem management plans.

Helgason, T., T. Daniell, R. Husband, A. Fitter and J. Young (1998). "Ploughing up the wood-wide web?" Nature **394**(6692): 431-431.

Category: Agriculture-induced impacts

Keywords: *Soil, fungi, mycorrhiza, diversity, woodland, ploughing, soil nutrients/cycling*

Abstract: Key species groups that affect major ecological processes are vital components of community diversity. Many such key groups are found in the soil, including the mycorrhizal fungi that may connect plants into a functional "wood-wide web". Arbuscular mycorrhizal associations are formed by fungi of the order Glomales with 90% of land plant families, and many arbuscular mycorrhizal fungi are thought to have a broad host range. Here we show that, despite this broad host range, the diversity of arbuscular mycorrhizal fungi is strikingly low in arable sites compared with a woodland.

Henderson, D., E. Riga, R. Ramirez, J. Wilson and W. Snyder (2009). "Mustard biofumigation disrupts biological control by Steinernema spp. nematodes in the soil." Biological Control **48**(3): 316-322.

Category: Ecosystem services

Keywords: *Biofumigant, non-target effects, Colorado potato beetle, plant-parasitic nematode, entomopathogenic nematode, leptinotarsa decemlineata, meloidogyne chitwoodi, pest regulation*

Abstract: Mustard green manures or seed meal high in glucosinolates, which produce a natural biofumigant upon incorporation into the soil, form an alternative to synthetic fumigants. However, the non-target impacts of these biofumigants in the field are unclear. We examined the effectiveness of soil incorporation of Brassica carinata seed meal both in controlling the plant-parasitic Columbia root-knot nematode (Meloidogyne chitwoodi), and on the biological control exerted by the entomopathogenic nematodes Steinernemafeltiae and Steinernema riobrave on root-knot nematodes and the Colorado potato beetle (Leptinotarsa decemlineata). Singly, both the seed meal and Steinernema spp. reduced root-knot nematode damage to potato tubers and increased marketable tuber yields. However, there was a negative interaction between the two bioagents such that their combination did not further improve suppression of plant-parasitic nematodes. Thus, mustard seed meal applications harmful to the target root-knot nematode also disrupted the ability of Steinernema spp. to act as biocontrol agents. Further, we observed modest disruption of the biological control of potato beetles following biofumigation. But, the potato beetles were less likely to lay eggs on potato plants grown in mustard-amended soil, suggesting a counteracting benefit of mustard application. Multiple, complementary controls must be integrated to replace the very effective pest suppression typical of synthetic soil fumigants. Our study suggests significant interference between biofumigation and biocontrol agents in the soil, presenting challenges in combining these two environmentally friendly approaches to managing plant-parasitic nematodes and other pests.

Hodgson, J., W. Kunin, C. Thomas, T. Benton and D. Gabriel (2010). "Comparing organic farming and land sparing: optimizing yield and butterfly populations at a landscape scale." Ecology Letters **13**(11): 1358-1367.

Category: Ecosystem services

Keywords: *Biodiversity, conservation, easement, land use, protected area, restoration, sustainable agriculture, trade-off, wildlife-friendly farming, yield, sustainable intensification*

Abstract: Organic farming aims to be wildlife-friendly, but it may not benefit wildlife overall if much greater areas are needed to produce a given quantity of food. We measured the density and species richness of butterflies on organic farms, conventional farms and grassland nature reserves in 16 landscapes. Organic farms supported a higher density of butterflies than conventional farms, but a lower density than reserves. Using our data, we predict the optimal land-use strategy to maintain yield whilst maximizing butterfly abundance under different scenarios. Farming conventionally and sparing land as nature reserves is better for butterflies when the organic yield per hectare falls below 87% of conventional yield. However, if the spared land is simply extra field margins, organic farming is optimal whenever organic yields are over 35% of conventional yields. The optimal balance of land sparing and wildlife-friendly farming to maintain production and biodiversity will differ between landscapes.

Hodgson, J. G., G. Montserrat-Marti, J. Tallowin, K. Thompson, S. Diaz, M. Cabido, J. P.

Grime, P. J. Wilson, S. R. Band, A. Bogard, R. Cabido, D. Caceres, P. Castro-Diez, C. Ferrer, M. Maestro-Martinez, M. C. Perez-Rontome, M. Charles, J. H. C. Cornelissen, S. Dabbert, N. Perez-Harguindeguy, T. Krimly, F. J. Sijtsma, D. Strijker, F. Vendramini, J. Guerrero-Campo, A. Hynd, G. Jones, A. Romo-Diez, L. de Torres Espuny, P. Villar-Salvador and M. R. Zak (2005). "How much will it cost to save grassland diversity?" Biological Conservation **122**(2): 263-273.

Category: Ecosystem services

Keywords: *Biodiversity, site productivity, economic factors, effectiveness of conservation initiatives, wild biodiversity*

Abstract: Organic farming aims to be wildlife-friendly, but it may not benefit wildlife overall if much greater areas are needed to produce a given quantity of food. We measured the density and species richness of butterflies on organic farms, conventional farms and grassland nature reserves in 16 landscapes. Organic farms supported a higher density of butterflies than conventional farms, but a lower density than reserves. Using our data, we predict the optimal land-use strategy to maintain yield whilst maximizing butterfly abundance under different scenarios. Farming conventionally and sparing land as nature reserves is better for butterflies when the organic yield per hectare falls below 87% of conventional yield. However, if the spared land is simply extra field margins, organic farming is optimal whenever organic yields are over 35% of conventional yields. The optimal balance of land sparing and wildlife-friendly farming to maintain production and biodiversity will differ between landscapes.

Hoehn, P., T. Tscharntke, J. Tylianakis and I. Steffan-Dewenter (2008). "Functional group diversity of bee pollinators increases crop yield." Proceedings of the Royal Society B: Biological Sciences **275**(1648): 2283-2291.

Category: Ecosystem services

Keywords: *Complementary resource use, ecosystem services, land-use management gradient, fruit set, tropical ecology, spatio-temporal variability, pollinators*

Abstract: Niche complementarity is a commonly invoked mechanism underlying the positive relationship between biodiversity and ecosystem functioning, but little empirical evidence exists for complementarity among pollinator species. This study related differences in three functional traits of pollinating bees (flower height preference, daily time of flower visitation and within-flower behaviour) to the seed set of the obligate cross-pollinated pumpkin Cucurbita moschata Duch. ex Poir. across a land-use intensity gradient from tropical rainforest and agroforests to grassland in Indonesia. Bee richness and abundance changed with habitat variables and we used this natural variation to test whether complementary resource use by the diverse pollinator community enhanced final yield. We found that pollinator diversity, but not abundance, was positively related to seed set of pumpkins. Bees showed species-specific spatial and temporal variation in flower visitation traits and within-flower behaviour, allowing for classification into functional guilds. Diversity of functional groups explained even more of the variance in seed set (r2=45%) than did species richness (r2=32%) highlighting the role of functional complementarity. Even though we do not provide experimental, but rather correlative evidence, we can link spatial and temporal complementarity in highly diverse pollinator communities to pollination success in the field, leading to enhanced crop yield without any managed

honeybees.

Hoekstra, J., T. Boucher, T. Ricketts and C. Roberts (2005). "Confronting a biome crisis: global disparities of habitat loss and protection." Ecology Letters **8**(1): 23-29.
Category: Ecosystem services
Keywords: *Biodiversity conservation, ecosystem services, extinction crisis, habitat loss, protected areas, wild biodiversity*
Abstract: Human impacts on the natural environment have reached such proportions that in addition to an 'extinction crisis', we now also face a broader 'biome crisis'. Here we identify the world's terrestrial biomes and, at a finer spatial scale, ecoregions in which biodiversity and ecological function are at greatest risk because of extensive habitat conversion and limited habitat protection. Habitat conversion exceeds habitat protection by a ratio of 8 : 1 in temperate grasslands and Mediterranean biomes, and 10 : 1 in more than 140 ecoregions. These regions include some of the most biologically distinctive, species rich ecosystems on Earth, as well as the last home of many threatened and endangered species. Confronting the biome crisis requires a concerted and comprehensive response aimed at protecting not only species, but the variety of landscapes, ecological interactions, and evolutionary pressures that sustain biodiversity, generate ecosystem services, and evolve new species in the future.

Hol, W., W. De Boer, A. Termorshuizen, K. Meyer, J. Schneider, N. Van Dam, J. Van Veen and W. Van Der Putten (2010). "Reduction of rare soil microbes modifies plant–herbivore interactions." Ecology Letters **13**(3): 292-301.
Category: Ecosystem services
Keywords: *Biodiversity, dominant, species interactions, soil, soil nutrients/cycling*
Abstract: Rare species are assumed to have little impact on community interactions and ecosystem processes. However, very few studies have actually attempted to quantify the role of rare species in ecosystems. Here we compare effects of soil community assemblages on plant-herbivore interactions and show that reduction of rare soil microbes increases both plant biomass and plant nutritional quality. Two crop plant species growing in soil where rare microbes were reduced, had tissues of higher nutritional quality, which theoretically makes them more susceptible to pest organisms such as shoot-feeding aphids and root-feeding nematodes. Reduction of rare microbes increased aphid body size in the absence of nematodes; nematodes always reduced aphid body size independent of the soil microbial community. This study is the first to show that rare soil microbes are not redundant but may play a role in crop protection by enhancing aboveground and belowground plant defence. It remains to be tested whether these are direct effects of rare soil microbes on plants and herbivores, or indirect effects via shifts in the microbial soil community assemblages.

Holland, J. (2004). "The environmental consequences of adopting conservation tillage in Europe: reviewing the evidence." Agriculture, Ecosystems & Environment **103**(1): 1-25.

Category: Agriculture-induced impacts

Keywords: *Soil, pesticides, integrated farming, pollution, water, Europe, soil nutrients/cycling*

Abstract: Conservation tillage (CT) is practised on 45 million ha world-wide, predominantly in North and South America but its uptake is also increasing in South Africa, Australia and other semi-arid areas of the world. It is primarily used as a means to protect soils from erosion and compaction, to conserve moisture and reduce production costs. In Europe, the area cultivated using minimum tillage is increasing primarily in an effort to reduce production costs, but also as a way of preventing soil erosion and retain soil moisture. A large proportion (16%) of Europe's cultivated land is also prone to soil degradation but farmers and governments are being slow to recognise and address the problem, despite the widespread environmental problems that can occur when soils become degraded. Conservation tillage can improve soil structure and stability thereby facilitating better drainage and water holding capacity that reduces the extremes of water logging and drought. These improvements to soil structure also reduce the risk of runoff and pollution of surface waters with sediment, pesticides and nutrients. Reducing the intensity of soil cultivation lowers energy consumption and the emission of carbon dioxide, while carbon sequestration is raised though the increase in soil organic matter (SOM). Under conservation tillage, a richer soil biota develops that can improve nutrient recycling and this may also help combat crop pests and diseases. The greater availability of crop residues and weed seeds improves food supplies for insects, birds and small mammals. All these aspects are reviewed but detailed information on the environmental benefits of conservation tillage is sparse and disparate from European studies. No detailed studies have been conducted at the catchment scale in Europe, therefore some findings must be treated with caution until they can be verified at a larger scale and for a greater range of climatic, cropping and soil conditions.

Holmes, T., J. Bergstrom, E. Huszar, S. Kask and F. Orr Iii (2004). "Contingent valuation, net marginal benefits, and the scale of riparian ecosystem restoration." Ecological Economics **49**(1): 19-30.

Category: Farmer and societal benefits

Keywords: *Riparian restoration, contingent valuation, super-additivity, complements in valuation*

Abstract: A study was undertaken to estimate the benefits and costs of riparian restoration projects along the Little Tennessee River in western North Carolina. Restoration benefits were described in terms of five indicators of ecosystem services: abundance of game fish, water clarity, wildlife habitat, allowable water uses, and ecosystem naturalness. A sequence of dichotomous choice contingent valuation questions were presented to local residents to assess household willingness to pay increased county sales taxes for differing amounts of riparian restoration. Results showed that the benefits of ecosystem restoration were a non-linear function of restoration scale and the benefits of full restoration were super-additive. We estimated the costs of riparian restoration activities by collecting and analyzing data from 35 projects in the study area. After adjusting our estimated

valuation function for socio-economic characteristics of the local population, the benefit/cost ratio for riparian restoration ranged from 4.03 (for 2 miles of restoration) to 15.65 (for 6 miles of restoration). Riparian restoration in this watershed is therefore an economically feasible investment of public funds at all measured spatial scales.

Holtkamp, R., A. van der Wal, P. Kardol, W. van der Putten, P. de Ruiter and S. Dekker (2011). "Modelling C and N mineralisation in soil food webs during secondary succession on ex-arable land." Soil Biology and Biochemistry **43**(2): 251-260.

Category: Ecosystem services

Keywords: *Food web model, trophic levels, energy channels, direct and indirect effects, land use change, soil nutrients/cycling*

Abstract: The rate of secondary succession after land abandonment depends on the interplay between aboveground and belowground processes. Changes in vegetation composition lead to altered amounts and composition of soil organic matter (SOM) with consequences for the abundance and functioning of the soil food web. In turn, soil food web structure determines the mineralisation rate of nutrients that can be taken up by plants. This study analyses changes in the C and N mineralisation rates along with soil food web structure during secondary succession after land abandonment.

In a previous study, changes in soil food web structure and SOM quantity and quality were measured at different stages of secondary succession on abandoned arable fields (abandoned for 2, 9 and 22 years and a heathland, which is the assumed target of the secondary succession). Based on these measurements we expected the C and N mineralisation rates to increase during secondary succession. The key hypothesis is that with a description of the soil food webs in terms of quantified biomasses, natural death rates, energy conversion efficiencies and diets enables a calculation of C and N mineralisation rates in soils. The basic assumptions connected to this hypothesis are that on a time-scale of years the population sizes are in steady state. We also calculated mineralisation rates per trophic level and energy channel. Based on the same measurements we expected that the contributions by the lower trophic level groups will increase as well as the mineralisation rates by bacterial and fungal energy channels.

Measured C and N mineralisation indeed increased during the 22-year period of abandonment. The calculated C and N mineralisation rates showed the same trend after land abandonment as the measured values.

Calculated contributions to mineralisation of organisms at trophic level 1 increase during secondary succession following land abandonment. The fungal decomposition channel contributed more to N mineralisation than the bacterial decomposition channel, whereas both channels contributed equally to C mineralisation rates. Direct contributions by higher trophic levels to mineralisation decreased during secondary succession. However, higher trophic levels were direct important for N mineralisation and indirect for both C and N mineralisation due to their effect on biomass turnover rates of groups at lower trophic levels.

The increasing total N mineralisation rate of the soil food web, however, does not benefit plants, as during succession plant species that mainly grow under high

nutrient availability are replaced by species that can grow in nutrient poor condition.

Holzschuh, A., C. Dormann, T. Tscharntke and I. Steffan-Dewenter (2011). "Expansion of mass-flowering crops leads to transient pollinator dilution and reduced wild plant pollination." Proceedings of the Royal Society B: Biological Sciences **278**(1723): 3444-3451.
Category: Agriculture-induced impacts
Keywords: *Canola, competition, facilitation, oilseed rape, pollination, spill-over*

Abstract: Agricultural land use results in direct biodiversity decline through loss of natural habitat, but may also cause indirect cross-habitat effects on conservation areas. We conducted three landscape-scale field studies on 67 sites to test the hypothesis that mass flowering of oilseed rape (Brassica napus) results in a transient dilution of bees in crop fields, and in increased competition between crop plants and grassland plants for pollinators. Abundances of bumble-bees, which are the main pollinators of the grassland plant Primula veris, but also pollinate oilseed rape (OSR), decreased with increasing amount of OSR. This landscape-scale dilution affected bumble-bee abundances strongly in OSR fields and marginally in grass- lands, where bumble-bee abundances were generally low at the time of Primula flowering. Seed set of Primula veris, which flowers during OSR bloom, was reduced by 20 per cent when the amount of OSR within 1 km radius increased from 0 to 15 per cent. Hence, the current expansion of bee-attractive biofuel crops results in transient dilution of crop pollinators, which means an increased competition for pollinators between crops and wild plants. In conclusion, mass-flowering crops potentially threaten fitness of concurrently flowering wild plants in conservation areas, despite the fact that, in the long run, mass-flowering crops can enhance abundances of generalist pollinators and their pollination service.

Holzschuh, A., I. Steffan-Dewenter, D. Kleijn and T. Tscharntke (2007). "Diversity of flower-visiting bees in cereal fields: effects of farming system, landscape composition and regional context." Journal of applied ecology **44**(1): 41-49.
Category: Agriculture-induced impacts
Keywords: *Agri-environment schemes, biodiversity, flowering plants, landscape structure, organic farming, pollination, spatial scales, weeds, winter wheat*

Summary

1. Agri-environment schemes promote organic farming in an attempt to reduce the negative effects of agricultural intensification on farmland biodiversity and ecosystem services such as pollination. Farming system, landscape context and regional differences may all influence biodiversity, but their relative impact and possible interactions have been little explored.

2. The study was performed in three regions (150 km apart, 400–500 km2 per region) differing in land use intensity. Within each region, seven pairs of conventionally and organically cultivated wheat fields (mean size 4 ha, 42 study fields) were selected to encompass a gradient from heterogeneous to homogeneous landscapes within a 1-km radius around each field.

3. Farming system had the greatest influence on biodiversity. Higher bee diversity, flower cover and diversity of flowering plants were recorded in organic compared

with conventional fields. Bee diversity was related both to flower cover and diversity of flowering plants, suggesting plant-mediated effects of the farming system.
4. Differences in bee diversity between organic and conventional fields increased with the proportion of arable crops in the surrounding landscape, indicating that processes at the landscape level modified the effectiveness of organic farming in promoting biodiversity. Similar patterns for flower cover and diversity of flowering plants suggested that landscape effects on bee diversity were mainly resource-mediated. After statistically removing the variance explained by flower parameters, residual bee diversity increased with increasing landscape heterogeneity.
5. Bee diversity differed between the three regions, but the effects of farming systems and landscape context were independent of regional differences.
6. Synthesis and applications. Bee diversity in wheat fields was mainly influenced by farming system, but an understanding of local bee diversity needs to incorporate both landscape and regional perspectives. The consistency of the results in three regions provides a reliable basis for management decisions. Agri-environment schemes that promote organic farming in homogeneous landscapes where there are few remaining flower-rich habitats could have the highest relative impact. However, while organic farming could help to sustain pollination services by generalist bees in agricultural landscapes, other measures are required to conserve more specialized bee species in semi-natural habitats.

Holzschuh, A., I. Steffan-Dewenter and T. Tscharntke (2008). "Agricultural landscapes with organic crops support higher pollinator diversity." Oikos **117**(3): 354-361.

Category: Agriculture-induced impacts; Agroecology and agroecological practices; Ecosystem services

Keywords: *Interspecific relation, breeding site, animal plant relation, rural landscape, weed, feeding, flower, nesting site, foraging behavior, habitat, solitary bee, density, species richness, fallow, ecological abundance, flowering, diversity, pollinator, pollination*

Abstract: Pollinators are traditionally thought to perceive non-flowering crop fields as hostile landscape matrix. In this study, we show that landscapes composed of higher proportions of organic crop fields support more bee species at greater abundances in fallow strips. An increase in organic cropping in the surrounding landscape from 5% to 20% enhanced bee species richness in fallow strips by 50%, density of solitary bees by 60% and bumble bee density by 150%. Bee species richness and bumble bee density responded strongest to organic cropping in landscape sectors with 500 m radius, solitary bee density in landscape sectors with 250 m radius. The most likely source of these results is that crop and noncrop habitats are strongly connected via bee foraging at the landscape scale. It seems likely that bees depending on nesting sites in fallow strips benefited from the more abundant flower resources provided by broadleaved weeds in organic crop fields. We conclude that the incorporation of organic crop fields into conventionally managed agricultural landscapes can provide food resources needed to sustain greater pollinator species richness in noncrop habitats.

Holzschuh, A., I. Steffan-Dewenter and T. Tscharntke (2009). "Grass strip corridors in

agricultural landscapes enhance nest-site colonization by solitary wasps." Ecological applications **19**(1): 123-132.

Category: Agriculture-induced impacts

Keywords: *Cereal fields, connectivity, dispersal, fallow strips, field margins, forest edges, habitat fragmentation, hedges, natural enemies, parasitoids, predators, trap nests, pest regulation*

Abstract: Corridors that connect otherwise isolated habitats have often been proposed as a management strategy to mitigate negative effects of habitat fragmentation. Non-crop corridors may have the potential to enhance the connectivity for arthropod predators in cropland landscapes, especially for species that require multiple habitats, such as cavity- nesting wasps which use wooded habitat for nesting and grassland habitat for foraging. However, the effects of corridors in nonexperimental landscapes have been rarely examined. We studied the species richness and abundance of cavity-nesting wasps and their parasitoids in standardized trap nests located in three habitat types (forest edge, hedge, grass strip) and in three grass-strip types (connected to a forest edge, slightly isolated, highly isolated from a forest edge).

Species richness and the abundance of wasps (Hymenoptera: Sphecidae, Eumenidae, Pompilidae) were highest at forest edges, which provide natural nesting sites, and lowest in grass strips, with few natural nesting sites. Wasp abundance in grass strips connected to forest edges was 270% higher than in slightly isolated grass strips and 600% higher than in highly isolated grass strips. The abundance of caterpillar-hunting eumenid wasps was 600% higher in connected grass strips than in slightly and highly isolated grass strips. Species richness of wasps was enhanced by 180% in connected grass strips compared to highly isolated grass strips. Parasitism rates were not directly influenced by habitat or grass-strip type, but increased with increasing parasitoid diversity that was higher at forest edges than in grass strips.

We conclude that grass-strip corridors enhance the colonization of nesting sites, presumably by facilitating wasp movements. In agricultural landscapes, where nesting sites are limited and food availability changes frequently, rapid colonization of nests may enhance population viability. Higher wasp abundance in connected nesting sites may be directly linked to higher biocontrol of pest caterpillars within the foraging range around nests. Although grass strips can reduce the negative effects of habitat fragmentation, non-crop habitats such as forest habitats and hedges providing nesting sites are required within the home range of wasps to allow reproduction in agricultural landscapes.

Holzschuh, A., I. Steffan-Dewenter and T. Tscharntke (2010). "How do landscape composition and configuration, organic farming and fallow strips affect the diversity of bees, wasps and their parasitoids?" Journal of Animal Ecology **79**(2): 491-500.

Category: Agriculture-induced impacts

Keywords: *Agri-environment schemes, field margins, pollinators, predators, trophic interactions*

Summary

1. Habitat destruction and increasing land use intensity result in habitat loss, fragmentation and degradation, and subsequently in the loss of species diversity.

The fact that these factors are often highly confounded makes disentangling their effects extremely difficult, if not impossible, and their relative impact on species loss is mostly speculative.

2. In a two-year study, we analysed the relative importance of changed landscape composition (increased areas of cropped habitats), reduced habitat connectivity and reduced habitat quality on nest colonization of cavity-nesting bees, wasps and their parasitoids. We selected 23 pairs of conventional and organic wheat fields in the centre of landscape circles (500 m radius) differing in edge densities (landscape configuration) and % non-crop habitats (landscape composition). Standardized trap nests were established in the field centres and in neighbouring permanent fallow strips (making a total of 92 nesting sites).

3. Factors at all three scales affected nest colonization. While bees were enhanced by high proportions of non-crop habitat in the landscape, wasps profited from high edge densities, supporting our hypothesis that wasps are enhanced by connecting corridors. Colonization of herbivore-predating wasps was lower in field centres than in fallow strips for conventional sites, but not for organic sites, indicating a fallow-like connectivity value of organic fields. The relative importance of habitat type and farming system varied among functional groups suggesting that their perception of crop–non-crop boundaries or the availability of their food resources differed.

4. Local and landscape effects on parasitoids were mainly mediated by their hosts. Parasitism rates were marginally affected by local factors. A specialist parasitoid was more sensitive to high land use intensity than its host, whereas generalist parasitoids were less sensitive.

5. We conclude that the conversion of cropland into non-crop habitat may not be a sufficiently successful strategy to enhance wasps or other species that suffer more from isolation than from habitat loss. Interestingly, habitat connectivity appeared to be enhanced by both higher edge densities and by organic field management. Thus, we conclude that high proportions of conventionally managed and large crop fields threaten pollination and biological control services at a landscape scale.

Hooper, D. U., F. S. Chapin, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, D. M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setala, A. J. Symstad, J. Vandermeer and D. A. Wardle (2005). "Effects of biodiversity on ecosystem functioning: a consensus of current knowledge." Ecological Monographs **75**(1): 3-35.

Category: Ecosystem services

Keywords: *Biodiversity, complementary resource use, ecosystem goods and services, ecosystem processes, ecosystem properties, functional characteristics, functional diversity, net primary production, sampling effect, species extinction, species invasions, species richness, stability*

Abstract: Humans are altering the composition of biological communities through a variety of activities that increase rates of species invasions and species extinctions, at all scales, from local to global. These changes in components of the Earth's biodiversity cause concern for ethical and aesthetic reasons, but they also have a strong potential to alter ecosystem properties and the goods and services they provide to humanity. Ecological experiments, observations, and theoretical developments show that ecosystem properties depend greatly on biodiversity in

terms of the functional characteristics of organisms present in the ecosystem and the distribution and abundance of those organisms over space and time. Species effects act in concert with the effects of climate, resource availability, and disturbance regimes in influencing ecosystem properties. Human activities can modify all of the above factors; here we focus on modification of these biotic controls.

The scientific community has come to a broad consensus on many aspects of the relationship between biodiversity and ecosystem functioning, including many points relevant to management of ecosystems. Further progress will require integration of knowledge about biotic and abiotic controls on ecosystem properties, how ecological communities are structured, and the forces driving species extinctions and invasions. To strengthen links to policy and management, we also need to integrate our ecological knowledge with understanding of the social and economic constraints of potential management practices. Understanding this complexity, while taking strong steps to minimize current losses of species, is necessary for responsible management of Earth's ecosystems and the diverse biota they contain.

Based on our review of the scientific literature, we are certain of the following conclusions:

1) Species' functional characteristics strongly influence ecosystem properties. Functional characteristics operate in a variety of contexts, including effects of dominant species, keystone species, ecological engineers, and interactions among species (e.g., competition, facilitation, mutualism, disease, and predation). Relative abundance alone is not always a good predictor of the ecosystem-level importance of a species, as even relatively rare species (e.g., a keystone predator) can strongly influence pathways of energy and material flows.

2) Alteration of biota in ecosystems via species invasions and extinctions caused by human activities has altered ecosystem goods and services in many well-documented cases. Many of these changes are difficult, expensive, or impossible to reverse or fix with technological solutions.

3) The effects of species loss or changes in composition, and the mechanisms by which the effects manifest themselves, can differ among ecosystem properties, ecosystem types, and pathways of potential community change.

4) Some ecosystem properties are initially insensitive to species loss because (a) ecosystems may have multiple species that carry out similar functional roles, (b) some species may contribute relatively little to ecosystem properties, or (c) properties may be primarily controlled by abiotic environmental conditions.

5) More species are needed to insure a stable supply of ecosystem goods and services as spatial and temporal variability increases, which typically occurs as longer time periods and larger areas are considered.

We have high confidence in the following conclusions:

1) Certain combinations of species are complementary in their patterns of resource use and can increase average rates of productivity and nutrient retention. At the same time, environmental conditions can influence the importance of complementarity in structuring communities. Identification of which and how many species act in a complementary way in complex communities is just beginning.

2) Susceptibility to invasion by exotic species is strongly influenced by species composition and, under similar environmental conditions, generally decreases with

increasing species richness. However, several other factors, such as propagule pressure, disturbance regime, and resource availability also strongly influence invasion success and often override effects of species richness in comparisons across different sites or ecosystems.

3) Having a range of species that respond differently to different environmental perturbations can stabilize ecosystem process rates in response to disturbances and variation in abiotic conditions. Using practices that maintain a diversity of organisms of different functional effect and functional response types will help preserve a range of management options.

Uncertainties remain and further research is necessary in the following areas:

1) Further resolution of the relationships among taxonomic diversity, functional diversity, and community structure is important for identifying mechanisms of biodiversity effects.

2) Multiple trophic levels are common to ecosystems but have been understudied in biodiversity/ecosystem functioning research. The response of ecosystem properties to varying composition and diversity of consumer organisms is much more complex than responses seen in experiments that vary only the diversity of primary producers.

3) Theoretical work on stability has outpaced experimental work, especially field research. We need long-term experiments to be able to assess temporal stability, as well as experimental perturbations to assess response to and recovery from a variety of disturbances. Design and analysis of such experiments must account for several factors that covary with species diversity.

4) Because biodiversity both responds to and influences ecosystem properties, understanding the feedbacks involved is necessary to integrate results from experimental communities with patterns seen at broader scales. Likely patterns of extinction and invasion need to be linked to different drivers of global change, the forces that structure communities, and controls on ecosystem properties for the development of effective management and conservation strategies.

5) This paper focuses primarily on terrestrial systems, with some coverage of freshwater systems, because that is where most empirical and theoretical study has focused. While the fundamental principles described here should apply to marine systems, further study of that realm is necessary.

Despite some uncertainties about the mechanisms and circumstances under which diversity influences ecosystem properties, incorporating diversity effects into policy and management is essential, especially in making decisions involving large temporal and spatial scales. Sacrificing those aspects of ecosystems that are difficult or impossible to reconstruct, such as diversity, simply because we are not yet certain about the extent and mechanisms by which they affect ecosystem properties, will restrict future management options even further. It is incumbent upon ecologists to communicate this need, and the values that can derive from such a perspective, to those charged with economic and policy decision-making.

Hovestadt, T., B. Binzenhöfer, P. Nowicki and J. Settele (2011). "Do all inter-patch movements represent dispersal? A mixed kernel study of butterfly mobility in fragmented landscapes." Journal of Animal Ecology **80**(5): 1070-1077.

Category: Ecosystem services

Keywords: *dispersal kernel, immigration, long-distance dispersal, Maculinea nausithous, negative exponential function, routine movements, wild diversity*

Summary

1. In times of ongoing habitat fragmentation, the persistence of many species is determined by their dispersal abilities. Consequently, understanding the rules underlying movement between habitat patches is a key issue in conservation ecology.

2. We have analysed mark-release-recapture (MRR) data on inter-patches movements of the Dusky Large Blue butterfly Maculinea nausithous in a fragmented landscape in northern Bavaria, Germany. The aim of the analysis was to quantify distance dependence of dispersal as well as to evaluate the effect of target patch area on immigration probability. For statistical evaluation, we apply a 'reduced version' of the virtual migration model (VM), only fitting parameters for dispersal distance and immigration. In contrast to other analyses, we fit a mixed dispersal kernel to the MRR data.

3. A large fraction of recaptures happened in other habitat patches than those where individuals were initially caught. Further, we found significant evidence for the presence of a mixed dispersal kernel. The results indicate that individuals follow different strategies in their movements. Most movements are performed over small distances, nonetheless involving travelling between nearby habitat patches (median distance c. 480 m). A small fraction (c. 0·025) of the population has a tendency to move over larger distances (median distance c. 3800 m). Further, immigration was positively affected by patch area ($I \sim A\zeta$), with the scaling parameter $\zeta = 0{\cdot}5$.

4. Our findings should help to resolve the long-lasting dispute over the suitability of the negative exponential function vs. inverse-power one for modelling dispersal. Previous studies on various organisms found that the former typically gives better overall fit to empirical distance distributions, but that the latter better represents long-distance movement probabilities. As long-distance movements are more important for landscape-level effects and thus, e.g. for conservation-oriented analyses like PVAs, fitting inverse-power kernels has often been preferred.

5. We conclude that the above discrepancy may simply stem from the fact that recorded inter-patch movements are an outcome of two different processes: daily routine movements and genuine dispersal. Consequently, applying mixed dispersal kernels to disentangle the two processes is recommended.

Hubert, B., M. Rosegrant, M. A. J. S. van Boekel and R. Ortiz (2010). "The Future of Food: Scenarios for 2050." Crop Sci. **50**(Supplement_1): S-33-S-50.

Category: Policy

Keywords: *Food security, food safety, food quality, future scenarios, food systems, ecological intensification*

Abstract: This background article addresses key challenges of adequately feeding a population of 9 billion by 2050, while preserving the agro-ecosystems from which other services are also expected. One of the scenario-buildings uses the Agrimonde platform, which considers the following steps: choosing the scenarios and their underlying building principles, developing quantitative scenarios, and building

complete scenarios by combining quantitative scenarios with qualitative hypotheses. These scenarios consider how food issues link to production, for example, the percentage of animal vs. vegetal calorie intake in the full diet. The first section of this article discusses Agrimonde GO and Agrimonde 1 scenarios, which indicate that global economic growth and ecological intensification remain as main challenges for feeding the earth's growing population toward the mid-21st century. The second section provides the outcomes of the analysis of alternative futures for agricultural supply and demand and food security to 2050, based on research done for the International Assessment of Agricultural Science and Technology for Development. The last section of this article provides a summary analysis of food systems and functions, as well as the role of food technology that address some of the global challenges affecting the supply of more nutritious and healthy diets. It also highlights the food production by novel means (e.g., alternatives for animal products based on plant materials) and increasing the presence of potentially health-promoting compounds in food to improve human and animal health. Finally, this article proposes priority areas that should be included in further agri-food research.

Hunt, H., D. Coleman, E. Ingham, R. Ingham, E. Elliott, J. Moore, S. Rose, C. Reid and C. Morley (1987). "The detrital food web in a shortgrass prairie." Biology and Fertility of Soils **3**(1-2): 57-68.

Category: Ecosystem services

Keywords: *Detrital food web, microbes, mineralization, soil fauna, soil, belowground biodiversity, soil nutrients/cycling*

Abstract: Several experimental approaches have been taken to demonstrate the importance of soil fauna in nitrogen mineralization, but there have been difficulties interpreting the results. We have supplemented the experimental approach with theoretical calculations of nitrogen transformations in a shortgrass prairie. The calculations incorporate a wide array of information on decomposer organisms, including their feeding preferences, nitrogen contents, life spans, assimilation efficiencies, productio:assimilation ratios, decomposabilities, and population sizes. The results are estimates of nitrogen transfer rates through the detrital food web, including rates of N mineralization by bacteria, fungi, root-feeding nematodes, collembolans, fungal-feeding mites, fungal-feeding nematodes, flagellates, bacterial-feeding nematodes, amoebae, omnivorous nematodes, predaceous nematodes, nematode-feeding mites, and predaceous mites.

Bacteria are estimated to mineralize the most N (4.5 g N m−2 year−1), followed by the fauna (2.9), and fungi (0.3). Bacterial-feeding amoebae and nematodes together account for over 83% of N mineralization by the fauna.

The detrital food web in a shortgrass prairie is similar to that of a desert grassland. The shortgrass detrital web seems to be divided into bacteria- and fungus-based components, although these two branches are united at the level of predaceous nematodes and mites.

IAASTD (2009). Agriculture at a Crossroad: The Global Report, International Assessment of Agricultural Science and Technology for Development.

Category: Policy; Agriculture-induced impacts

Keywords: *Sustainability indicators, AKST Systems, agriculture, development, policy, knowledge, economy, technology*

Abstract: The IAASTD was a four-year collaborative effort, begun in 2004, that assessed our capacity to meet development and sustainability goals of reducing hunger and poverty, improving nutrition, health, and rural livelihoods, and facilitating social and environmental sustainability. Governed by a multi-stakeholder bureau comprising representatives from government and from civil society, the process brought together the whole range of actors ranging from governments to experts, NGOs, the private sector, producers, consumers, the scientific community, etc. In addition to assessing existing conditions and knowledge, the IAASTD used a simple set of model projections to look at the future, based on knowledge from past events and existing trends such as population growth, rural/urban food and poverty dynamics, loss of agricultural land, water availability, and climate change effects.

The IAASTD is crucial in the history of agricultural science assessments in that it assesses both formal science and technology, and local and traditional knowledge; addresses not only production and productivity but also the multifunctionality of agriculture; and recognizes that multiple perspectives exist regarding the role and nature of AKST. It was also unique in the sense that it was a capacity-development process, enabling the participants to get practice in undertaking assessments, a process different from writing scientific publications or reviews.

Isbell, F., V. Calcagno, A. Hector, J. Connolly, W. Harpole, P. Reich, M. Scherer-Lorenzen, B. Schmid, D. Tilman and J. van Ruijven (2011). "High plant diversity is needed to maintain ecosystem services." Nature **477**(7363): 199-202.

Category: Ecosystem services

Keywords: *Ecosystem services, ecosystem functioning, vegetation, species diversity, wild biodiversity*

Abstract: Biodiversity is rapidly declining worldwide1, and there is consensus that this can decrease ecosystem functioning and services2–7. It remains unclear, though, whether few8 or many9 of the species in an ecosystem are needed to sustain the provisioning of ecosystem services. It has been hypothesized that most species would promote ecosystem services if many times, places, functions and environmental changes were considered9; however, no previous study has considered all of these factors together. Here we show that 84% of the 147 grassland plant species studied in 17 biodiversity experi- ments promoted ecosystem functioning at least once. Different species promoted ecosystem functioning during different years, at different places, for different functions and under different environmental change scenarios. Furthermore, the species needed to provide one function during multiple years were not the same as those needed to provide multiple functions within one year. Our results indicate that even more species will be needed to maintain ecosystem functioning and services than previously suggested by studies that have either (1) considered only the number of species needed to promote one function under one set of environmental conditions, or (2) separately considered the importance of bio- diversity for providing ecosystem functioning across multiple years10–14, places15,16, functions14,17,18 or environmental change

scenarios12,19–22. Therefore, although species may appear functionally redundant when one function is considered under one set of environmental conditions7, many species are needed to maintain multiple functions at multiple times and places in a changing world.

Jackson, D. L. and L. Jackson (2002). The farm as natural habitat: reconnecting food systems with ecosystems, Island Press.

Category: Ecosystem services; Agroecology and agroecological practices

Keywords: *Sustainable agriculture, sustainable food, ecological restoration, biodiversity, agroecology*

From Amazon.com: The Farm as Natural Habitat is a vital new contribution to the debate about agriculture and its impacts on the land. Arising from the conviction that the agricultural landscape as a whole could be restored to a healthy diversity, the book challenges the notion that the dominant agricultural landscape - bereft of its original vegetation and wildlife and despoiled by chemical runoff - is inevitable if we are to feed ourselves. Contributors bring together insights and practices from the fields of conservation biology, sustainable agriculture, and environmental restoration to link agriculture and biodiversity, farming and nature, in celebrating a unique alternative to conventlonal agriculture. Rejecting the idea that "ecological sacrifice zones" are a necessary part of feeding a hungry world, the book offers compelling examples of an alternative agriculture that can produce not only healthful food, but fully functioning ecosystems and abundant populations of native species. Contributors include Collin Bode, George Boody, Brian DeVore, Arthur (Tex) Hawkins, Buddy Huffaker, Rhonda Janke, Richard Jefferson, Nick Jordan, Cheryl Miller, Heather Robertson, Carol Shennan, Judith Soule, Beth Waterhouse, and others. The Farm as Natural Habitat is both hopeful and visionary, grounded in real examples, and guided by a commitment to healthy land and thriving communities. It is the first book to offer a viable approach to addressing the challenges of protecting and restoring blodiversity on private agricultural land and is essential reading for anyone concerned with issues of land or blodiversity conservation, farming and agriculture, ecological restoration, or the health of rural communities and landscapes.

Jackson, W. (2002). "Natural systems agriculture: a truly radical alternative." Agriculture, Ecosystems & Environment **88**(2): 111-117.

Category: Agroecology and agroecological practices

Keywords: *Agriculture, sustainable, polyculture, nature*

Abstract: The natural systems agriculture (NSA) idea was developed at The Land Institute in 1977 and was published in 1978. Less than 20 years later, research efforts at The Land Institute and by other researchers familiar with research questions had satisfactorily answered the difficult biological questions launching the possibility of a new agricultural paradigm toward fruition. This new paradigm features an ecologically sound perennial food-grain-producing system where soil erosion goes to near zero, chemical contamination from agrochemicals plummets, along with agriculture's dependence on fossil fuels. NSA is predicated on an

evolutionary-ecological view of the world in which the essentials for sustainable living have been sorted out and tested in nature's ecosystems over millions of years. From numerous studies, evolutionary biologists and ecologists have learned much about how ecological bills are paid by ecosystems which hold and build soil, manage insects, pathogens and weeds. A primary feature of NSA is to sufficiently mimic the natural structure to be granted the function of its components. Domesticating wild perennials and increasing seed yield and at the same time perennializing the major crops to be planted as domestic prairies is a major goal. For the first time in 10,000 years, humans can now build an agriculture based on nature's ecosystems. As a prototype this means we explore in-depth how the never-plowed native prairie works and then develop a diverse, perennial vegetative structure capable of producing desirable edible grains in abundance including perennializing the major grain crops. A paradigm shift of relatively easily manageable proportions is available to solve the problem of agriculture and is antithetical to solving problems in agriculture.

Jarvis, D. I., T. Hodgkin, B. R. Sthapit, C. Fadda and I. Lopez-Noriega (2011). "An Heuristic Framework for Identifying Multiple Ways of Supporting the Conservation and Use of Traditional Crop Varieties within the Agricultural Production System." Critical Reviews in Plant Sciences **30**(1-2): 125-176.

Category: Ecosystem services

Keywords: *Adaptability, agroecosystem resilience, collective action, biodiversity, community management, farmer selection, genetic diversity, incentives, local institutions, participatory breeding, seed systems*

Abstract: This paper reviews and discusses how studies on (i) on-farm diversity assessment, (ii) access to diversity and information, (iii) extent of use of available materials and information, and (iv) benefits obtained by the farmer or farming community from their use of local crop diversity, are necessary to identify the different ways of supporting farmers and farming communities in the maintenance of traditional varieties and crop genetic diversity within their production systems. Throughout this paper two key themes are emphasized. First, any description or analysis within the four main areas (assessment, access, use and benefit) can, and most probably will, lead to a number of different actions. Second, the decision to implement a particular action, and therefore its success, will depend on farmers and the farming community having the knowledge and leadership capacity to evaluate the benefits that this action will have for them. This in turn emphasizes the importance of activities (whether by local, national and international organizations and agencies) of strengthening local institutions so as to enable farmers to take a greater role in the management of their resources.

Jax, K. (2010). Ecosystem functioning, Cambridge University Press.

Category: Ecosystem services

Keywords: *Ecosystem functioning, biodiversity, science, society, ecological restoration*

Abstract: In the face of decreasing biodiversity and ongoing global changes, maintaining ecosystem functioning is seen both as a means to preserve biological

diversity and for safeguarding human well-being by securing the services ecosystems provide. The concept today is prominent in many fields of ecology and conservation biology, such as biodiversity research, ecosystem management or restoration ecology. Although the idea of ecosystem functioning is important, the concept itself remains rather vague and elusive. This book provides a novel analysis and integrated synthesis of different approaches to conceptualising and assessing ecosystem functioning. It links the natural sciences with methodologies from philosophy and the social sciences, and introduces a new methodology for a clearer and more efficient application of ecosystem functioning concepts in practice. Special emphasis is laid on the social dimensions of the concept and on the ways in which these influence research practice. Several case studies relate theoretical analyses to practical application.

Jeffery, S., C. Gardi, A. Jones, L. Montanarella, L. Marmo, L. Miko, K. Ritz, G. Peres, J. Rombke and W. Van der Putten (2010). European atlas of soil biodiversity, European Commission. Publications Office of the European Union.

Category: Ecosystem services

Keywords: *Soil biology, soil fauna, distribution, europe, protection, climatic change, plant diseases, soil biodiversity, soil ecology, soil nutrients/cycling*

Preface: Fertile soil is vital for human survival. An estimated 99% of the world's food comes from the terrestrial environment - crops are grown in soil and livestock maintained on it. Soils have a real role in shaping our planet. They can absorb rainwater and act as a buffer against both floods and droughts. Soils also hold more than twice the amount of carbon than is currently contained in the atmosphere. However, most people are unaware that the key drivers of soil ecosystems that control fertility and terrestrial global nutrient cycles are the quantity and quality of living organisms within the soil.

Our knowledge of this habitat is limited. Many of the essential bacteria and fungi are minute, and therefore difficult to visualise. Large-scale investigations are also hampered by accessibility and the inherent variability of soil across the landscape. Therefore, understanding the highly complex and dynamic interactions which occur in life below ground remains one of the most formidable challenges facing scientists if we wish to assess environmental and global change processes and explore possible mitigation strategies.

Growing pressures from an ever increasing global population, as well as threats such as climate change and soil erosion, are placing increasing stresses on the ability of soil to sustain its important role in the planet's survival. Evidence suggests that while increased use of mono-cultures and intensive agriculture has led to a decline in soil biodiversity in some areas, the precise consequences of this loss are not always clear.

The United Nations has declared 2010 to be the International Year of Biodiversity and, for the first time, the biodiversity of soil is in the spotlight. For this reason, we are pleased that an international group of experts and scientists from the Joint Research Centre (JRC), in close collaboration with colleagues from DG Environment, have produced the first ever "European Atlas of Soil Biodiversity". This innovative atlas is a step towards raising awareness on the key role of life within the soil in

maintaining life on Earth. The atlas represents a major contribution to the new EU target of halting the loss of biodiversity and ecosystem services in the EU by 2020, and insofar as possible, restoring them.

Given that at least a quarter of the Earth's biodiversity can be found in the soil, and in order to achieve our own biodiversity target and substantiate our support for the Convention on Biological Diversity, we must protect soil biodiversity. As an integral part of its Soil Thematic Strategy, the European Commission has proposed a Soil Framework Directive in an attempt to prevent further soil degradation across the European Union, and to repair the damage that has already been done. This is a growing problem, and unless we tackle it soon and in a coordinated manner, it will cost a lot more to put it right.

We believe that this impressive publication will become a widely-used text and it marks a crucial step towards a better understanding of the role of life below ground. We are also convinced that it will highlight the need for improving the protection of soil and the diverse life within it.

Jenkins, W., B. Murray, R. Kramer and S. Faulkner (2010). "Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley." Ecological Economics **69**(5): 1051-1061.

Category: Ecosystem services; Farmer and societal benefits

Keywords: *Ecosystem service, economic valuation, Wetlands Reserve Program, ecosystem markets, social value, market value, watershed ecosystem services*

Abstract: This study assesses the value of restoring forested wetlands via the U.S. government's Wetlands Reserve Program (WRP) in the Mississippi Alluvial Valley by quantifying and monetizing ecosystem services. The three focal services are greenhouse gas (GHG) mitigation, nitrogen mitigation, and waterfowl recreation. Site- and region-level measurements of these ecosystem services are combined with process models to quantify their production on agricultural land, which serves as the baseline, and on restored wetlands. We adjust and transform these measures into per-hectare, valuation-ready units and monetize them with prices from emerging ecosystem markets and the environmental economics literature. By valuing three of the many ecosystem services produced, we generate lower bound estimates for the total ecosystem value of the wetlands restoration. Social welfare value is found to be between $1435 and $1486/ha/year, with GHG mitigation valued in the range of $171 to $222, nitrogen mitigation at $1248, and waterfowl recreation at $16. Limited to existing markets, the estimate for annual market value is merely $70/ha, but when fully accounting for potential markets, this estimate rises to $1035/ha. The estimated social value surpasses the public expenditure or social cost of wetlands restoration in only 1 year, indicating that the return on public investment is very attractive for the WRP. Moreover, the potential market value is substantially greater than landowner opportunity costs, showing that payments to private landowners to restore wetlands could also be profitable for individual landowners.

Johnson, D., P. Vandenkoornhuyse, J. Leake, L. Gilbert, R. Booth, J. Grime, J. Young and D. Read (2004). "Plant communities affect arbuscular mycorrhizal fungal diversity and

community composition in grassland microcosms." New Phytologist **161**(2): 503-515.
Category: Ecosystem services
Keywords: *Terminal restriction fragment length polymorphism (T-RFLP), arbuscular mycorrhiza (AM), plant functional type, diversity, shoot phosphorus, shoot nitrogen, soil nutrients/cycling*

Summary

The diversity of arbuscular mycorrhizal (AM) fungi was investigated in an unfertilized limestone grassland soil supporting different synthesized vascular plant assemblages that had developed for 3 yr.

The experimental treatments comprised: bare soil; monocultures of the nonmycotrophic sedge Carex flacca; monocultures of the mycotrophic grass Festuca ovina; and a species-rich mixture of four forbs, four grasses and four sedges. The diversity of AM fungi was analysed in roots of Plantago lanceolata bioassay seedlings using terminal-restriction fragment length polymorphism (T-RFLP). The extent of AM colonization, shoot biomass and nitrogen and phosphorus concentrations were also measured.

The AM diversity was affected significantly by the floristic composition of the microcosms and shoot phosphorus concentration was positively correlated with AM diversity. The diversity of AM fungi in P. lanceolata decreased in the order: bare soil > C. flacca > 12 species > F. ovina.

The unexpectedly high diversity in the bare soil and sedge monoculture likely reflects differences in the modes of colonization and sources of inoculum in these treatments compared with the assemblages containing established AM-compatible plants.

Jonsen, I. and L. Fahrig (1997). "Response of generalist and specialist insect herbivores to landscape spatial structure." Landscape Ecology **12**(3): 185-197.
Category: Agriculture-induced impacts
Keywords: *Alfalfa, diversity, farmland, habitat patch, arthropods, isolation, landscape pattern, leafhoppers, scale, weevils, pest regulation*

Abstract: The purpose of this study was to investigate the effect of changes in landscape pattern on generalist and specialist insects. We did this by comparing the species richness and abundance of generalist and specialist herbivorous insects in alfalfa (Medicago sativa, L.) fields on 26 agricultural landscapes that differed in spatial structure. The insects were from the families Curculionidae (Coleoptera), weevils, and Cicadellidae (Auchennorhyncha), leafhoppers. We hypothesized that: (1) generalist richness and abundance would be highest in landscapes with high diversity (Shannon-Wiener); (2) specialist richness and abundance would behighest in landscapes with (i) high percent cover alfalfa and (ii) low mean inter-patch distance. We tested for these effects after controlling for the patch-level effects of field size, field age, frequency of disturbance and vegetation texture. The important findings of the study are: (1) generalist richness and abundance increased with increasing landscape diversity and (2) isolation (percent cover alfalfa in the landscape and/or mean inter-patch distance) does not affect specialist insects. These results are significant because they indicate that both generalist and specialist insects may move over much larger distances than previously thought. This is one of

the first studies to demonstrate a large scale effect of spatial structure on insects across a broad range of landscapes.

Jonsson, M., S. Wratten, D. A. Landis and G. Gurr (2008). "Recent advances in conservation biological control of arthropods by arthropods." Biological Control **45**(2): 172-175.

Category: Ecosystem services

Keywords: *Chemical ecology, economic assessment, ecosystem services, food sprays, grower adoption, habitat manipulation, honeydew, landscape management, natural enemy diversity, resource subsidies, shelter, pest regulation*

Abstract: Conservation biological control (CBC) aims at improving the efficacy of natural enemies and can contribute to safer and more effective biological control practices. Considerable progress in this field has been made during recent years, and it is therefore justified to review key findings in a special issue of Biological Control. The following topics, with primary emphasis on CBC of arthropods by arthropods are covered in this issue: (1) honeydew as a food source for natural enemies, (2) artificial food sprays, (3) shelter habitats, (4) chemical ecology and CBC, (5) natural enemy diversity and CBC, (6) CBC at a landscape scale, (7) CBC as provider of multiple ecosystem services, and (8) economics and adoption of CBC. These reviews present substantial evidence that CBC can attract and/or improve the fitness of natural enemies. However, studies showing that this translates into decreased pest damage, increased crop yield or quality and improved economic profit for growers are still rare. We conclude that future researchers should investigate the effect of CBC at these levels, but also that we need a better understanding of which conditions CBC will reduce pest populations in the field. CBC has the potential to increase ecosystem services other than biological control and consideration of the economic benefits of this will increase the likelihood of adoption of CBC.

Jonsson, M., S. Wratten, D. A. Landis, J.-M. Tompkins and R. Cullen (2010). "Habitat manipulation to mitigate the impacts of invasive arthropod pests." Biological Invasions **12**(9): 2933-2945.

Category: Ecosystem services

Keywords: *Conservation biological control, ecosystem services, habitat management, pest management, pest regulation*

Abstract: Exotic invaders are some of the most serious insect pests of agricultural crops around the globe. Increasingly, the structure of landscape and habitat is recognized as having a major influence on both insect pests and their natural enemies. Habitat manipulation that aims at conserving natural enemies can potentially contribute to safer and more effective control of invasive pests. In this paper, we review habitat management experiments, published during the last 10 years, which have aimed to improve biological control of invasive pests. We then discuss during what conditions habitat management to conserve natural enemies is likely to be effective and how the likelihood of success of such methods can be improved. We finally suggest an ecologically driven research agenda for habitat management programmes.

Jonsson, M., S. Wratten, K. Robinson and S. Sam (2009). "The impact of floral resources and omnivory on a four trophic level food web." Bulletin of Entomological Research **99**(03): 275-285.

Category: Ecosystem services

Keywords: *Food web complexity, omnivory, floral resources, biological control, fourth trophic level, pest regulation*

Abstract: Omnivory is common among arthropods, but little is known about how availability of plant resources and prey affects interactions between species operating at the third and fourth trophic level. We used laboratory and field cage experiments to investigate how the provision of flowers affects an omnivorous lacewing, Micromus tasmaniae (Hemerobiidae) and its parasitoid Anacharis zealandica (Figitidae). The adult lacewing is a true omnivore that feeds on both floral resources and aphids, whereas the parasitoid is a life-history omnivore, feeding on lacewing larvae in the larval stage and floral nectar as an adult. We showed that the effect of floral resources (buckwheat) on lacewing oviposition depends on prey (aphid) density, having a positive effect only at low prey density and that buckwheat substantially increases the longevity of the adult parasitoid. In field cages, we tested how provision of flowering buckwheat affects the dynamics of a four trophic level system, comprising parasitoids, lacewings, pea aphids and alfalfa. We found that provision of buckwheat decreased the density of lacewings in the first phase of the experiment when the density of aphids was high. This effect was probably caused by increased rate of parasitism by the parasitoid, which benefits from the presence of buckwheat. Towards the end of the experiment when the aphid populations had declined to low levels, the effect of buckwheat on lacewing density became positive, probably because lacewings were starving in the no-buckwheat treatment. Although presence of buckwheat flowers did not affect aphid populations in the field cages, these findings highlight the need to consider multitrophic interactions when proposing provision of floral resources as a technique for sustainable pest management.

Jordan, N. and K. Warner (2013). Towards multifunctional agricultural landscapes for the upper Midwest Region of the USA. Ecosystem Services in Agricultural and Urban Landscapes, A John Wiley & Sons**:** 137-156.

Category: Agroecology and agroecological practices

Keywords: *Agroecological partnerships, Koda Energy fuelshed project, multifunctional agriculture (MFA), theory of change, Upper Midwest*

Abstract: This chapter proposes an integrative and heuristic strategy — a 'theory of change' — to address interlocking challenges of climate change and sustainable management of agriculture and bioresources. It aims to increase the multifunctionality of agriculture in the Upper Midwest region of the USA by pursuing change at three distinct levels of integration. The chapter first describes the central system level, which addresses development of new economic opportunities and related systems of management and policy, for farmers of multifunctional agroecosystems. Next, it portrays a pivotal subsystem of the enterprise development model, agroecological partnerships, that produce knowledge needed for

multifunctional agriculture (MFA). Third, the chapter describes how social values shape the supersystem of public opinion and policy. The chapter finally presents a case study — the Koda Energy Fuelshed project — which outlines the challenges in realizing the potential of MFA.

Jose, S. (2009). "Agroforestry for ecosystem services and environmental benefits: an overview." Agroforestry Systems **76**(1): 1-10.
Category: Agroecology and agroecological practices
Keywords: *Biodiversity conservation, carbon sequestration, clean air, clean water, multifunctional working landscape, soil enrichment, soil nutrients/cycling*

Abstract: Agroforestry systems are believed to provide a number of ecosystem services; however, until recently evidence in the agroforestry literature supporting these perceived benefits has been lacking. This special issue brings together a series of papers from around the globe to address recent findings on the ecosystem services and environmental benefits provided by agroforestry. As prelude to the special issue, this paper examines four major ecosystem services and environmental benefits of agroforestry: (1) carbon sequestration, (2) biodiversity conservation, (3) soil enrichment and (4) air and water quality. Past and present evidence clearly indicates that agroforestry, as part of a multifunctional working landscape, can be a viable land-use option that, in addition to alleviating poverty, offers a number of ecosystem services and environmental benefits. This realization should help promote agroforestry and its role as an integral part of a multifunctional working landscape the world over.

Kabir, Z. and R. Koide (2002). "Effect of autumn and winter mycorrhizal cover crops on soil properties, nutrient uptake and yield of sweet corn in Pennsylvania, USA." Plant and Soil **238**(2): 205-215.
Category: Agroecology and agroecological practices
Keywords: *External hyphae, oats (Avena sativa L.), P uptake, rye (Secale cereale L.), soil aggregate stability, vesicular-arbuscular mycorrhiza, soil nutrients/cycling*

Abstract: We investigated the effects of an autumn sowing of contrasting cover crops (oats, rye and a combination of oats and rye) on soil aggregate stability, mycorrhizal colonization, phosphorus uptake and yield of sweet corn planted the following summer. Rye is a common cover crop in the middle Atlantic region of the United States of America. It grows slowly in the autumn, survives the winter, grows rapidly in the spring and flowers in the summer. Thus, herbicide is commonly used to kill rye prior to planting spring crops. Oats, in contrast, grows rapidly in the autumn but is killed by frost during the winter. Thus, with oats, potentially less herbicide is needed to prepare the field for spring planting. When compared to fallow, oats was as effective as rye in increasing mycorrhizal colonization of sweet corn, density of mycorrhizal hyphae, and soil aggregate stability. An oats cover crop may thus be a viable alternative to rye. The combination of cover crops (rye and oats), however, was significantly better than single species of cover crops in terms of sweet corn mycorrhizal colonization, P uptake and yield of sweet corn.

Karlen, D., G. Varvel, D. Bullock, R. Cruse and L. Donald (1994). Crop rotations for the 21st Century. Advances in agronomy, Academic Press. **Volume 53:** 1-45.
Category: Agroecology and agroecological practices
Keywords: *Rotational cropping, soil chemico-physical properties*

Abstract: The practice of crop rotation or sequentially growing a sequence of plant species on the same land has been in existence for thousands of years. The chapter discusses three phases of crop rotations—that is, pre-world war II, post-world war II developments, and 21st century outlook. Agronomic impacts of crop rotation—for example, crop yield, water use efficiency, nutrient use efficiency, and disease and pest interactions are explained in the chapter. Critical factors in most soil quality assessments include measurements of soil structure, aggregation, bulk density, water infiltration, water retention, soil erosivity, and organic matter. All of these factors are influenced by crop selection and rotation. It is logical to examine the effects of crop rotations on the various soil quality indicators to assess the need to re-emphasize rotations in 21st century farming systems. Crop rotation affects soil organic matter in several ways. Factors affecting it include rotation length, losses caused by tillage operations, mineralization, and interaction with fertilization practices. Crop spatial arrangements effectively add another dimension, or opportunity, to rotation management in developing environmentally sound and highly productive cropping systems. Crop rotation has an impact on the returns associated with alternative tillage systems, and responses will be different on different soils and in different regions. Farm policy influences profitability of crop rotation through five processes: deficiency payments, acreage reduction, base-acreage levels, crop prices, and risk reduction. Public policies that influence land use decisions—such as crop rotation—need to be as flexible as possible to encourage adoption of practices that are economically viable, environmentally sustainable, and socially acceptable.

Kedziora, A. (2010). "Landscape management practices for maintenance and enhancement of ecosystem services in a countryside." Ecohydrology & Hydrobiology **10**(2-4): 133-152.
Category: Ecosystem services; Agroecology and agroecological practices
Keywords: *Shelterbelts, landscape structure, water resources, biodiversity, ecosystem services*

Abstract: The paper presents a review of research on functioning of agricultural landscape, mainly on protection of ecosystem services, carried out by the Institute for Agricultural and Forest Environment, Polish Academy of Sciences in Turew in the period of 1970–2009. The paper concentrates on water balance and water pollution control and the protection of biodiversity in an agricultural landscape. The results of the researches show that the best way for maintenance ecosystem services is development of landscape complexity. Introduction of non-productive elements like shelterbelts, strips of meadows, small ponds allows for improvement of water balance, reduction of groundwater pollution even by 90% and enhancement of biodiversity.

Keene, M. and A. Pullin (2011). "Realizing an effectiveness revolution in environmental management." Journal of Environmental Management **92**(9): 2130-2135.

Category: Policy

Keywords: *Program evaluation, adaptive management, systematic review, performance measurement, policy effectiveness, collaboration, transparency and accountability, information sharing*

Abstract: The environmental movement of the 20th century has evolved into a large, diverse and well-financed global community that is increasingly required to prove its worth. Though the environmental sector collects and uses data to determine the status of ecological and social systems, the effectiveness of the programs and policies it uses to affect this status remains largely untested. As governments and donor institutions insist on greater transparency, accountability and evidence of what works and what does not, much is being learned from other fields (e.g. health services, education, international development) and increasingly sophisticated approaches are emerging to manage effectiveness. For example, program evaluation, adaptive management, and systematic review provide frameworks and methods to collect and use information to measure and improve performance. However, the critical data and collaborations necessary for an effectiveness revolution are marginalized by technical, cultural and political obstacles. Learning from other fields, the environmental sector must exploit key leverage points, such as flows of information and self-organization, to overcome impediments and create incentives to initiate and realize an era of effectiveness in environmental management.

Kelemen, E., G. Nguyen, T. Gomiero, E. Kovacs, J.-P. Choisis, N. Choisis, M. Paoletti, L. Podmaniczky, J. Ryschawy, J.-P. Sarthou, F. Herzog, P. Dennis and K. Balazs (2013). "Farmers´ perceptions of biodiversity: Lessons from a discourse-based deliberative valuation study." Land Use Policy **35**(0): 318-328.

Category: Farmer and societal benefits

Keywords: *Biodiversity, discourse-based deliberative valuation, focus group, organic farming, conventional farming*

Abstract: In agricultural landscapes farmers have a large impact on biodiversity through the management decisions they apply to their land. Farmers' perceptions of biodiversity and its different values influence their willingness to apply biodiversity friendly farming practices. The results of a discourse-based, deliberative biodiversity valuation are presented in this paper. Organic and conventional farmers' perceptions of the different values of biodiversity were analyzed across three European countries. Focus group methodology was used to explore how farmers perceive biodiversity and how they assess its values.

Our results suggest that farmers' perceptions of biodiversity are strongly embedded in their everyday lives and linked to farming practices. Besides recognizing the importance of species and habitat diversity, farmers also acknowledge wider landscape processes and attach value to the complexity of ecological systems. Organic farmers tended to have a more complex and philosophical approach to biodiversity and they were relatively homogeneous in this aspect, while conventional farmers showed larger heterogeneity. Ethical and social values were important for all

farmers. Economic value was more dominant in the conventional focus groups.

The discourse based deliberative valuation method is worth applying in relation to biodiversity for two reasons. First, this method is able to reflect the heterogeneity of non-scientist participants and the context in which they are embedded, which both have a great impact on the results of the valuation. Second, deliberation upon the importance of biodiversity makes possible to understand the competing perceptions of biodiversity and to include different value aspects in the valuation process. The policy oriented consequence of the research can be drawn from the observation that farmers have a strong acknowledgement of ethical and social biodiversity values. This suggests that soft policy tools could also foster biodiversity sensitive farming methods, complementary to mainstream monetary incentives.

Kenmore, P., C. Stannard and P. Thompson (2004). The ethics of sustainable agricultural intensification. Rome, FAO.

Category: Policy; Ecosystem services

Keywords: *Agricultural intensification, ethics, crop production*

First two paragraphs: Over the 10 000 years since the Neolithic Age, human population growth has been correlated with intensification in food production systems, primarily agriculture, which has also greatly modified the world's ecosystems, for better or for worse. Given the present and anticipated increases in world population, not to mention current and projected environmental problems and ecological stress from agriculture, further agricultural intensification will be needed. What ethical issues have been (or might have been) raised in connection with past episodes of agricultural intensification? Who can make a difference in directing the course of future intensification, and what ethical responsibilities do these potential actors bear?

Any answer to these questions will be complex. It will involve sophisticated analyses of the historical and natural processes that have influenced and continue to influence episodes of agricultural intensification. It will also involve an account of the social, economic and psychological underpinnings of both individual and collective action, and this account will need to be woven into detailed factual analyses of the land, climatic and genetic endowments in specific places. The focus in this ethics paper is just one element of the problem: the way that ethical concepts and terms can be used to articulate the normative dimension – what ought to be the case with respect to human purpose and conduct whenever episodes of intensification occur. Although several examples from the history of intensification are discussed, the paper does not attempt to provide an exhaustive or representative survey of ethical issues that have been raised in connection with intensification. Neither does it offer a general or universally applicable answer to any of the questions above, much less to the comprehensive question, "What ought to be done with respect to intensification?" Instead, the focus is on building capacity for debate and analysis of these ethical questions, with the expectation that specific answers will be the result of more focused inquiries conducted by people with more proximate access to and knowledge of circumstances that are relevant to specific cases.

Kennedy, C., E. Lonsdorf, M. Neel, N. Williams, T. Ricketts, R. Winfree, R. Bommarco, C. Brittain, A. Burley, D. Cariveau, L. Carvalheiro, N. Chacoff, S. Cunningham, B. Danforth, J.-H. Dudenhöffer, E. Elle, H. Gaines, L. Garibaldi, C. Gratton, A. Holzschuh, R. Isaacs, S. Javorek, S. Jha, A. Klein, K. Krewenka, Y. Mandelik, M. Mayfield, L. Morandin, L. Neame, M. Otieno, M. Park, S. Potts, M. Rundlöf, A. Saez, I. Steffan-Dewenter, H. Taki, B. Viana, C. Westphal, J. Wilson, S. Greenleaf and C. Kremen (2013). "A global quantitative synthesis of local and landscape effects on wild bee pollinators in agroecosystems." Ecology Letters **16**(5): 584-599.

Category: Ecosystem services

Keywords: *Agri-environment schemes, diversified farming system, ecologically scaled landscape index, ecosystem services, farm management, habitat fragmentation, landscape structure, organic farming, pollinators, pollination*

Abstract: Bees provide essential pollination services that are potentially affected both by local farm management and the surrounding landscape. To better understand these different factors, we modelled the relative effects of landscape composition (nesting and floral resources within foraging distances), landscape configuration (patch shape, interpatch connectivity and habitat aggregation) and farm management (organic vs. conventional and local-scale field diversity), and their interactions, on wild bee abundance and richness for 39 crop systems globally. Bee abundance and richness were higher in diversified and organic fields and in landscapes comprising more high-quality habitats; bee richness on conventional fields with low diversity benefited most from high-quality surrounding land cover. Landscape configuration effects were weak. Bee responses varied slightly by biome. Our synthesis reveals that pollinator persistence will depend on both the maintenance of high-quality habitats around farms and on local management practices that may offset impacts of intensive monoculture agriculture.

Kleijn, D. and A. Baldi (2005). "Effects of set-aside land on farmland biodiversity: comments on Van Buskirk and Willi." Conservation Biology **19**(3): 963-966.

Category: Agriculture-induced impacts

Keywords: *Effects, set-aside land, farmland biodiversity, Europe*

(commentary; thus no abstract)

Kleijn, D., F. Kohler, A. Baldi, P. Batary, E. Concepcion, Y. Clough, M. Diaz, D. Gabriel, A. Holzschuh, E. Knop, A. Kovacs, E. Marshall, T. Tscharntke and J. Verhulst (2009). "On the relationship between farmland biodiversity and land-use intensity in Europe." Proceedings of the Royal Society B: Biological Sciences **276**(1658): 903-909.

Category: Agriculture-induced impacts

Keywords: *Agriculture, conservation ecology, farmland wildlife, fertilizer, plant species richness, policy implications, ecosystem services, Europe*

Abstract: Worldwide agriculture is one of the main drivers of biodiversity decline. Effective conservation strategies depend on the type of relationship between biodiversity and land-use intensity, but to date the shape of this relationship is unknown. We linked plant species richness with nitrogen (N) input as an indicator of land- use intensity on 130 grasslands and 141 arable fields in six European countries.

Using Poisson regression, we found that plant species richness was significantly negatively related to N input on both field types after the effects of confounding environmental factors had been accounted for. Subsequent analyses showed that exponentially declining relationships provided a better fit than linear or unimodal relationships and that this was largely the result of the response of rare species (relative cover less than 1%). Our results indicate that conservation benefits are disproportionally more costly on high-intensity than on low- intensity farmland. For example, reducing N inputs from 75 to 0 and 400 to 60 kg haK1 yrK1 resulted in about the same estimated species gain for arable plants. Conservation initiatives are most (cost-)effective if they are preferentially implemented in extensively farmed areas that still support high levels of biodiversity.

Kleijn, D., M. Rundlof, J. Scheper, H. G. Smith and T. Tscharntke (2011). "Does conservation on farmland contribute to halting the biodiversity decline?" Trends in ecology & evolution **26**(9): 474-481.

Category: Agriculture-induced impacts

Keywords: *Farmland, biodiversity, agroecosystem, conservation, wild biodiversity*

Abstract: Biodiversity continues to decline, despite the implementation of international conservation conventions and measures. To counteract biodiversity loss, it is pivotal to know how conservation actions affect biodiversity trends. Focussing on European farmland species, we review what is known about the impact of conservation initiatives on biodiversity. We argue that the effects of conservation are a function of conservation-induced ecological contrast, agricultural land-use intensity and landscape context. We find that, to date, only a few studies have linked local conservation effects to national biodiversity trends. It is therefore unknown how the extensive European agri-environmental budget for conservation on farmland contributes to the policy objectives to halt biodiversity decline. Based on this review, we identify new research directions addressing this important knowledge gap.

Klein, A., I. Steffan-Dewenter and T. Tscharntke (2003). "Fruit set of highland coffee increases with the diversity of pollinating bees." Proceedings of the Royal Society of London. Series B: Biological Sciences **270**(1518): 955-961.

Category: Ecosystem services

Keywords: *Pollinators, Coffea arabica, pollinator diversity, ecosystem functions, biodiversity, pollination*

Abstract: The worldwide decline of pollinators may negatively affect the fruit set of wild and cultivated plants. Here, we show that fruit set of the self–fertilizing highland coffee (Coffea arabica) is highly variable and related to bee pollination. In a comparison of 24 agroforestry systems in Indonesia, the fruit set of coffee could be predicted by the number of flower–visiting bee species, and it ranged from ca. 60% (three species) to 90% (20 species). Diversity, not abundance, explained variation in fruit set, so the collective role of a species–rich bee community was important for pollination success. Additional experiments showed that single flower visits from rare solitary species led to higher fruit set than with abundant social species.

Pollinator diversity was affected by two habitat parameters indicating guild–specific nesting requirements: the diversity of social bees decreased with forest distance, whereas the diversity of solitary bees increased with light intensity of the agroforestry systems. These results give empirical evidence for a positive relationship between ecosystem functions such as pollination and biodiversity. Conservation of rainforest adjacent to adequately managed agroforestry systems could improve the yields of farmers.

Klein, A.-M., B. Vaissiere, J. Cane, I. Steffan-Dewenter, S. Cunningham, C. Kremen and T. Tscharntke (2007). "Importance of pollinators in changing landscapes for world crops." Proceedings of the Royal Society B: Biological Sciences **274**(1608): 303-313.

Category: Ecosystem services

Keywords: *Pollination, crop production, agricultural intensification, crop diversity, wild bees, conservation, spatial ecology*

Abstract: The extent of our reliance on animal pollination for world crop production for human food has not previously been evaluated and the previous estimates for countries or continents have seldom used primary data. In this review, we expand the previous estimates using novel primary data from 200 countries and found that fruit, vegetable or seed production from 87 of the leading global food crops is dependent upon animal pollination, while 28 crops do not rely upon animal pollination. However, global production volumes give a contrasting perspective, since 60% of global production comes from crops that do not depend on animal pollination, 35% from crops that depend on pollinators, and 5% are unevaluated. Using all crops traded on the world market and setting aside crops that are solely passively self-pollinated, wind- pollinated or parthenocarpic, we then evaluated the level of dependence on animal-mediated pollination for crops that are directly consumed by humans. We found that pollinators are essential for 13 crops, production is highly pollinator dependent for 30, moderately for 27, slightly for 21, unimportant for 7, and is of unknown significance for the remaining 9. We further evaluated whether local and landscape-wide management for natural pollination services could help to sustain crop diversity and production. Case studies for nine crops on four continents revealed that agricultural intensification jeopardizes wild bee communities and their stabilizing effect on pollination services at the landscape scale.

Klemick, H. (2011). "Shifting cultivation, forest fallow, and externalities in ecosystem services: Evidence from the Eastern Amazon." Journal of Environmental Economics and Management **61**(1): 95-106.

Category: Agriculture-induced impacts

Keywords: Forest, farms, fallow, ecosystem services, land use, spatial econometrics, externalities, Brazil

Abstract: This study examines the value of fallow ecosystem services in shifting cultivation, including hydrological externalities that may affect other farms. Using farm-level survey data from the Brazilian Amazon, I estimate a production function to assess the value of forest fallow and test whether it provides local externalities to

agricultural production. Soil quality controls, instrumental variables, and spatial econometric approaches help address endogeneity issues. I use GIS data on external forest cover at the farm level and model the hydrological externality as an upstream-to-downstream process. The estimated parameters indicate that fallow contributes significantly to productivity both on farm and downstream. In addition, most farms allocate sufficient land to fallow, accounting for both the value of hydrological spillovers and the opportunity cost of land left out of cultivation. These results suggest that farming communities may have some self-interest in preserving forest cover locally—a finding that may bolster policy efforts aimed at conserving tropical forests for their global public goods.

Koellner, T. (2003). Land use in product life cycles and ecosystem quality, Peter Lang Publishing.

Category: Agriculture-induced impacts

Keywords: *Product life cycle, impact assessment, food products, agriculture, urban area, land use types, Corine, ecosystem damage, plant species diversity*

Abstract: Life Cycle Assessment (LCA) is widely used for environmental planning and decision-making. However, land use and its consequences for ecosystem quality still are not adequately taken into account in LCA. Land use is an economic activity that generates large benefits for human society. As a side effect it has caused many environmental problems such as endangerment of species, nutrification of lakes and rivers, loss of fertile soil, and impact on landscapes' aesthetics. All of these impacts put pressure on the regional ecosystem quality. This book focuses on biodiversity, which is conceptualised as an important part of ecosystem quality. A method for assessing land use impacts on biodiversity is developed and the general method is made operable using empirical information on species diversity. The developed set of characterisation factors EDPsp-div for different land use types can be easily integrated in damage oriented methods of Life Cycle Impact Assessment. A case study on food products shows the application of the method.

Koellner, T., L. Baan, T. Beck, M. Brandao, B. Civit, M. Goedkoop, M. Margni, L. Canals, R. Muller-Wenk, B. Weidema and B. Wittstock (2013). "Principles for life cycle inventories of land use on a global scale." The International Journal of Life Cycle Assessment **18**(6): 1203-1215.

Category: Agriculture-induced impacts; Ecosystem services

Keywords: *Global, land cover, Life Cycle Assessment, regionalization*

Purpose: To assess the diverse environmental impacts of land use, a standardization of quantifying land use elementary flows is needed in life cycle assessment (LCA). The purpose of this paper is to propose how to standardize the land use classification and how to regionalize land use elementary flows.

Materials and methods

In life cycle inventories, land occupation and transformation are elementary flows providing relevant information on the type and location of land use for land use impact assessment. To find a suitable land use classification system for LCA, existing global land cover classification systems and global approaches to define

biogeographical regions are reviewed.
Results and discussion
A new multi-level classification of land use is presented. It consists of four levels of detail ranging from very general global land cover classes to more refined categories and very specific categories indicating land use intensities. Regionalization is built on five levels, first distinguishing between terrestrial, freshwater, and marine biomes and further specifying climatic regions, specific biomes, ecoregions and finally indicating the exact geo-referenced information of land use. Current land use inventories and impact assessment methods do not always match and hinder a comprehensive assessment of land use impact. A standardized definition of land use types and geographic location helps to overcome this gap and provides the opportunity to test the optimal resolution of land cover types and regionalization for each impact pathway.
Conclusions and recommendation
The presented approach provides the necessary flexibility to providers of inventories and developers of impact assessment methods. To simplify inventories and impact assessment methods of land use, we need to find archetypical situations across impact pathways, land use types and regions, and aggregate inventory entries and methods accordingly.

Koellner, T., L. Baan, T. Beck, M. Brandao, B. Civit, M. Margni, L. Canals, R. Saad, D. Souza and R. Muller-Wenk (2013). "UNEP-SETAC guideline on global land use impact assessment on biodiversity and ecosystem services in LCA." The International Journal of Life Cycle Assessment **18**(6): 1188-1202.
Category: Ecosystem services
Keywords: *Biodiversity, ecological functions, ecosystem services, Life Cycle Assessment, land use*
Purpose: As a consequence of the multi-functionality of land, the impact assessment of land use in Life Cycle Impact Assessment requires the modelling of several impact pathways covering biodiversity and ecosystem services. To provide consistency amongst these separate impact pathways, general principles for their modelling are provided in this paper. These are refinements to the principles that have already been proposed in publications by the UNEP-SETAC Life Cycle Initiative. In particular, this paper addresses the calculation of land use interventions and land use impacts, the issue of impact reversibility, the spatial and temporal distribution of such impacts and the assessment of absolute or relative ecosystem quality changes. Based on this, we propose a guideline to build methods for land use impact assessment in Life Cycle Assessment (LCA).
Results
Recommendations are given for the development of new characterization models and for which a series of key elements should explicitly be stated, such as the modelled land use impact pathways, the land use/cover typology covered, the level of biogeographical differentiation used for the characterization factors, the reference land use situation used and if relative or absolute quality changes are used to calculate land use impacts. Moreover, for an application of the characterisation factors (CFs) in an LCA study, data collection should be transparent with respect to

the data input required from the land use inventory and the regeneration times. Indications on how generic CFs can be used for the background system as well as how spatial-based CFs can be calculated for the foreground system in a specific LCA study and how land use change is to be allocated should be detailed. Finally, it becomes necessary to justify the modelling period for which land use impacts of land transformation and occupation are calculated and how uncertainty is accounted for.

Discussion

The presented guideline is based on a number of assumptions: Discrete land use types are sufficient for an assessment of land use impacts; ecosystem quality remains constant over time of occupation; time and area of occupation are substitutable; transformation time is negligible; regeneration is linear and independent from land use history and landscape configuration; biodiversity and multiple ecosystem services are independent; the ecological impact is linearly increasing with the intervention; and there is no interaction between land use and other drivers such as climate change. These assumptions might influence the results of land use Life Cycle Impact Assessment and need to be critically reflected.

Conclusions and recommendations

In this and the other papers of the special issue, we presented the principles and recommendations for the calculation of land use impacts on biodiversity and ecosystem services on a global scale. In the framework of LCA, they are mainly used for the assessment of land use impacts in the background system. The main areas for further development are the link to regional ecological models running in the foreground system, relative weighting of the ecosystem services midpoints and indirect land use.

Koellner, T. and R. Geyer (2013). "Global land use impact assessment on biodiversity and ecosystem services in LCA." The International Journal of Life Cycle Assessment **18**(6): 1185-1187.

Category: Agriculture-induced impacts, Ecosystem services

Keywords: *Land use, biodiversity, ecosystem services*

First paragraph: Land use and land use change have severe effects on biodiversity and the capacity of ecosystems to deliver services, such as biomass production or water filtration. Whereas research on impacts of land use on biodiversity is a well-established field, research on ecosystem services motivated by Daily (1997) is less developed, but steadily catching up. The Millennium Ecosystem Assessment (2005) on ecosystem changes has begun to address this gap and has highlighted the importance of nature's services for human well-being. Meanwhile, operational assessment methods support decision-makers in planning and optimizing landscapes with respect to biodi- versity and multiple ecosystem services (Chan et al. 2006; Daily et al. 2009; Groot et al. 2010; Maes et al. 2012). However, until now, those methodologies have mainly focused on regional systems with distinct spatial boundaries. However, the ecological assessment of land use in product systems requires a global approach.

Koellner, T. and O. Schmitz (2006). "Biodiversity, ecosystem function, and investment risk." BioScience **56**(12): 977-985.

Category: Ecosystem services

Keywords: *Biodiversity, ecosystem services, productivity, resilience, investment risk*

Abstract: Biodiversity has the potential to influence ecological services. Management of ecological services thus includes investments in biodiversity, which can be viewed as a portfolio of genes, species, and ecosystems. As with all investments, it becomes critical to understand how risk varies with the diversity of the portfolio. The goal of this article is to develop a conceptual framework, based on portfolio theory, that links levels of biodiversity and ecosystem services in the context of risk-adjusted performance. We illustrate our concept with data from temperate grassland experiments conducted to examine the link between plant species diversity and biomass production or yield. These data suggest that increased plant species diversity has considerable insurance potential by providing higher levels of risk-adjusted yield of biomass. We close by discussing how to develop conservation strategies that actively manage biodiversity portfolios in ways that address performance risk, and suggest a new empirical research program to enhance progress in this field.

Koellner, T. and R. Scholz (2007). "Assessment of land use impacts on the natural environment. Part 1: An analytical framework for pure land occupation and land use change." The International Journal of Life Cycle Assessment **12**(1): 16-23.

Category: Agriculture-induced impacts

Keywords: *Restoration time, characterization factor, ecosystem, damage function, LCA, impact, land use*

Preamble: This series of two papers is based on a PhD thesis (Koellner 2003) and develops a method on how to assess land use impacts on biodiversity in the framework of LCA. Part 1 further expands the analytical framework of the thesis for pure land occupation and land use change. Part 2 rests on a much richer database compared to the thesis in order to quantify generic characterization factors for local species' richness.

Abstract Goal, Scope and Background. In the framework of LCA, land use is broadly accepted as an impact category. However, the methodology for the assessment of damages on the natural environment was and still is the subject of discussion. The main objective of this paper is to contribute to that discussion by providing a consistent methodological framework for the assessment of land occupation and transformation.

Methods

We clarify the context of LCA relevant land use decisions. Based on that, we develop a formal model with damage functions and generic characterization factors for quantifying damages on ecosystems from land occupation and land transformation. The characterization factor for land occupation and land use change is labeled Ecosystem Damage Potential (EDP). We analytically address the substitutability of area and time occupied in order to produce a constant output.

Results

Based on the proposed method, it is possible to calculate the damages from complex

series of land transformation, land occupation, and land restoration. A main feature of the method is that land transformation is assessed based on a factual or virtual, restoration time. This means that the damage of land transformation is largest for land use types which are difficult to restore and need extremely long to develop (e.g. thousand of years and more for primary forest and peatbog). In addition, we could show that area and time of occupation are not substitutable. The more severe the damage potential of a specific land use type is, the better it is to minimize the area and maximize the duration of occupation.

Discussion

An approach for the assessment of pure land occupation and land use change was developed in this paper, which is not geographically referenced. Developing geographically-referenced land use inventories and impact assessment methods can increase their accuracy. The information cost to provide geographically referenced data on land use for practical LCA applications, however, would increase enormously.

Conclusions

An impact assessment method for land use with generic characterization factors improves the basis for decision-making in industry and other organizations. It can best be applied to marginal land use decisions; that is, to decisions in which the consequences are so small that the quality or quantity of environmental parameters of a region is not noticeably altered.

Recommendations and Perspective

One main problem to address is the development of reliable generic characterization factors, which express the ecosystem damage potential of specific land use types. The characterization factors should be developed on an empirical basis, which allow decision makers to get access to knowledge from environmental sciences in a very condensed form. In order to support decisions on distinct land use projects, methods should be developed, which allow accomplishing a generic assessment with site-dependent assessments.

Koellner, T. and R. Scholz (2008). "Assessment of land use impacts on the natural environment. Part 2: Generic characterization factors for local species diversity in Central Europe." The International Journal of Life Cycle Assessment **13**(1): 32-48.

Category: Agriculture-induced impacts

Keywords: *Generic assessment, impacts, land use, LCA, species diversity*

Goal, Scope and Background

Land use is an economic activity that generates large benefits for human society. One side effect, however, is that it has caused many environmental problems throughout history and still does today. Biodiversity, in particular, has been negatively influenced by intensive agriculture, forestry and the increase in urban areas and infrastructure. Integrated assessment such as Life Cycle Assessment (LCA), thus, incorporate impacts on biodiversity. The main objective of this paper is to develop generic characterization factors for land use types using empirical information on species diversity from Central Europe, which can be used in the assessment method developed in the first part of this series of paper.

Methods

Based on an extensive meta-analysis, with information about species diversity on 5581 sample plots, we calculated characterization factors for 53 land use types and six intensity classes. The typology is based on the CORINE Plus classification. We took information on the standardized α-diversity of plants, moss and mollusks into account. In addition, threatened plants were considered. Linear and nonlinear models were used for the calculation of damage potentials (EDP S). In our approach, we use the current mean species number in the region as a reference, because this determines whether specific land use types hold more or less species diversity per area. The damage potential calculated here is endpoint oriented. The corresponding characterization factors EDP S can be used in the Life Cycle Impact Assessment as weighting factors for different types of land occupation and land use change as described in Part 1 of this paper series.

Results

The result from ranking the intensity classes based on the mean plant species number is as expected. High intensive forestry and agriculture exhibit the lowest species richness (5.7–5.8 plant species/m2), artificial surfaces, low intensity forestry and non-use have medium species richness (9.4–11.1 plant species/m2) and low-intensity agriculture has the highest species richness (16.6 plant species/m2). The mean and median are very close, indicating that the skewedness of the distribution is low. Standard error is low and is similar for all intensity classes. Linear transformations of the relative species numbers are linearly transformed into ecosystem damage potentials (EDP linear S). The integration of threatened plant species diversity into a more differentiated damage function EDPStotallinear makes it possible to differentiate between land use types that have similar total species numbers, but intensities of land use that are clearly different (e.g., artificial meadow and broad-leafed forest). Negative impact values indicate that land use types hold more species per m2 than the reference does. In terms of species diversity, these land use types are superior (e.g. near-to-nature meadow, hedgerows, agricultural fallow).

Discussion

Land use has severe impacts on the environment. The ecosystem damage potential EDP S is based on assessment of impacts of land use on species diversity. We clearly base EDP S factors on α-diversity, which correlates with the local aspect of species diversity of land use types. Based on an extensive meta-analysis of biologists' field research, we were able to include data on the diversity of plant species, threatened plant species, moss and mollusks in the EDP S. The integration of other animal species groups (e.g. insects, birds, mammals, amphibians) with their specific habitat preferences could change the characterization factors values specific for each land use type. Those mobile species groups support ecosystem functions, because they provide functional links between habitats in the landscape.

Conclusions

The use of generic characterization factors in Life Cycle Impact Assessment of land use, which we have developed, can improve the basis for decision-making in industry and other organizations. It can best be applied for marginal land use decisions. However, if the goal and scope of an LCA requires it this generic assessment can be complemented with a site-dependent assessment.

Recommendations and Perspectives

We recommend utilizing the developed characterization factors for land use in Central Europe and as a reference methodology for other regions. In order to assess the impacts of land use in other regions it would be necessary to sample empirical data on species diversity and to develop region specific characterization factors on a worldwide basis in LCA. This is because species diversity and the impact of land use on it can very much differ from region to region.

Koellner, T., J. Sell, M. Gahwiler and R. Scholz (2008). "Assessment of the management of organizations supplying ecosystem services from tropical forests." Global Environmental Change **18**(4): 746-757.

Category: Policy; Ecosystem services

Keywords: *Ecosystem services, Payments for ecosystem services (PES), tropical forests, management, assessment, balanced scorecard*

Abstract: Global environmental change leads to degradation of tropical forests in many countries. In response to this pressure, programs for payments for ecosystem services (PES) are developing and organizations are emerging which manage forests in order to supply ecosystem services, rather than only harvest timber. Typically such services are carbon sequestration, biodiversity conservation, pollination, and watershed protection. Public or private actors interested to invest in or donate money for the provisioning of such services are faced with the problem of choosing the appropriate organization supplying ecosystem services. The goal of this paper was to develop an assessment framework based on the balanced scorecard concept including drivers, impact, performance and context variables. Results of a survey of international market actors were used to determine assessment criteria and their weights. Putting the focus of this paper on drivers and impacts, we assessed Latin American organizations that “sell” ecosystem services from tropical forests in terms of their general management, marketing, forest management, client and stakeholder satisfaction, and forest ecosystem status. We found that supplying organizations vary widely with respect to their achievements in these areas. However, the variance of assessment results is influenced even more by the variance in weights the international market actors allocate to the assessment criteria. The insights of this study can contribute to the continuous improvement of management processes in supplying organizations and can support investors and donors in their decision-making with respect to organization supplying ecosystem services.

Koellner, T., J. Sell and G. Navarro (2010). "Why and how much are firms willing to invest in ecosystem services from tropical forests? A comparison of international and Costa Rican firms." Ecological Economics **69**(11): 2127-2139.

Category: Policy; Ecosystem services

Keywords: *Ecosystem services, tropical forests, business, Willingness to Invest WTI*

Abstract: In recent years, schemes for payment for ecosystem services PES have emerged in tropical countries. Besides public demand, the private demand offers the opportunity to develop PES. The goal of this paper is to investigate the potential demand by firms for four ecosystem services from tropical forests: biodiversity conservation, carbon sequestration, scenic beauty, and watershed protection. Those

are the four granted in the forest legislation and rewarded for in the PES scheme in Costa Rica. To explain stated willingness to invest WTI, we assess influential factors: expectations with respect to financial and non-financial benefits of investing in ecosystem services; experience with forest ecosystem services; firm attributes, like origin, sector membership, and size; and finally, perceived behavioral control. We sent a questionnaire to over 900 international and Costa Rican firms from different sectors. The low response rate of the survey of overall 6% can be explained by – in a business context – rather new topic of ecosystem services from tropical forests. The analysis showed that a firm's willingness to invest (WTI) depends on the origin of the firm. International firms are interested in buying certificates mainly for carbon sequestration; Costa Rican firms, for all four ecosystem services in the following order: watershed protection, biodiversity conservation, carbon sequestration, and scenic beauty. Indirect and non-financial benefits are surprisingly important and can impede the development of ecosystem service markets. At the same time, the activities of intrinsically motivated green entrepreneurs in a financially oriented firm setting might be a prerequisite within a firm context for bringing such innovative topics as ecosystem services from tropical forests to the table.

Korthals, G. W., P. Smilauer, C. Van Dijk and W. H. Van Der Putten (2001). "Linking above- and below-ground biodiversity: abundance and trophic complexity in soil as a response to experimental plant communities on abandoned arable land." Functional Ecology **15**(4): 506-514.

Category: Ecosystem services

Keywords: *Nematodes, old-field succession, restoration, set-aside, soil food web, soil, soil nutrients/cycling*

Abstract:

1. This study investigates the effects of experimental plant communities on different trophic levels in the soil food web of abandoned arable land.
2. In April 1996, a biodiversity experiment commenced using a continuation of agricultural crop rotation (CCR), spontaneous succession with naturally colonizing plant species (NC) and late-successional plant species sown in low-diversity (LD, four plant species) and high-diversity (HD, 15 plant species) communities. The nematode community was used as an indicator of the influence of the experimental plant communities on different trophic levels in the soil food web.
3. The nematode abundance in the experimental plant communities differed from that of the continued crop rotation, but there were hardly any differences between the natural, the low-diversity and the high-diversity plant communities.
4. Theabundant plant-feeding nematodes and the somewhat less abundant bacterivorous nematodes were stimulated most by the sowing treatments. Fungivorous nematodes were stimulated less, while the numbers of omnivorous and carnivorous nematodes did not change significantly.
5. The diversity of the nematode community did not change over 2 years.
6. It is concluded that experimental plant communities have either small short-term effects or a delayed impact on the soil food web compared with the effect they have on above-ground invertebrate community development.

Kovacs-Hostyanszki, A. and A. Baldi (2012). "Set-aside fields in agri-environment schemes can replace the market-driven abolishment of fallows." Biological Conservation **152**(0): 196-203.

Category: Ecosystem services; Policy

Keywords: *Agricultural policy, farmland bird, semi-natural grassland, vegetation structure, winter cereal*

Abstract: Economic pressures from increased commodity prices and the growing demand for land for biomass plantations led to the abolition of compulsory set-aside fields in the European Union in 2008, affecting ca. 10% of total agricultural area. This area is now managed more intensively, and this is expected to adversely affect farmland biodiversity. Unfortunately, no mitigation of set-aside loss was introduced. Here we examined, whether or not set-aside fields managed in voluntary agri-environment schemes have the potential to improve farmland bird populations, as indicators of farmland biodiversity. We chose one, two and three year-old set-aside fields sown by a grass–legume mixture when established and selected winter cereal fields and semi-natural grasslands in Hungary as control sites. Relative abundance of birds was assessed; species were assigned to feeding guilds and classified according to their European conservation status. Species richness of herbaceous plants, cover of bare ground and vegetation height were used as covariates. Set-aside fields had higher species richness and abundance of birds compared to the adjacent winter cereal fields, similar to semi-natural grasslands. We found a positive correlation between set-aside age and farmland bird species richness and abundance. This can be explained mainly by the altered vegetation, especially the shorter vegetation height from the second year in the set-aside fields. We found no difference in the distribution pattern of species richness and abundance between feeding guilds according to set-aside age and habitat types. The wide scale application of voluntary set-aside management in agri-environment programs therefore has a high potential to mitigate the negative effects from the loss of compulsory set-aside schemes, and thus need the allocation of considerable resources in the forthcoming reformed CAP.

Kovacs-Hostyanszki, A., P. Batary and A. Baldi (2011). "Local and landscape effects on bee communities of Hungarian winter cereal fields." Agricultural and Forest Entomology **13**(1): 59-66.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Apidae, body size, fertilizer, insecticide, pollination, semi-natural habitat, stability*

Abstract:

1. Pollination is a key ecosystem service. Although bees are the most important pollinators, they are endangered by intensive agricultural practices. The present study investigated the effects of farmland management and environmental factors at local and landscape scales on bees in Central Hungary.

2. Bees were sampled in winter cereal fields that varied in the amount of applied fertilizer and insecticide use. Measurements included total, small and large bee species richness and abundance; stability of total species richness and abundance (coefficient of variation, CV); the nitrogen content of fertilizers; the number of insecticide applications; within-field location; species richness and abundance of

insect-pollinated plants; and the percentage of semi-natural areas in a 500-m radius circle around the fields under study.

3. Increasing the amount of fertilizer decreased total and small bee abundance and increased the CV of total bee abundance. Insecticide use had a significant negative effect on total and small bee species richness and on large bee abundance. The percentage of semi-natural habitats in a 500-m radius did not influence bee species richness and abundance.

4. The results obtained confirms that the intensification of farmland management poses a threat to bee diversity, and thus may reduce pollination services. Recently-introduced agri-environment schemes are one potential approach for managing agricultural land use: reduced amounts of fertilizer and a cessation of insecticide application might lead to high bee species richness and abundance and ensure the pollination of wild plants and flowering crops.

Kovacs-Hostyanszki, A., Z. Elek, K. Balazs, C. Centeri, E. Falusi, P. Jeanneret, K. Penksza, L. Podmaniczky, O. Szalkovszki and A. Baldi (2013). "Earthworms, spiders and bees as indicators of habitat quality and management in a low-input farming region: A whole farm approach." Ecological Indicators **33**(0): 111-120.

Category: Ecosystem services

Keywords: *Extensive farming, farmland biodiversity grazing intensity, invertebrates, BIOBIO project, bees, earthworms, spiders, pollination, soil nutrients/cycling*

Abstract: The benefits of low input farming on biodiversity and ecosystem services are already well-established, however most of these studies focus only on the focal field scales. We aimed to study whether these benefits exist at the whole farm scale, to find the main environmental driving effects on biodiversity at the whole farm scale in farms of different grassland grazing intensity, applying three well-known species diversity indicator groups of different ecological traits.

Edaphic (earthworms), epigeic (spiders) and flying (bees) taxa were sampled in each identified habitat type within 18 low-input farms in Central Hungary, 2010. The number of habitat types, the number of grassland plots, the cumulative area of grasslands and habitat type had an effect on the species richness and abundance of spiders, while grassland grazing intensity influenced the species richness of bees. Both bees and spiders were sensitive to vegetation and weather conditions, resulting in more bees on flower-rich farms and those having higher temperature; and more spiders on farms with more heterogeneous vegetation structure and in low-wind areas. Relatively few earthworms were found in the whole study, and their abundance was not influenced by any of the farm composition and management variables.

We conclude that local field management (grazing intensity of grassland patches) can have a farm scale effect, detectable on species diversity indicators that have high dispersal ability and strong connection to grasslands as important foraging sites (bees). However, other farmland biota (spiders) is also strongly determined by farmland composition and habitat diversity, therefore the maintenance of a mosaic within-farm habitat structure is strongly recommended. The application of earthworms as farmland composition or management indicators is strongly restricted because of their special needs of soil conditions.

Kovacs-Hostyanszki, A., A. Korosi, K. Orci, P. Batary and A. Baldi (**2011**). "Set-aside promotes insect and plant diversity in a Central European country." Agriculture, Ecosystems & Environment **141**(3-4): 296-301.

Category: Ecosystem services

Keywords: *Agri-environment schemes, bee, butterfly, grassland, Hungary, Orthopteran, plant species richness, wheat field, wild biodiversity, pollination, pest regulation*

Abstract: The area of non-cropped habitats has been decreasing in Europe largely due to land conversion into cropland and energy crops. In Hungary, special agri-environment schemes in Environmentally Sensitive Areas require the establishment of sown set-aside fields especially for endangered bird species. We tested if these set-aside fields are beneficial for plants and insects of agricultural landscapes. We compared the herbaceous flora, grasshopper (Orthoptera), bee (Apidae) and butterfly (Rhopalocera) fauna of five field types (1, 2 and 3 year-old set-aside, winter cereal fields and semi-natural grasslands). Species richness, abundance and species composition of insects were tested against field type and plant species richness. The wheat fields were the poorest habitats for all taxa. The species richness and abundance of the studied insects were usually higher in set-aside than in cereal fields with no significant difference between set-aside of different age. We found the highest number of orthopteran species and butterfly individuals in semi-natural grasslands. At community level, field type and plant species richness had a significant effect on orthopteran assemblages. Butterfly assemblages were significantly affected by field type. Bee assemblages were not significantly related to the above variables. We can conclude that set-aside fields provide important habitat patches for plants and insects, in some cases with similar value to semi-natural grasslands. Our results emphasise the importance of set-aside within the Hungarian agri-environment scheme. Establishment of set-aside management in other Central European countries will likely to be of a similar value as the Hungarian set-aside fields.

Krauss, J., R. Bommarco, M. Guardiola, R. K. Heikkinen, A. Helm, M. Kuussaari, R. Lindborg, E. Öckinger, M. Pärtel, J. Pino, J. Pöyry, K. M. Raatikainen, A. Sang, C. Stefanescu, T. Teder, M. Zobel and I. Steffan-Dewenter (2010). "Habitat fragmentation causes immediate and time-delayed biodiversity loss at different trophic levels." Ecology Letters **13**(5): 597-605.

Category: Agriculture-induced impacts

Keywords: *Conservation, extinction cascades, extinction debt, grassland communities, habitat loss, habitat management, landscape change, relaxation time, species longevity*

Abstract: Intensification or abandonment of agricultural land use has led to a severe decline of semi-natural habitats across Europe. This can cause immediate loss of species but also time-delayed extinctions, known as the extinction debt. In a pan-European study of 147 fragmented grassland remnants, we found differences in the extinction debt of species from different trophic levels. Present-day species richness of long-lived vascular plant specialists was better explained by past than current landscape patterns, indicating an extinction debt. In contrast, short-lived butterfly specialists showed no evidence for an extinction debt at a time scale of c. 40 years.

Our results indicate that management strategies maintaining the status quo of fragmented habitats are insufficient, as time-delayed extinctions and associated co-extinctions will lead to further biodiversity loss in the future.

Krauss, J., I. Gallenberger and I. Steffan-Dewenter (2011). "Decreased functional diversity and biological pest control in conventional compared to organic crop fields." PloS one **6**(5): e19502.

Category: Ecosystem services

Keywords: *Pest control, diversity, pollinator diversity, vascular plants, organic farming system, conventional farming system, predator abundance, pest regulation*

Abstract: Organic farming is one of the most successful agri-environmental schemes, as humans benefit from high quality food, farmers from higher prices for their products and it often successfully protects biodiversity. However there is little knowledge if organic farming also increases ecosystem services like pest control. We assessed 30 triticale fields (15 organic vs. 15 conventional) and recorded vascular plants, pollinators, aphids and their predators. Further, five conventional fields which were treated with insecticides were compared with 10 non-treated conventional fields. Organic fields had five times higher plant species richness and about twenty times higher pollinator species richness compared to conventional fields. Abundance of pollinators was even more than one-hundred times higher on organic fields. In contrast, the abundance of cereal aphids was five times lower in organic fields, while predator abundances were three times higher and predator-prey ratios twenty times higher in organic fields, indicating a significantly higher potential for biological pest control in organic fields. Insecticide treatment in conventional fields had only a short-term effect on aphid densities while later in the season aphid abundances were even higher and predator abundances lower in treated compared to untreated conventional fields. Our data indicate that insecticide treatment kept aphid predators at low abundances throughout the season, thereby significantly reducing top-down control of aphid populations. Plant and pollinator species richness as well as predator abundances and predator-prey ratios were higher at field edges compared to field centres, highlighting the importance of field edges for ecosystem services. In conclusion organic farming increases biodiversity, including important functional groups like plants, pollinators and predators which enhance natural pest control. Preventative insecticide application in conventional fields has only short-term effects on aphid densities but long-term negative effects on biological pest control. Therefore conventional farmers should restrict insecticide applications to situations where thresholds for pest densities are reached.

Kremen, C. (2005). "Managing ecosystem services: what do we need to know about their ecology?" Ecology Letters **8**(5): 468-479.

Category: Climate change; Ecosystem services

Keywords: *Adaptive management, community structure, conservation planning, diversity–function, ecological economics, ecosystem function, functional structure, natural, resource management redundancy, resilience, policy*

Abstract: Human domination of the biosphere has greatly altered ecosystems, often overwhelming their capacity to provide ecosystem services critical to our survival. Yet ecological understanding of ecosystem services is quite limited. Previous work maps the supply and demand for services, assesses threats to them, and estimates economic values, but does not measure the underlying role of biodiversity in providing services. In contrast, experimental studies of biodiversity–function examine communities whose structures often differ markedly from those providing services in real landscapes. A bridge is needed between these two approaches. To develop this research agenda, I discuss critical questions and key approaches in four areas: (1) identifying the important 'ecosystem service providers'; (2) determining the various aspects of community structure that influence function in real landscapes, especially compensatory community responses that stabilize function, or non-random extinction sequences that rapidly erode it; (3) assessing key environmental factors influencing provision of services, and (4) measuring the spatio-temporal scale over which providers and services operate. I show how this research agenda can assist in developing environmental policy and natural resource management plans.

Kremen, C. and A. Miles (2012). "Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs." Ecology and Society **17**(4): 40.

Category: Ecosystem services

Keywords: *Agricultural food production, agricultural intensification, agrobiodiversity, agroecology, biodiversity, conventional agriculture, conventional farming systems, diversified farming systems, ecosystem services, land-sharing, landsparing, organic agriculture, sustainable agriculture, sustainable intensification*

Abstract: We hypothesize that biological diversification across ecological, spatial, and temporal scales maintains and regenerates the ecosystem services that provide critical inputs—such as maintenance of soil quality, nitrogen fixation, pollination, and pest control—to agriculture. Agrobiodiversity is sustained by diversified farming practices and it also supplies multiple ecosystem services to agriculture, thus reducing environmental externalities and the need for off-farm inputs. We reviewed the literature that compares biologically diversified farming systems with conventional farming systems, and we examined 12 ecosystem services: biodiversity; soil quality; nutrient management; water-holding capacity; control of weeds, diseases, and pests; pollination services; carbon sequestration; energy efficiency and reduction of warming potential; resistance and resilience to climate change; and crop productivity. We found that compared with conventional farming systems, diversified farming systems support substantially greater biodiversity, soil quality, carbon sequestration, and water-holding capacity in surface soils, energy-use efficiency, and resistance and resilience to climate change. Relative to conventional monocultures, diversified farming systems also enhance control of weeds, diseases, and arthropod pests and they increase pollination services; however, available evidence suggests that these practices may often be insufficient to control pests and diseases or provide sufficient pollination. Significantly less public funding has been applied to agroecological research and the improvement of diversified farming

systems than to conventional systems. Despite this lack of support, diversified farming systems have only somewhat reduced mean crop productivity relative to conventional farming systems, but they produce far fewer environmental and social harms. We recommend that more research and crop breeding be conducted to improve diversified farming systems and reduce yield gaps when they occur. Because single diversified farming system practices, such as crop rotation, influence multiple ecosystem services, such research should be holistic and integrated across many components of the farming system. Detailed agroecological research especially is needed to develop crop- and region-specific approaches to control of weeds, diseases, and pests.

Kremen, C., N. Williams, M. Aizen, B. Gemmill-Herren, G. LeBuhn, R. Minckley, L. Packer, S. Potts, T. Roulston, I. Steffan-Dewenter, D. P. Vázquez, R. Winfree, L. Adams, E. E. Crone, S. S. Greenleaf, T. H. Keitt, A.-M. Klein, J. Regetz and T. Ricketts (2007). "Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change." Ecology Letters **10**(4): 299-314.

Category: Ecosystem services

Keywords: *Conservation biology, ecosystem service, habitat loss, landscape ecology, mobile link, natural resource management, pollinator, pollination*

Abstract: Many ecosystem services are delivered by organisms that depend on habitats that are segregated spatially or temporally from the location where services are provided. Management of mobile organisms contributing to ecosystem services requires consideration not only of the local scale where services are delivered, but also the distribution of resources at the landscape scale, and the foraging ranges and dispersal movements of the mobile agents. We develop a conceptual model for exploring how one such mobile-agent-based ecosystem service (MABES), pollination, is affected by land-use change, and then generalize the model to other MABES. The model includes interactions and feedbacks among policies affecting land use, market forces and the biology of the organisms involved. Animal-mediated pollination contributes to the production of goods of value to humans such as crops; it also bolsters reproduction of wild plants on which other services or service-providing organisms depend. About one-third of crop production depends on animal pollinators, while 60–90% of plant species require an animal pollinator. The sensitivity of mobile organisms to ecological factors that operate across spatial scales makes the services provided by a given community of mobile agents highly contextual. Services vary, depending on the spatial and temporal distribution of resources surrounding the site, and on biotic interactions occurring locally, such as competition among pollinators for resources, and among plants for pollinators. The value of the resulting goods or services may feed back via market-based forces to influence land-use policies, which in turn influence land management practices that alter local habitat conditions and landscape structure. Developing conceptual models for MABES aids in identifying knowledge gaps, determining research priorities, and targeting interventions that can be applied in an adaptive management context.

Kremen, C., N. Williams, R. Bugg, J. Fay and R. Thorp (2004). "The area requirements of an ecosystem service: crop pollination by native bee communities in California." Ecology Letters **7**(11): 1109-1119.

Category: Ecosystem services

Keywords: *Agriculture, Apis mellifera, Apoidea, bee community, bee foraging distance, conservation planning, landscape ecology, pollination service, scale effects, pollination*

Abstract: Managing ecosystem services is critical to human survival, yet we do not know how large natural areas must be to support these services. We investigated how crop pollination services provided by native, unmanaged, bee communities varied on organic and conventional farms situated along a gradient of isolation from natural habitat. Pollination services from native bees were significantly, positively related to the proportion of upland natural habitat in the vicinity of farm sites, but not to any other factor studied, including farm type, insecticide usage, field size and honeybee abundance. The scale of this relationship matched bee foraging ranges. Stability and predictability of pollination services also increased with increasing natural habitat area. This strong relationship between natural habitat area and pollination services was robust over space and time, allowing prediction of the area needed to produce a given level of pollination services by wild bees within this landscape.

Ladygina, N., T. Johansson, B. Canbäck, A. Tunlid and K. Hedlund (2009). "Diversity of bacteria associated with grassland soil nematodes of different feeding groups." FEMS Microbiology Ecology **69**(1): 53-61.

Category: Ecosystem services

Keywords: *Nematode feeding groups, 16S rRNA genes, trophic interactions, Pseudomonas, rickettsias, soil, soil nutrients/cycling*

Abstract: The bacterial diversity associated with soil nematodes and its relationship with their feeding habits are as yet poorly understood. In the present study the diversity and abundance of bacteria from nematodes and their surrounding soil were analysed and compared. The nematodes were collected from a grassland soil and sorted into bacterial, fungal, plant, predatory and omnivore feeding groups and assigned to taxonomic groups. Total DNA was extracted from the nematodes and partial bacterial 16S rRNA genes were PCR amplified, cloned and sequenced. The abundance and composition of bacterial taxa differed between and within feeding groups. The lowest bacterial diversity was found in the predatory nematodes Prionchulus sp., whereas the highest bacterial diversity was associated with the bacterial-feeding nematode Acrobeles sp. The soil had a more diverse bacterial community than the communities found in the nematode groups. The 16S rRNA gene sequences of bacteria associated with nematodes did not overlap with those detected in soil as determined using the cloning screening approach. However, bacterial sequences identified from nematodes could be detected in the soil with targeted PCR. Our data suggest that the nematodes do not feed on the most abundant bacteria present in soil. Furthermore, several nematodes contained suspected bacterial symbionts and parasites.

Lal, R. (2011). "Sequestering carbon in soils of agro-ecosystems." Food Policy **36, Supplement 1**(0): S33-S39.

Category: Climate change

Keywords: *Soil quality, adaptation and mitigation of climate change, food security, soil restoration, carbon sequestration, soil nutrients/cycling*

Abstract: Soils of the world's agroecosystems (croplands, grazing lands, rangelands) are depleted of their soil organic carbon (SOC) pool by 25–75% depending on climate, soil type, and historic management. The magnitude of loss may be 10 to 50 tons C/ha. Soils with severe depletion of their SOC pool have low agronomic yield and low use efficiency of added input. Conversion to a restorative land use and adoption of recommended management practices, can enhance the SOC pool, improve soil quality, increase agronomic productivity, advance global food security, enhance soil resilience to adapt to extreme climatic events, and mitigate climate change by off-setting fossil fuel emissions. The technical potential of carbon (C) sequestration in soils of the agroecosystems is 1.2–3.1 billion tons C/yr. Improvement in soil quality, by increase in the SOC pool of 1 ton C/ha/yr in the root zone, can increase annual food production in developing countries by 24–32 million tons of food grains and 6–10 million tons of roots and tubers. The strategy is to create positive soil C and nutrient budgets through adoption of no-till farming with mulch, use of cover crops, integrated nutrient management including biofertilizers, water conservation, and harvesting, and improving soil structure and tilth.

Landis, D., M. Gardiner, W. van der Werf and S. Swinton (2008). "Increasing corn for biofuel production reduces biocontrol services in agricultural landscapes." Proceedings of the National Academy of Sciences **105**(51): 20552-20557.

Category: Ecosystem services

Keywords: *Bioenergy, biological control, ecosystem services, pest regulation*

Abstract: Increased demand for corn grain as an ethanol feedstock is altering U.S. agricultural landscapes and the ecosystem services they provide. From 2006 to 2007, corn acreage increased 19% nationally, resulting in reduced crop diversity in many areas. Biological control of insects is an ecosystem service that is strongly influenced by local landscape structure. Here, we estimate the value of natural biological control of the soybean aphid, a major pest in agricultural landscapes, and the economic impacts of reduced biocontrol caused by increased corn production in 4 U.S. states (Iowa, Michigan, Minnesota, and Wisconsin). For producers who use an integrated pest management strategy including insecticides as needed, natural suppression of soybean aphid in soybean is worth an average of $33 ha−1. At 2007–2008 prices these services are worth at least $239 million y−1 in these 4 states. Recent biofuel-driven growth in corn planting results in lower landscape diversity, altering the supply of aphid natural enemies to soybean fields and reducing biocontrol services by 24%. This loss of biocontrol services cost soybean producers in these states an estimated $58 million y−1 in reduced yield and increased pesticide use. For producers who rely solely on biological control, the value of lost services is much greater. These findings from a single pest in 1 crop suggest that the value of biocontrol services to the U.S. economy may be underestimated. Furthermore, we

suggest that development of cellulosic ethanol production processes that use a variety of feedstocks could foster increased diversity in agricultural landscapes and enhance arthropod-mediated ecosystem services.

Landis, W., J. Durda, M. Brooks, P. Chapman, C. Menzie, R. Stahl and J. Stauber (2013). "Ecological risk assessment in the context of global climate change." Environmental Toxicology and Chemistry **32**(1): 79-92.

Category: Climate change; Ecosystem services

Keywords: *Ecosystem service, multiple stressors, regional risk assessment, uncertainty*

Abstract: Changes to sources, stressors, habitats, and geographic ranges; toxicological effects; end points; and uncertainty estimation require significant changes in the implementation of ecological risk assessment (ERA). Because of the lack of analog systems and circumstances in historically studied sites, there is a likelihood of type III error. As a first step, the authors propose a decision key to aid managers and risk assessors in determining when and to what extent climate change should be incorporated. Next, when global climate change is an important factor, the authors recommend seven critical changes to ERA. First, develop conceptual cause–effect diagrams that consider relevant management decisions as well as appropriate spatial and temporal scales to include both direct and indirect effects of climate change and the stressor of management interest. Second, develop assessment end points that are expressed as ecosystem services. Third, evaluate multiple stressors and nonlinear responses—include the chemicals and the stressors related to climate change. Fourth, estimate how climate change will affect or modify management options as the impacts become manifest. Fifth, consider the direction and rate of change relative to management objectives, recognizing that both positive and negative outcomes can occur. Sixth, determine the major drivers of uncertainty, estimating and bounding stochastic uncertainty spatially, temporally, and progressively. Seventh, plan for adaptive management to account for changing environmental conditions and consequent changes to ecosystem services. Good communication is essential for making risk-related information understandable and useful for managers and stakeholders to implement a successful risk-assessment and decision-making process

Larsen, F., W. Turner and T. Brooks (2012). "Conserving critical sites for biodiversity provides disproportionate benefits to people." PloS one **7**(5): e36971.

Category: Farmer and societal benefits

Keywords: *Natural habitat, biodiversity, human well-being*

Abstract: Protecting natural habitats in priority areas is essential to halt the loss of biodiversity. Yet whether these benefits for biodiversity also yield benefits for human well-being remains controversial. Here we assess the potential human well-being benefits of safeguarding a global network of sites identified as top priorities for the conservation of threatened species. Conserving these sites would yield benefits – in terms of a) climate change mitigation through avoidance of CO2 emissions from deforestation; b) freshwater services to downstream human populations; c) retention of option value; and d) benefits to maintenance of human

cultural diversity – significantly exceeding those anticipated from randomly selected sites within the same countries and ecoregions. Results suggest that safeguarding sites important for biodiversity conservation provides substantial benefits to human well-being.

Lavorel, S., J. Storkey, R. Bardgett, F. de Bello, M. Berg, X. Le Roux, M. Moretti, C. Mulder, R. Pakeman, S. Díaz and R. Harrington (2013). "A novel framework for linking functional diversity of plants with other trophic levels for the quantification of ecosystem services." Journal of Vegetation Science **24**(5): 942-948.

Category: Ecosystem services

Keywords: *Functional trait, ecosystem functioning, biotic interactions, plant-soil interactions, biotic control, environmental change, pollination, grassland, soil nitrogen, field margins, pest regulation, soil nutrients/cycling*

Abstract: A novel conceptual framework is presented that proposes to apply trait-based approaches to predicting the impact of environmental change on ecosystem service delivery by multi-trophic systems. Development of the framework was based on an extension of the response–effect trait approach to capture functional relationships that drive trophic interactions. The framework was populated with worked examples to demonstrate its flexibility and value for linking disparate data sources, identifying knowledge gaps and generating hypotheses for quantitative models.

Lebuhn, G., S. Droege, E. F. Connor, B. Gemmill-Herren, S. G. Potts, R. L. Minckley, T. Griswold, R. Jean, E. Kula, D. W. Roubik, J. Cane, K. W. Wright, G. Frankie and F. Parker (2012). "Detecting insect pollinator declines on regional and global scales." Conservation Biology **27**(1): 113-120.

Category: Ecosystem services

Keywords: *Apiformes, Apoidea, bees, monitoring, power analysis, pollination*

Abstract: Recently there has been considerable concern about declines in bee communities in agricultural and natural habitats. The value of pollination to agriculture, provided primarily by bees, is >$200 billion/year worldwide, and in natural ecosystems it is thought to be even greater. However, no monitoring program exists to accurately detect declines in abundance of insect pollinators; thus, it is difficult to quantify the status of bee communities or estimate the extent of declines. We used data from 11 multiyear studies of bee communities to devise a program to monitor pollinators at regional, national, or international scales. In these studies, 7 different methods for sampling bees were used and bees were sampled on 3 different continents. We estimated that a monitoring program with 200–250 sampling locations each sampled twice over 5 years would provide sufficient power to detect small (2–5%) annual declines in the number of species and in total abundance and would cost U.S.$2,000,000. To detect declines as small as 1% annually over the same period would require >300 sampling locations. Given the role of pollinators in food security and ecosystem function, we recommend establishment of integrated regional and international monitoring programs to detect changes in pollinator communities.

Ledoux, L., S. Crooks, A. Jordan and R. Kerry Turner (2000). "Implementing EU biodiversity policy: UK experiences." Land Use Policy **17**(4): 257-268.
Category: Policy
Keywords: *Biodiversity policy, habitats directive, mitigation banking, participatory approaches*

Abstract: This paper offers a critical review of the European Union Habitats Directive, which requires Member States to designate and protect a network of habitats of European importance. In the UK, several problems linked to implementation have already appeared at the local level. These are illustrated through two case studies where an often restrictive and static interpretation of the legal requirements of the Directive has led to management conflicts. It is suggested that the use of participatory approaches and instruments adapted to no-net-loss policies such as mitigation banking, while not entirely unproblematic, could ease some of the practical problems of implementing the Directive.

Letourneau, D., J. Jedlicka, S. Bothwell and C. Moreno (2009). "Effects of natural enemy biodiversity on the suppression of arthropod herbivores in terrestrial ecosystems." Annual review of ecology, evolution, and systematics **40**(1): 573-592.
Category: Ecosystem services
Keywords: *Carnivores, meta-analysis, parasitism, parasitoid, pest control, predation, predator, species richness, pest regulation*

Abstract: Claims about the role of predator diversity in maintaining ecosystem function and providing ecosystem services such as pest control are controversial, but evaluative tests are beginning to accumulate. Empirical and experimental comparisons of species-rich versus species-poor assemblages of entomophagous arthropods and vertebrates range from strong suppression to facilitative release of herbivorous arthropod prey. Top-down control can be strengthened when natural enemies complement each other, dampened by negative interactions, balanced by both factors, and driven by single influential species. A meta-analytic synthesis shows a significant overall effect of enemy richness increasing top-down control of herbivores, which is consistent in agricultural studies conducted in tropical versus temperate zones, in studies using caged versus open-field designs, but not so in nonagricultural habitats. Synthetic analyses address theory and help set precautionary policy for conserving ecological services broadly, while characterizing uncertainty associated with herbivore response to changes in enemy diversity.

Levidow, L. (2012). Chapter 9. Contending European agendas for agricultural innovation. System Innovations, Knowledge Regimes and Design Practices towards Transitions for Sustainable Agriculture. M. Barbier and B. Elzen. Paris, INRA**:** 171-192.
Category: Ecosystem services
Keywords: *Agricultural innovation, Europe, sustainable agriculture, ecofunctional intensification, life sciences, agroecology, knowledge-based bioeconomy, value chains, research priorities*

Abstract: Amid expectations for a European 'transition to sustainable agriculture', there are competing transitional processes. Given the widely acknowledged harm from agro-industrial systems, unsustainable agriculture has divergent diagnoses and innovative solutions. In the EU policy context of a Knowledge-Based Bio-Economy (KBBE), there are also divergent accounts of its key terms: biological resources, economy, relevant knowledge and knowledge-producers. These accounts can be analysed as contending agendas for future agriculture.

The dominant agenda favours laboratory-based techno-scientific innovation as a means to use renewable resources more efficiently for competitive advantage in global value chains. Agriculture potentially becomes a factory for capital-intensive inputs to produce decomposable biomass for novel processes and industrial products. By contrast, a marginal agenda promotes farmers' knowledge of natural resources, especially via agro-ecological methods, alongside agro-food- energy re-localisation. Through short supply chains that valorise a comprehensive identity for agro-food products, producers can gain more of the value that they add. These agendas contend for influence over EU research priorities. Through their divergent agendas, stakeholders also promote different power relations: between farmers, the agro-input supply industry, research institutions, knowledge and markets.

Levidow, L., M. Pimbert, P. Stassart and G. Vanloqueren (2013). Draft. Agroecology in Europe - Conforming or transforming the dominant agro-food regime? Agroecology for Sustainable Food Systems in Europe: A Transformative Agenda. Brussels, Belgium**:** 36.

Category: Ecosystem services; Agroecology and agroecological practices

Keywords: *Agroecology, Europe, conservation agriculture, analytical perspectives, conformation dominant regime, transformation dominant regime, agro-food regime, sustainable intensification*

From conference paper:

• Transformative empowerment strategies can be facilitated by various changes in policy frameworks and decision-making processes, in particular (from our detailed case studies):

• CAP rural development measures linking farm-level agroecological methods with resource synergies and better remunerating those methods through urban-rural short food-supply chains;

• local territorial development strategies collectively formulated through stakeholder cooperation, e.g. through the Local Action Groups in the Leader programme, and more recently through the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-A);

• agrarian reform for more equitable access to fertile land and guaranteed tenure rights for farmers in both rural and urban areas;

• farmers' rights to re-sow saved seeds from the previous year's harvest, to freely select, exchange and disseminate their seeds and livestock breeds, to access any of their seeds and livestock embryos stored in gene banks, and to protect those varieties from bio-piracy and contamination by GMOs;

• public-procurement criteria favouring local small-scale farmers using agroecological methods;

• research & innovation agenda-setting through farmer-citizen participatory

processes as a basis for addressing practical problems of agroecological practices, for producing transdisciplinary knowledge, for transforming research institutions and for extending collective-action networks;

• new partnerships for multi-actor knowledge-exchange, with new structures remunerating practitioners and researchers for such collaborative efforts, beyond the conventional academic reward systems;

• eco-functional intensification as an overall strategy for more effectively using natural resources through knowledge of agroecological methods (e.g. recycling nutrients, enhancing biodiversity and the health of soils, crops and livestock – in agroforestry as well as arable farming), while also linking farm-level practices with wider agroecosystems.

Together those proposals highlight and empower agroecological experiments. Such efforts undergo tensions between agroecology conforming versus transforming the dominant agro-food regime. By recognising these tensions, collective-action networks can better develop transformative strategies for and through agroecology. This means transforming wider institutions on which farm-level practices depend.

Lewan, L. and T. Soderqvist (2002). "Knowledge and recognition of ecosystem services among the general public in a drainage basin in Scania, Southern Sweden." Ecological Economics **42**(3): 459-467.

Category: Farmer and societal benefits; Ecosystem services

Keywords: *Knowledge, ecosystem services, preferences, ranking, plant nutrient, Sweden*

Abstract: Human preferences are likely to depend on such things as knowledge and information, propaganda and advertising, and formal (laws) and informal (norms) institutions. We focus on knowledge about how nature works and how this may be manifested in recognition of ecosystem services among the general public. Participants and non-participants in a plant nutrient abatement programme with detention ponds in a river drainage area in Scania, Southern Sweden, were asked to rank some selected ecosystem services, classified as visible services, invisible services and services involving human activities in nature. Three studied groups of local actors were originally not familiar with the concept of ecosystem services, but the concept was easily grasped. The results of the study include the following findings: (1) The groups of local actors were consistent in ranking the groups of visible and invisible services higher than the group of services involving human activities, but there were considerable differences in their ranking of individual services. (2) The generally high priority given to invisible services can partly, but not fully, be explained by the existence of the abatement programme. (3) There was uncertainty regarding relationships among and the relative importance of different ecosystem services. (4) Some informants had multiple preferences. In fact the role people chose to play may have larger impact on preferences than the level of information. (5) Several interviewees objected to the idea of ranking services, and preferred to view nature as a whole. The results are discussed from a knowledge perspective, and we conclude that a widespread recognition of ecosystem services in policy and economics cannot be expected until the general public has gained some critical level of basic knowledge about functions in nature.

Lichtfouse, E., M. Navarrete, P. Debaeke, S. Veronique, C. Alberola, E. Malezieux, Y. Crozat, C. Dupraz, M. Laurans, D. Makowski, H. Ozier-Lafontaine, B. Rapidel, S. Tourdonnet and M. Valantin-Morison (2009). Mixing Plant Species in Cropping Systems: Concepts, Tools and Models: A Review. Sustainable Agriculture, Springer Netherlands**:** 329-353.

Category: Agroecology and agroecological practices

Keywords: *Agrobiodiversity, agroforestry system, competition, crop model, cropping system, facilitation, plant mixture, resource sharing, species mixture, crop rotation, agroecology*

Abstract: The evolution of natural ecosystems is controled by a high level of biodiversity, in sharp contrast, intensive agricultural systems involve monocultures associated with high input of chemical fertilisers and pesticides. Intensive agricultural systems have clearly negative impacts on soil and water quality and on biodiversity conservation. Alternatively, cropping systems based on carefully designed species mixtures reveal many potential advantages under various conditions, both in temperate and tropical agriculture. This article reviews those potential advantages by addressing the reasons for mixing plant species; the concepts and tools required for understanding and designing cropping systems with mixed species; and the ways of simulating multispecies cropping systems with models. Multispecies systems are diverse and may include annual and perennial crops on a gradient of complexity from 2 to n species. A literature survey shows potential advantages such as (1) higher overall productivity, (2) better control of pests and diseases, (3) enhanced ecological services and (4) greater economic profitability. Agronomic and ecological conceptual frameworks are examined for a clearer understanding of cropping systems, including the concepts of competition and facilitation, above- and belowground interactions and the types of biological interactions between species that enable better pest management in the system. After a review of existing models, future directions in modelling plant mixtures are proposed. We conclude on the need to enhance agricultural research on these multispecies systems, combining both agronomic and ecological concepts and tools

Liebman, M. and E. Dyck (1993). "Crop rotation and intercropping strategies for weed management." Ecological applications **3**(1): 92-122.

Category: Agroecology and agroecological practices

Keywords: *Weeds, weed control, cultural control, biology, rotational cropping, intercropping, seeds, plant population, biological competition, allelopathy, crop rotation, diversification, tillage, weed ecophysiology, wee d managment, weed population ecology*

Abstract: Results of a literature survey indicate that weed population density and biomass production may be markedly reduced using crop rotation (temporal diversification) and intercropping (spatial diversification) strategies. Crop rotation resulted in emerged weed densitites in test crops that were lower in 21 cases, higher in 1 case and equivalent in 5 cases in comparison to monoculture systems. In 12 cases where weed seed density was reported, seed density in crop in crop rotation was lower in 9 casess and equivalent in 3 cases when compared to moncultures of the component crops. In intercropping systems where a main crop was intersown

with a "smother" crop species, weed biomass iin the intercrop was lower in 47 cases and higher in 4 cases than in the main crop grown alone (as a sole crop); a variable response was observed in 3 cases. When intercrops were composed of two or more main crops, weed biomass in the intercrop was lower than in all of the component sole crops in 12 cases, intermediate between coponent sole crops in 10 cases, and higher than all sole crops in 2 cases. It is unclear why crop rotation studies have focused on weed density, whereas intercropping studies have focused on weed biomass.

The success of rotation systems for weed suppression appears to be based on the use of crop sequences that create varying patterns of resource competition, allelopathic interference, soil disturbance and mechanical damage to provide an unstable and frequently inhospitable environment that prevents the proliferation of a particular weed species. The relative importance and most effective combinations of these weed control tactics have not been adequately assessed. In addition, the weed-supporessive effects of other related factors, such as manipulation of soil fertility dynamics in rotation sequences, need to be examined.

Intercrops may demonstrate weed control advantages over sole crops in two ways. First, greater crop yield and less weed growth may be achieved if intercrops are more effective than sole crops in usurping resources from weeds or suppressing weed growth through allelopathy. Alternatively, intercrops may provide yield advantages without suppressing weed growth below levels observed in component sole crops if intercrops use resources that are not exploitable by weeds or convert rexources to harvestable material more efficiently than sole crops. Because of the difficulty of monitoring the use of multiple resources by intercrop/weed mixtures throughout the growing season, identification of specific mechanisms of weed suppression and yield enhancement in intercrop systems has so far proven elusive.

Significant advances in the design and improvemement of weed-suppressive crop rotation and intercropping systems are most likely to occur if three important areas of research are addressed. First, there must be continued attention to the study of weed population dynamics and crop-weed interference in crop rotation and intercropping systems. More information is needed concerning the effects of diversification of cropping systems on weed seed longevity, weed seedling emergence, weed seed production and dormancy, agents of weed mortaliity, differential resource consumption by crops and weeds, and allelopathic interactions. Second, there needs to be systematic manipulation of specific components of rotation and intercropping systems to isolate and improve those elements (e.g., interrow cultivation, choice of crop genotype) or combination of elements that maybe especially important for weed control. Finally, the weed-related impacts of combining crop rotation and intercropping strategies should be assessed through careful study of extant, complex farming systems and the design and testing of new integrated approaches.

Many aspects of crop rotation and intercropping are compatible with current farming practices and could become more accessible to farmers if government policies are restructured to reflect the true environmental costs of agricultural production.

Lin, B. (2011). "Resilience in agriculture through crop diversification: Adaptive management for environmental change." BioScience **61**(3): 183-193.
Category: Climate change
Keywords: *Resilience, climate change, diversified agroecosystems, adaptation, trade-off, diversification*

Abstract: Recognition that climate change could have negative consequences for agricultural production has generated a desire to build resilience into agricultural systems. One rational and cost-effective method may be the implementation of increased agricultural crop diversification. Crop diversification can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events. Such benefits point toward the obvious value of adopting crop diversification to improve resilience, yet adoption has been slow. Economic incentives encouraging production of a select few crops, the push for biotechnology strategies, and the belief that monocultures are more productive than diversified systems have been hindrances in promoting this strategy. However, crop diversification can be implemented in a variety of forms and at a variety of scales, allowing farmers to choose a strategy that both increases resilience and provides economic benefits.

Lobell, D., K. Cassman and C. Field (2009). "Crop yield gaps: Their importance, magnitudes, and causes." Annual Review of Environment and Resources **34**(1): 179-204.
Category: Climate change
Keywords: *Dynamical climatology, potential yield, environment, irrigation, yield, food security, climate change, constraint, food production, uncertainty, agriculture, economic aspect, cultivated plant*

Abstract: Future trajectories of food prices, food security, and cropland expansion are closely linked to future average crop yields in the major agricultural regions of the world. Because the maximum possible yields achieved in farmers' fields might level off or even decline in many regions over the next few decades, reducing the gap between average and potential yields is critical. In most major irrigated wheat, rice, and maize systems, yields appear to be at or near 80% of yield potential, with no evidence for yields having exceeded this threshold to date. A fundamental constraint in these systems appears to be uncertainty in growing season weather; thus tools to address this uncertainty would likely reduce gaps. Otherwise, short-term prospects for yield gains in irrigated agriculture appear grim without increased yield potential. Average yields in rainfed systems are commonly 50% or less of yield potential, suggesting ample room for improvement, though estimation of yield gaps for rainfed regions is subject to more errors than for irrigated regions. Several priorities for future research are identified

Lobell, D. and C. Field (2007). "Global scale climate-crop yield relationships and the impacts of recent warming." Environmental Research Letters **2**(1): 014002.
Category: Climate change

Keywords: *Climate change, crop yield, food production*

Abstract: Changes in the global production of major crops are important drivers of food prices, food security and land use decisions. Average global yields for these commodities are determined by the performance of crops in millions of fields distributed across a range of management, soil and climate regimes. Despite the complexity of global food supply, here we show that simple measures of growing season temperatures and precipitation—spatial averages based on the locations of each crop—explain ~30% or more of year-to-year variations in global average yields for the world's six most widely grown crops. For wheat, maize and barley, there is a clearly negative response of global yields to increased temperatures. Based on these sensitivities and observed climate trends, we estimate that warming since 1981 has resulted in annual combined losses of these three crops representing roughly 40 Mt or $5 billion per year, as of 2002. While these impacts are small relative to the technological yield gains over the same period, the results demonstrate already occurring negative impacts of climate trends on crop yields at the global scale.

Long, A. J. and P. K. R. Nair (1999). "Trees outside forests: agro-, community, and urban forestry." New Forests **17**(1-3): 145-174.

Category: Agroecology and agroecological practices

Keywords: *Planted forest, sustainability, agroforestry, community forestry, social forestry, semi-natural habitats*

Abstract: Planted forests are often considered to consist of tree plantings at a scale large enough to satisfy such objectives as commercial production of timber and fiber, protection of watersheds, and preservation of natural habitats. However, trees are planted also at greatly reduced scales in agroforestry systems or as community woodlots to provide a mixture of products and services to resident households, local communities, and regional cultures.

Agroforestry systems represent a major form of small-scale tree planting, where trees are grown in purposeful combinations with agricultural crops and/or livestock in order to take advantage of tree-crop interactions, and thereby enhance crop production, diversify farm output, stabilize or improve soils, or ameliorate harsh environmental conditions. Some important examples of these systems in tropical countries include homegardens, alley cropping, improved fallows, intercropped trees for shade and fodder production, and trees planted in hedgerows and along fence lines. Throughout the tropics, there is a large variety of indigenous practices and species mixtures that represent adaptations of these systems to meet localized needs and opportunities. Research and development programs have supported the expansion and refinement of many of these systems during the last 20 years, but substantial constraints on tree planting still exist in the form of land-tenure practices, population pressures that relegate agroforestry practices to degraded lands, subsistence needs that prevent extended periods of tree growth, and insufficient technical information or technology dissemination.

Agroforestry systems in temperate, industrialized countries include combinations of trees, pasture, and livestock; fruit or nut trees interplanted with vegetable or grain crops; windbreaks and shelterbelts; multispecies riparian buffer strips; and forest farming systems for specialty crops. Compared to the tropics, however, temperate-

zone systems tend to focus on one or two high-value crops, often involve some level of mechanization, and frequently represent an opportunistic approach to improving the economic profitability of farms rather than meeting subsistence needs. In both tropical and temperate regions, agroforestry systems and community woodlots will be an important component of new sustainable agriculture and environmental protection programs.

Although species diversity is an essential feature of all agroforestry systems, community forests generally involve planting only a few species in small woodlots near farms, around villages, along roads, and as riparian buffers. Provincial or state governments and the local populace are often involved in landownership and plantation establishment. Major objectives of these forests are production of fuelwood for local consumption and of other tree products for market; soil stabilization, reclamation, or improvement; and protection of water quality. As with many other planted forests, the number of species widely used in community forests has been relatively small, with the genera Eucalyptus, Pinus, and Acacia providing the bulk of the species. Major issues with these “planted forests” focus on rights for use of the products, tending responsibilities once trees are established, protection until trees are large enough for their designated use, increasing interest in using “native” species, and greater community involvement in planning and management.

Trees planted along streets and waterways, or as woodlots in parks and other public places, represent a major group of planted forests in many urban and periurban landscapes. In addition to providing many of the same environmental services that agroforests and community forests do, these urban plantings have unique aesthetic and recreational value. For much of the world's ever-increasing urban population, these may be the only tangible reference points for understanding planted forests.

These relatively little-recognized forms of planted forests -- planted trees, to be more appropriate -- are now receiving much greater attention. There are, however, some serious technical and sociopolitico-institutional constraints to their development as more widely adopted systems in both tropical and temperate regions.

Lonsdorf, E., C. Kremen, T. Ricketts, R. Winfree, N. Williams and S. Greenleaf (2009). "Modelling pollination services across agricultural landscapes." Annals of botany **103**(9): 1589-1600.

Category: Ecosystem services

Keywords: *Agriculture, bees, ecosystem services, landscape ecology, model, land use, pollinators, pollination*

Abstract:

Background and Aims: Crop pollination by bees and other animals is an essential ecosystem service. Ensuring the maintenance of the service requires a full understanding of the contributions of landscape elements to pollinator populations and crop pollination. Here, the first quantitative model that predicts pollinator abundance on a landscape is described and tested.

Methods: Using information on pollinator nesting resources, floral resources and foraging distances, the model predicts the relative abundance of pollinators within nesting habitats. From these nesting areas, it then predicts relative abundances of

pollinators on the farms requiring pollination services. Model outputs are compared with data from coffee in Costa Rica, watermelon and sunflower in California and watermelon in New Jersey–Pennsylvania (NJPA).

Key Results: Results from Costa Rica and California, comparing field estimates of pollinator abundance, richness or services with model estimates, are encouraging, explaining up to 80 % of variance among farms. However, the model did not predict observed pollinator abundances on NJPA, so continued model improvement and testing are necessary. The inability of the model to predict pollinator abundances in the NJPA landscape may be due to not accounting for fine-scale floral and nesting resources within the landscapes surrounding farms, rather than the logic of our model.

Conclusions: The importance of fine-scale resources for pollinator service delivery was supported by sensitivity analyses indicating that the model's predictions depend largely on estimates of nesting and floral resources within crops. Despite the need for more research at the finer-scale, the approach fills an important gap by providing quantitative and mechanistic model from which to evaluate policy decisions and develop land-use plans that promote pollination conservation and service delivery.

Loomis, J., P. Kent, L. Strange, K. Fausch and A. Covich (2000). "Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey." Ecological Economics **33**(1): 103-117.

Category: Farmer and societal benefits

Keywords: *Ecosystem services, willingness to pay, total economic value, contingent valuation method*

Abstract: Five ecosystem services that could be restored along a 45-mile section of the Platte river were described to respondents using a building block approach developed by an interdisciplinary team. These ecosystem services were dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation. Households were asked a dichotomous choice willingness to pay question regarding purchasing the increase in ecosystem services through a higher water bill. Results from nearly 100 in-person interviews indicate that households would pay an average of $21 per month or $252 annually for the additional ecosystem services. Generalizing this to the households living along the river yields a value of $19 million to $70 million depending on whether those refusing to be interviewed have a zero value or not. Even the lower bound benefit estimates exceed the high estimate of water leasing costs ($1.13 million) and conservation reserve program farmland easements costs ($12.3 million) necessary to produce the increase in ecosystem services.

Loveland, P. and J. Webb (2003). "Is there a critical level of organic matter in the agricultural soils of temperate regions: a review." Soil and Tillage Research **70**(1): 1-18.

Category: Ecosystem services

Keywords: *Soil organic carbon, soil organic matter, critical levels, soil quality, temperate soils, England, Wales, soil nutrient/cycling*

Abstract: Soil organic matter (SOM) is a complex mixture, which influences a number

of soil properties and nutrient cycling, and is itself influenced in kind and amount by land-use, soil type, climate and vegetation. There is considerable concern that, if SOM concentrations in soils are allowed to decrease too much, then the productive capacity of agriculture will be compromised by deterioration in soil physical properties and by impairment of soil nutrient cycling mechanisms. This has clear implications for the sustainable use of soil. We have focussed our discussion from the standpoint of the sustainability of UK agriculture, because we know that best, but similar concerns are equally valid elsewhere in the world. Although soil scientists would expect to find different behaviour in different soils at different 'critical' concentrations of SOM, it seems widely believed that a major threshold is 2% soil organic carbon (SOC) (ca. 3.4% SOM), below which potentially serious decline in soil quality will occur.

This review summarises what is known about critical thresholds of SOC or SOM, mainly in soils of temperate regions. It examines critically the quantitative, rather than anecdotal or descriptive, evidence for such thresholds and their potential effects on soil quality, soil physical properties and crop nutrition, and the links between these.

We conclude that the quantitative evidence for such thresholds is slight, although there is some evidence that there might be an desirable range of SOC covering a wide spectrum of soils, but again the quantitative evidence for this needs considerable development. There is also little quantitative evidence that reduction in SOC concentrations in the soils of England and Wales will have marked effects on other soil properties or crop yields. The data do suggest, however, that more research is required on the nature of SOC, particularly of the so-called 'active' or 'fresh' fraction and its influence on the properties of a range of soil types under different land uses. This is particularly relevant to the ongoing debate about soil quality, its definition, and the identification of appropriate indicators that relate soil quality to soil functions.

Lovell, S., S. DeSantis, C. Nathan, M. Olson, E. M., H. Kominami, D. Erickson, K. Morris and W. Morris (2010). "Integrating agroecology and landscape multifunctionality in Vermont: An evolving framework to evaluate the design of agroecosystems." Agricultural Systems **103**(5): 327-341.

Category: Agroecology and agroecological practices

Keywords: *Multifunctional agriculture, landscape multifunctionality, ecosystem services, ecological design, food systems, rural planning*

Abstract: Agroecosystems cover vast areas of land worldwide and are known to have a large impact on the environment, yet these highly modified landscapes are rarely considered as candidates for landscape design. While intentionally-designed agricultural landscapes could serve many different functions, few resources exist for evaluating the design of these complex landscapes, particularly at the scale of the whole-farm. The objective of this paper is to introduce an evolving framework for evaluating the design of agroecosystems based on a critical review of the literature on landscape multifunctionality and agroecology. We consider how agroecosystems might be designed to incorporate additional functions while adhering to agroecology principles for managing the landscape. The framework includes an assessment tool

for evaluating farm design based on the extent of fine-scale land use features and their specific functions, to consider the present state of the farm, to plan for future conditions, or to compare alternative futures for the design of the farm. We apply this framework to two farms in Vermont that are recognized locally as successful, multifunctional landscapes. The Intervale Center, an agricultural landscape located within the city limits, serves as an incubator for new farm startups and provides unique cultural functions that benefit the local community. Butterworks Farm, a private operation producing organic yogurt and other food products, achieves important ecological functions through an integrated crop-livestock system. These farms and many others in Vermont serve as models of a framework that integrates landscape multifunctionality and agroecology in the design of the landscape. In the discussion section, we draw from the literature and our work to propose a set of important themes that might be considered for future research.

Lu, Y. C., K. Watkins, J. Teasdale and A. Abdul-Baki (2000). "Cover crops in sustainable food production." Food Reviews International **16**(2): 121-157.

Category: Agroecology and agroecological practices

Keywords: *Cover crops, sustainable food production, tradeoffs, soil nutrients/cycling*

Abstract: Cover crops are important components of sustainable agricultural systems. They increase surface residue and aid in the reduction of soil erosion. They improve the structure and water-holding capacity of the soil and thus increase the effectiveness of applied N fertilizer. Legume cover crops such as hairy vetch and crimson clover fix nitrogen and contribute to the nitrogen requirements of subsequent crops. Cover crops can also suppress weeds, provide suitable habitat for beneficial predator insects, and act as non-host crops for nematodes and other pests in crop rotations. This paper reviews the agronomic and economic literature on using cover crops in sustainable food production and reports on past and present research on cover crops and sustainable agriculture at the Beltsville Agricultural Research Center, Maryland. Previous studies suggested that the profitability of cover crops is primarily the result of enhanced crop yields rather than reduced input costs. The experiments at the Beltsville Agricultural Research Center on fresh-market tomato production showed that tomatoes grown with hairy vetch mulch were higher yielding and more profitable than those grown with black polyethylene and no mulch system. Previous studies of cover crops in grain production indicated that legume cover crops such as hairy vetch and crimson clover are more profitable than grass cover crops such as rye or wheat because of the ability of legumes to contribute N to the following crop. A comparative analysis of four reduced-tillage corn based cropping systems at the Sustainable Agricultural Demonstration site showed that the cover crop system with corn following hairy vetch produced the largest average gross margin, followed by the conventional no-tillage system, a manure-based system, and a crown vetch living mulch system. The EPIC model to simulate the long-term economic and environmental impacts of incorporating cover crops into grain production systems in mid-Atlantic states was used. Results based on 60 simulation years indicated that there are tradeoffs between the competing objectives of increased profitability, lower soil erosion, and reduced nutrient and pesticide hazards to surface and groundwater supplies. A corn/soybean two-year

rotation was found to be the most profitable, while the cover crop system and the manure system were found to be the most environmentally sound.

Lukac, M., M. Gooding, S. Griffiths and H. P. Jones (2011). "Asynchronous flowering and within-plant flowering diversity in wheat and the implications for crop resilience to heat." Annals of botany **109**(4): 843-850.

Category: Climate change

Keywords: *Wheat, Triticum aestivum, flowering synchrony, pollination, climate change, heat resistance*

Abstract:

Background and Aims: Self-pollination dominates in wheat, with a small level of out-crossing due to flowering asynchrony and male sterility. However, the timing and synchrony of male and female flowering in wheat is a crucial determinant of seed set and may be an important factor affecting gene flow and resilience to climate change. Here, a methodology is presented for assessing the timing and synchrony of flowering in wheat, Triticum aestivum.

Methods: From the onset of flowering until the end of anthesis, the anther and stigma activity of each floret was assessed on the first five developing ears in potted plants grown under ambient conditions and originating from 'Paragon' or 'Spark-Rialto' backgrounds. At harvest maturity, seed presence, size and weight was recorded for each floret scored.

Key Results and Conclusions: The synchrony between pollen dehiscence and stigma collapse within a flower was dependent on its relative position in a spike and within a floret. Determined on the basis of synchrony within each flower, the level of pollination by pollen originating from other flowers reached approx. 30 % and did not change throughout the duration of flowering. A modelling exercise parameterized by flowering observations indicated that the temporal and spatial variability of anther activity within and between spikes may influence the relative resilience of wheat to sudden, extreme climatic events which has direct relevance to predicted future climate scenarios in the UK.

Maas, B., D. Putra, M. Waltert, Y. Clough, T. Tscharntke and C. Schulze (2009). "Six years of habitat modification in a tropical rainforest margin of Indonesia do not affect bird diversity but endemic forest species." Biological Conservation **142**(11): 2665-2671.

Category: Agriculture-induced impacts

Keywords: *Biotic homogenization, Sulawesi, deforestation, land-use change, temporal dynamics, impacts of agriculture, agriculture-induced impacts, negative exernalities on ecosystem services*

Abstract: Studies on temporal changes of tropical bird communities in response to habitat modification are rare. We quantified changes in bird assemblages at the rainforest margin of Lore Lindu National Park, Central Sulawesi, over an interval of 6 years. Standardized bird counts were conducted in the years 2001/2002 and 2008 at 15 census points representing natural forest, secondary forest, agroforest and openland sites. Although overall species richness remained nearly identical, different species groups were affected unequally by habitat modification within the forest

margin landscape. The mostly endemic forest species declined in abundance (72.0% of forest species) and were detected at fewer census points in 2008 (56.0%). In contrast, 81.8% of the solely widespread openland birds became more abundant and 63.6% of the species were recorded at a larger number of census points. Hence, recent human activities in the forest margin ecotone negatively affected species of high conservation value. Species richness turned out to be a poor indicator of habitat change, and our results underline the importance of considering species identities. Biotic homogenization as result of habitat conversion is a global phenomenon. In our study, the winners were widespread openland species, while the losers were endemic forest birds. In conclusion, our study shows that 6 years of land-use change had negative impacts on bird community structure and endangered species, but not on overall bird species richness.

Mace, G. and J. Baillie (2007). "The 2010 biodiversity indicators: Challenges for science and policy." Conservation Biology **21**(6): 1406-1413.

Category: Policy

Keywords: *Biodiversity measures, 2010 target, Countdown 2010, environmental indicators*

Abstract: The 2010 biodiversity target adopted globally and in Europe is an important political commitment for improved biodiversity conservation and management. Whether or not it is achieved will be judged by a set of biodiversity indicators now under development. We reviewed the development of these indicators in Europe and globally, paying particular attention to the need to make the indicators relevant to the purpose; to distinguish between measures of pressure, state, and response; to design and validate the indicators in context; to ensure effective communication with relevant audiences; to turn lists of measures into simple or composite indicators; and to maximize the cost-effectiveness of the indicator process. We conclude that urgent steps are needed to complete the indicator set, reduce and refine the agreed measures, ensure that work is started soon so that reliable reporting occurs in 2010, and start soon on planning for subsequent assessments.

Maes, J., B. Egoh, L. Willemen, C. Liquete, P. Vihervaara, J. Schagner, B. Grizzetti, E. Drakou, A. Notte, G. Zulian, F. Bouraoui, M. Luisa Paracchini, L. Braat and G. Bidoglio (2012). "Mapping ecosystem services for policy support and decision making in the European Union." Ecosystem Services **1**(1): 31-39.

Category: Farmer and societal benefits; Ecosystem services

Keywords: *Biodiversity policy, mapping ecosystem services, water purification, European Union, ecosystem services, water purification, water quality*

Abstract: Mainstreaming ecosystem services into policy and decision making is dependent on the availability of spatially explicit information on the state and trends of ecosystems and their services. In particular, the EU Biodiversity Strategy to 2020 addresses the need to account for ecosystem services through biophysical mapping and valuation. This paper reviews current mapping methods, identifies current knowledge gaps and provides the elements for a methodological framework for mapping and assessing ecosystems and their services at European scale. Current

mapping methodologies go beyond purely land cover based assessments and include the use of primary data of ecosystem services, the use of functional traits to map ecosystem services and the development of models and ecological production functions. Additional research is needed to cover marine ecosystems and to include the resilience of ecosystems to environmental change in spatially explicit assessments. The ecosystem services cascade which connects ecosystems to human wellbeing is argued to provide a suitable, stepwise framework for mapping ecosystem services in order to support EU policies in a more effective way. We demonstrate the use of this framework for mapping using the water purification service as case.

Maes, J., J. Hauck, M. Paracchini, O. Ratamaki, M. Hutchins, M. Termansen, E. Furman, M. Perez-Soba, L. Braat and G. Bidoglio (2013). "Mainstreaming ecosystem services into EU policy." Current Opinion in Environmental Sustainability **5**(1): 128-134.

Category: Farmer and societal benefits

Keywords: *PEER7 Research on Ecosystem Services, EU Biodiversity Strategy to 2020, ecosystem services, water purification, recreation, pollinator services*

Abstract: This paper presents a synthesis of the PRESS initiative (PEER7 Research on Ecosystem Services). In support of the EU Biodiversity Strategy to 2020, this initiative demonstrated a multi-scale mapping and assessment approach of ecosystem services using three case studies. The water purification case studied the impacts of agricultural and water policy scenarios on the capacity of ecosystems to purify water. The conclusion was that greening the subsidies to farmers in Europe would improve water quality and increase the benefits to society as measured via monetary valuation. Yet, scenario based nitrogen reduction levels differed among the different scales (EU and basin scale) suggesting that the assessment of policy measures is scale-dependent, which, in turn, justifies a multi-scale mapping and assessment approach. The recreation case presented evidence that millions of people visited forests several times per year and they expressed their willingness to pay to continue doing so. The visitor statistics that were used in this study suggested that the Recreation Opportunity Spectrum approach is a useful method to identify areas in terms of their accessibility and potential to provide recreation services. Finally, we demonstrated that the coverage and resolution of current datasets are already sufficient to map the potential of ecosystems to provide pollination services. Further research should contribute to better ecological observations of key pollinator species to include important drivers of pollinator abundance in modelling and mapping approaches.

Magdoff, F. and R. Weil (2004). Soil organic matter in sustainable agriculture, CRC Press.

Category: Ecosystem services

Keywords: *Humus, soil ecology, agriculture, soil nutrients/cycling, soil organic matter*

from Amazon.com:

Recognition of the importance of soil organic matter (SOM) in soil health and quality is a major part of fostering a holistic, preventive approach to agricultural management. Students in agronomy, horticulture, and soil science need a textbook

that emphasizes strategies for using SOM management in the prevention of chemical, biological, and physical problems.

Soil Organic Matter in Sustainable Agriculture gathers key scientific reviews concerning issues that are critical for successful SOM management. This textbook contains evaluations of the types of organic soil constituents—organisms, fresh residues, and well-decomposed substances. It explores the beneficial effects of organic matter on soil and the various practices that enhance SOM. Chapters include an examination of the results of crop management practices on soil organisms, organic matter gains and losses, the significance of various SOM fractions, and the contributions of fungi and earthworms to soil quality and crop growth.

Emphasizing the prevention of imbalances that lead to soil and crop problems, the text also explores the development of soils suppressive to plant diseases and pests, and relates SOM management to the supply of nutrients to crops. This book provides the essential scientific background and poses the challenging questions that students need to better understand SOM and develop improved soil and crop management systems.

Main, A. R. (1999). "How much biodiversity is enough?" Agroforestry Systems **45**(1-3): 23-41.

Category: Agroecology and agroecological practices

Keywords: *Agriculture, evolution, functional mimicry, natural ecosystems, sustainability, water quality, soil erosion, nutrient leaching, soil nutrients/cycling, weed control, pest regulation*

Abstract: This paper addresses the question of how much biodiversity is enough in the context of the concept of agriculture as a mimic of nature. Following an historical review of the likely origins of ecosystems I show that the currently accepted components of biodiversity, viz. genetic, species and ecosystem, and their functional expression, are relevant to agriculture. Examples of adequate biodiversity are given and it is concluded that what constitutes enough biodiversity in an agricultural system is dependent upon the goal in question and will be different depending on whether the aim is, for example, to increase yield stability or deal with salinity, ground water levels, soil erosion, leaching of nutrients or weed control. The point is made that ecosystems and their composition are contingent in nature so the history of events, their frequency and intensity all need to be considered when interpreting the natural biodiversity present and thus determining what is enough in particular circumstances.

Malezieux, E. (2012). "Designing cropping systems from nature." Agronomy for Sustainable Development **32**(1): 15-29.

Category: Ecosystem services; Agroecology and agroecological practices

Keywords: *Agroecology, ecological intensification, biological regulations in agroecosystems, sustainable agriculture, mimicry, pest regulation, soil nutrients/cycling*

Abstract: Despite huge gains in productivity, environmental impacts of industrial agriculture based on a few high-yielding crop cultivars and the massive use of chemical fertilisers and pesticides have led to a search for new pathways leading to

more sustainable agriculture in both temperate and tropical regions. New strategies incorporating ecological knowledge gained from the observation of natural ecosystems is an alternative to design “ecologically intensive” agroecosystems. Such systems are indeed both ecological and productive. Designing ecologically intensive agroecosystems calls for in- depth knowledge of biological regulations in ecosystems, and for the integration of traditional agricultural knowledge held by local farmers. This article reviews the main initiatives underlying ecologically intensive agroecosystems, analyses basic concepts, and proposes a framework for action. The rainforest model, the dry forest model, and the American Prairie are exemplified as three main natural systems at the basis of the mimicry concept. The link between biodiversity and the mimicry hypotheses, and the use of the concepts of productivity, efficiency, stability, and resilience for agro- ecosystems are discussed. Six main principles for cropping system design based on natural ecosystem mimicry are identified. A three-step framework for action is proposed, including nature observation, experimental design, and participatory design. Although far from being a panacea, the mimicry approach can provide new ways for agro- ecosystem design both in temperate and tropical countrie

Maracchi, G., O. Sirotenko and M. Bindi (2005). "Impacts of present and future climate variability on agriculture and forestry in the temperate regions: Europe." Climatic Change **70**(1-2): 117-135.

Category: Climate change

Keywords: *Agriculture, forestry, climate change, Europe*

Abstract: Agriculture and forestry will be particularly sensitive to changes in mean climate and climate variability in the northern and southern regions of Europe. Agriculture may be positively affected by climate change in the northern areas through the introduction of new crop species and varieties, higher crop production and expansion of suitable areas for crop cultivation. The disadvantages may be determined by an increase in need for plant protection, risk of nutrient leaching and accelerated breakdown of soil organic matter. In the southern areas the benefits of the projected climate change will be limited, while the disadvantages will be predominant. The increased water use efficiency caused by increasing CO2 will compensate for some of the negative effects of increasing water limitation and extreme weather events, but lower harvestable yields, higher yield variability and reduction in suitable areas of traditional crops are expected for these areas. Forestry in the Mediterranean region may be mainly affected by increases in drought and forest fires. In northern Europe, the increased precipitation is expected to be large enough to compensate for the increased evapotranspiration. On the other hand, however, increased precipitation, cloudiness and rain days and the reduced duration of snow cover and soil frost may negatively affect forest work and timber logging determining lower profitability of forest production and a decrease in recreational possibilities. Adaptation management strategies should be introduced, as effective tools, to reduce the negative impacts of climate change on agricultural and forestry sectors.

Marini, L., A. Bertolli, E. Bona, G. Federici, F. Martini, F. Prosser and R. Bommarco (2012). "Beta-diversity patterns elucidate mechanisms of alien plant invasion in mountains." Global Ecology and Biogeography **22**(4): 450-460.

Category: Climate change

Keywords: *Altitude, climate, directional filtering, dissimilarity, exotic, human population, Italian Alps, nestedness, replacement, species turnover*

Abstract:

Aim: Our aims were: (1) to separately evaluate the elevational patterns of β-diversity for nestedness, species richness difference and replacement, (2) to identify the drivers of β-diversity patterns by testing the effect of geographical and environmental distance (human population, temperature and land-use), and (3) to compare the response on native versus alien species to elucidate mechanisms of community assembly along elevational gradients.

Location: Two mountain regions (Bergamo-Brescia and Trento) in the Italian Alps.

Methods: We used two floristic datasets in which species composition was sampled within two regular grids. First, we extracted species elevational range and quantified species composition nestedness along the elevational gradient. Second, we partitioned β-diversity into its species richness difference and replacement components and tested drivers using regression on distance matrix and hierarchical partitioning. All analyses were performed on natives and aliens, separately.

Results: For aliens, we found lack of mountain specialists (i.e. species with a distribution range restricted to high elevations), large nestedness, large species richness difference and low species replacement between low and high elevations. All findings point in the same direction: a great majority of alien species were introduced to the lowlands and only a subset of this community spread up the mountains. Both human pressures and temperature selection were important processes underpinning the observed filtering, while geographical and land-use distances were not important. Natives present contrasting patterns with large replacement along the elevation gradients indicating different mechanisms of community assembly.

Main conclusions: The relatively large alien species replacement in the lowlands indicated the presence of a pool of species that may potentially invade the temperate mountains in the future. Investigations of the identity of alien species occurring in the lowlands and their climatic pre-adaptation might provide tools to prevent invasions in the mountains by predicting the potential invaders and their future elevational distribution.

Marini, L., R. Bommarco, P. Fontana and A. Battisti (2010). "Disentangling effects of habitat diversity and area on orthopteran species with contrasting mobility." Biological Conservation **143**(9): 2164-2171.

Category: Ecosystem services

Keywords: *Abandonment, dispersal limitation, fragmentation, habitat loss, heterogeneity, solation, wild biodiversity, grasslands, insect regulation*

Abstract: Loss of semi-natural grasslands and reduction of habitat diversity are considered major potential threats to arthropod diversity in agricultural landscapes. The main aim of this study was to investigate how area and habitat diversity,

mediated by shrub encroachment after grassland abandonment, affect species richness of orthopterans in island-like grasslands, and how contrasting mobility might alter species richness response to both factors. We selected 35 isolated patches in landscapes dominated by arable land (durum wheat) in order to obtain two statistically uncorrelated gradients: (i) one in habitat area ranging from 0.2 to 55 ha and (ii) one in habitat diversity ranging from patches dominated by one habitat (either open grasslands or shrublands) to patches with a mosaic of different habitats. Habitat loss due to land-use conversion into arable fields was associated with a substantial loss of species with a positive species–area relationship (SAR), with sedentary species having a steeper and stronger SAR than mobile species. Halting habitat loss is, therefore, needed to avoid further species extinctions. Shrub encroachment, triggered by abandonment, presented a hump-shaped relationship with habitat diversity. An increase in habitat diversity enhanced species richness irrespective of patch area and mobility. Maintaining or enhancing habitat diversity, by cutting or burning small sectors and by reintroducing extensive sheep grazing into abandoned grassland, are suggested as complementary strategies to mitigate further decline of orthopteran diversity in the remnant patches. This would be equally important in both small and large patches.

Marini, L., H. Bruun, R. Heikkinen, A. Helm, O. Honnay, J. Krauss, I. Kühn, R. Lindborg, M. Partel and R. Bommarco (2012). "Traits related to species persistence and dispersal explain changes in plant communities subjected to habitat loss." Diversity and Distributions **18**(9): 898-908.

Category: Agriculture-induced impacts

Keywords: *Clonality, competition, connectivity, dispersal, fragmentation, life-history trait*

Abstract:

Aim: Habitat fragmentation is a major driver of biodiversity loss but it is insufficiently known how much its effects vary among species with different life-history traits; especially in plant communities, the understanding of the role of traits related to species persistence and dispersal in determining dynamics of species communities in fragmented landscapes is still limited. The primary aim of this study was to test how plant traits related to persistence and dispersal and their interactions modify plant species vulnerability to decreasing habitat area and increasing isolation.

Location: Five regions distributed over four countries in Central and Northern Europe.

Methods: Our dataset was composed of primary data from studies on the distribution of plant communities in 300 grassland fragments in five regions. The regional datasets were consolidated by standardizing nomenclature and species life-history traits and by recalculating standardized landscape measures from the original geographical data. We assessed the responses of plant species richness to habitat area, connectivity, plant life-history traits and their interactions using linear mixed models.

Results: We found that the negative effect of habitat loss on plant species richness was pervasive across different regions, whereas the effect of habitat isolation on species richness was not evident. This area effect was, however, not equal for all the species, and life-history traits related to both species persistence and dispersal

modified plant sensitivity to habitat loss, indicating that both landscape and local processes determined large-scale dynamics of plant communities. High competitive ability for light, annual life cycle and animal dispersal emerged as traits enabling species to cope with habitat loss.

Main conclusions: In highly fragmented rural landscapes in NW Europe, mitigating the spatial isolation of remaining grasslands should be accompanied by restoration measures aimed at improving habitat quality for low competitors, abiotically dispersed and perennial, clonal species.

Marini, L., P. Fontana, A. Battisti and K. Gaston (2009). "Agricultural management, vegetation traits and landscape drive orthopteran and butterfly diversity in a grassland–forest mosaic: a multi-scale approach." Insect Conservation and Diversity **2**(3): 213-220.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Alps, cutting frequency, fertilisation, forest, hay meadows, herbivores, insect conservation, sward structure, wild biodiversity*

Abstract: 1.Most ecological processes at the population and community level act on multiple spatial scales. We identified the influence of grassland management, vegetation traits and landscape on orthopteran and butterfly diversity in 44 meadows located in a forest-dominated region in the Italian Alps. The meadows were sampled in landscapes characterised by different proportions of woody vegetation and grasslands quantified at 11 spatial scales (95–3000 m).

2. We applied a multi-scale approach to investigate the scale-dependent effects of landscape. Then, we built generalised linear models (Poisson and log-link function) to test simultaneously vegetation traits and landscape variables on insect species richness.

3. High fertilisation and cutting frequency created tall, species-poor plant communities. This change reduced orthopteran diversity by providing an unsuitable sward structure, and butterfly diversity by creating disturbed plant communities with low species richness and abundance of flowering forbs and host plants.

4. The proportion of woody vegetation had a strong positive effect on the richness of both groups at the smallest spatial scale (95 m), indicating the importance of undisturbed vegetation in the surrounding of mown meadows. The effect tended to disappear with increasing spatial extent.

5. A multi-scale approach was necessary to identify the effects of landscape factors in this study system. Conservation measures should endorse the maintenance of species-rich, sparse and short plant communities by reducing organic fertilisation and cutting frequency. However, these schemes should also promote the presence of undisturbed woody vegetation in the immediate surrounding landscape or at least should prevent the complete mowing of large areas.

Marini, L., P. Fontana, A. Battisti and K. Gaston (2009). "Response of orthopteran diversity to abandonment of semi-natural meadows." Agriculture, Ecosystems & Environment **132**(3-4): 232-236.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Alps, grassland management, insect conservation, mowing, reforestation,*

successional stages, wild biodiversity

Abstract: The response of orthopteran communities to abandonment of extensively managed hay meadows was investigated in an Alpine region. Fifty-five sites in four different successional stages were sampled: (i) mown meadows, (ii) young abandoned meadows, (iii) old abandoned meadows, and (iv) young forests. Mown meadows and young abandoned meadows (3–5 years since the last cut) had the highest, young forests the lowest mean number of orthopteran species. The change in vegetation structure and the shading by woody plants are considered the most important drivers determining the orthopteran diversity response to abandonment. Well-targeted agri-environment schemes are needed to maintain extensive semi-natural hay meadows with the provision of compensation payments to support transitional stages (young and old abandoned meadows). A mowing regime with a supra-annual cycle (e.g. 3–5 years) could be a suitable management practice to reduce direct mortality due to mechanical mowing and to halt forest invasion.

Marini, L., P. Fontana, S. Klimek, A. Battisti and K. Gaston (2009). "Impact of farm size and topography on plant and insect diversity of managed grasslands in the Alps." Biological Conservation **142**(2): 394-403.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Agricultural intensification, butterfly, eutrophication, grassland management, insect conservation, Orthoptera, farm size*

Abstract: Since the second half of the 20th century, the intensification of land-use practices and the associated decline in semi-natural habitats have been the major drivers of farmland biodiversity loss. In many marginal agricultural systems, a structural transformation of farms, from small and traditional to large and intensive, has also been observed. We unravelled the impact of farm size and slope on plant, orthopteran and butterfly diversity in 132 hay meadows in a region of the Italian Alps. We defined three farm size classes representing different levels of intensification and used mixed models to test the influence of farm size along with topographic slope. The diversity of plants, orthopterans and butterflies declined with management intensity at the field scale, which mainly depended on farm size and grassland topography. We found a positive effect of slope and a negative influence of farm size on species richness of the three taxonomic groups. Large farms were strongly associated with higher production of organic fertilizers and higher soil fertility than small traditional farms, irrespective of meadow slope. At the regional scale, we found that large farms managed flatter meadows (slope = 9.0) than small traditional farms (slope = 13.5), contributing to the abandonment of steep species-rich grassland areas. Regional stakeholders should consider targeted conservation schemes to prevent the ongoing substitution of small farms with large intensive farms. A complementary solution could be to target future conservation measures to support farms with low production of organic fertilizers and to reward the maintenance of the current management of steep meadows.

Marini, L., P. Fontana, M. Scotton and S. Klimek (2008). "Vascular plant and Orthoptera diversity in relation to grassland management and landscape composition in the European

Alps." Journal of applied ecology **45**(1): 361-370.
Category: Ecosystem services; Agriculture-induced impacts
Keywords: *Agri-environment schemes, Caelifera, conservation management, cutting frequency, Ensifera, fertilization, hay meadows, urbanization, Alps, Europe, wild biodiversity*

Abstract:
1. Several recent studies have considered the relative effects of local vs. landscape factors on diversity of several animal taxa in grasslands. However, very few have considered vascular plant or Orthoptera species, both of which are important biotic components of grassland ecosystems. The general aim of this study was to determine the effect of grassland management and landscape composition, and their potential interactions, on diversity patterns of vascular plants and Orthoptera in Alpine hay meadows.
2. We considered three groups of management regimes defined by different amounts of fertilizer nitrogen applied and cutting frequency: (i) extensive, (ii) low intensive and (iii) intensive meadows situated in different landscape contexts. To evaluate the relative importance of meadow management and landscape composition on diversity patterns, we applied analysis of covariance and variation partitioning analyses.
3. Diversity patterns of both taxonomic groups were affected primarily by grassland management. The extensive management regime was most suitable for conserving high species richness of both taxonomic groups. The intensive meadows were characterized by plant communities dominated by a few ruderal and competitor species, and by Orthoptera communities composed of only a few abundant Caelifera species (e.g. Chorthippus parallelus), while Ensifera species had very low individual densities.
4. Regarding the landscape determinants, plant diversity patterns were not significantly related to any landscape composition variables. In contrast, a high proportion of urban elements and grassland in the surrounding landscape (radius 500 m) affected Orthoptera species richness negatively.
5. Synthesis and applications. The implementation of well-targeted agri-environment schemes for compensation payments against intensification and abandonment of extensive hay meadows seems to be a promising tool to protect both taxonomic groups. In this context, we suggest that the existing Swiss ecological compensation area (ECA) hay meadow agri-environment scheme, which requires at least one cut every year and no fertilizer application, might also be suitable for the Italian Alps. Moreover, the significant influence of landscape composition on Orthoptera diversity suggests that the effectiveness of measures applied at a field scale may be improved by integration of protected area schemes, promoting extensive management at a farm scale.

Marini, L., S. Klimek and A. Battisti (2011). "Mitigating the impacts of the decline of traditional farming on mountain landscapes and biodiversity: a case study in the European Alps." Environmental Science & Policy **14**(3): 258-267.
Category: Agriculture-induced impacts
Keywords: *Agricultural change, agri-environment scheme, grassland, insect conservation,*

land use, plant diversity, farm size, traditional farming

Abstract: Taking a marginal area in the Italian Alps as a case study, we analysed the transition from traditional to modern dairy farming over the last decades. We explored potential causes and consequences of this process on land-use change, grassland farming, and biodiversity and proposed a regional agri-environment scheme (AES) to mitigate the impacts of the decline of traditional farming. Our results demonstrate that the number of traditional small farms strongly declines, being replaced by modern and larger farms. Despite previous studies showing a close relationship between this process and loss in grassland area, total meadow area does not change over the study period as modern farms progressively acquire the land formerly managed by traditional farms. Traditional farming systems are characterized by lower degree of specialization and use more environmentally friendly farming practices than modern systems. Importantly, our results indicate that the decline of traditional farming appears to be largely irreversible because it is closely linked to a broader process of social transformation. To mitigate this decline, we propose an AES that compensates farmers for keeping lower production of organic fertilizers at the farm scale and for maintaining the extensive management of steep meadows at the field scale. The proposed AES demonstrates to be positively related to both plant and insect diversity and might be easily implemented in future agri-environmental policy. However, we conclude that large and modern farms need to get more involved in biodiversity conservation as they will be the main actors in the future of Alpine farming.

Marten, G. G. (1988). "Productivity, stability, sustainability, equitability and autonomy as properties for agroecosystem assessment." Agricultural Systems **26**(4): 291-316.

Category: Agriculture-induced impacts; Ecosystem services

Keywords: *SUAN network, productivity, stability, sustainability, equitability, autonomy, agroecosystem assessment*

Abstract: The Southeast Asian Universities Agroecosystem network (SUAN) has used five system properties to assess agroecosystem performance: productivity, stability, sustainability, equitability and autonomy. Assessing these properties can be useful for agricultural research and development, but the assessment is complicated by several factors. First is the multidimensional character of these properties, due to (a) independent measures of agricultural production and (b) differences in the same property at different hierarchical levels of an agroecosystem. Secondly, there are significant limitations in generalizing agroecosystem assessment from one set of environmental and social conditions to another.

The SUAN network has examined trade-offs between these properties and implications of the trade-offs for agroecosystem design. Increases in productivity can be at the expense of other system properties, or they can be mutually reinforcing, depending on how the agroecosystem is organized.

Mastrangelo, M. and M. Gavin (2012). "Trade-offs between cattle production and bird conservation in an agricultural frontier of the Gran Chaco of Argentina." Conservation Biology **26**(6): 1040-1051.

Category: Agriculture-induced impacts

Keywords: *Dry forests, food production, land-use planning, silvopastoral systems*

Abstract: Intensification of food production in tropical landscapes in the absence of land-use planning can pose a major threat to biological diversity. Decisions on whether to spatially integrate or segregate lands for production and conservation depend in part on the functional relations between biological diversity and agricultural productivity. We measured diversity, density, and species composition of birds along a gradient of production intensification on an agricultural frontier of the Argentine Chaco, where dry tropical forests are cleared for cattle production. Bird species diversity in intact forests was higher than in any type of cattle-production system. Bird species richness decreased nonlinearly as cattle yield increased. Intermediate-intensity silvopastoral systems, those in which forest understory is selectively cleared to grow pastures of non-native plants beneath the tree canopy, produced 80% of the mean cattle yield obtained in pastures on cleared areas and were occupied by 70–90% of the number of bird species present in the nearest forest fragments. Densities of >50% of bird species were significantly lower in open pastures than in silvopastoral systems. Therefore, intermediate-intensity silvopastoral systems may have the greatest potential to sustain cattle yield and conserve a large percentage of bird species. However, compared with low-intensity production systems, in which forest structure and extent were intact, intermediate-intensity silvopastoral systems supported significantly fewer forest-restricted bird species and fewer frugivorous birds. These data suggest that the integration of production and conservation through intermediate-intensity silvopastoral systems combined with the protection of forest fragments may be required to maintain cattle yield, bird diversity, and conservation of forest-restricted species in this agricultural frontier.

Matson, P., W. Parton, A. Power and M. Swift (1997). "Agricultural intensification and ecosystem properties." Science **277**(5325): 504-509.

Category: Ecosystem services

Keywords: *Farmland, intensification, intensive farming, plant production, sustainability, ecologically-based management strategies*

Abstract: Expansion and intensification of cultivation are among the predominant global changes of this century. Intensification of agriculture by use of high-yielding crop varieties, fertilization, irrigation, and pesticides has contributed substantially to the tremendous increases in food production over the past 50 years. Land conversion and intensification, however, also alter the biotic interactions and patterns of resource availability in ecosystems and can have serious local, regional, and global environmental consequences. The use of ecologically based management strategies can increase the sustainability of agricultural production while reducing off-site consequences.

Matson, P. and P. Vitousek (2006). "Agricultural intensification: will land spared from farming be land spared for nature?" Conservation Biology **20**(3): 709-710.

Category: Policy; Ecosystem services

Keywords: *Land sparing, nature conservation, landscape, impacts*

Abstract: How can intensive agricultural systems be designed so that they have fewer and smaller impacts on surrounding ecosystems? This is not a new challenge, but its importance to conservation—particularly in developing regions—has become apparent in recent years. This chal- lenge is a major part of the ongoing effort to provide for the needs of a growing human population and at the same time sustain the life-support systems of the planet (Vitousek et al. 1997; National Resource Council 1999). To many in the conservation community, a growing human population makes the goal of harmonizing food production and conservation all but impossible. That psychological landscape has changed fundamentally, however— the end of human population growth is within sight over most of Earth (the peak population will be realized sooner and at a lower level with intensified, committed effort). Nevertheless, population will continue to grow for some decades. In many areas, standards of living and levels of nutrition will (and should) increase. What are the best ways to meet the dual challenges of agricultural production and conservation?

Many agronomists suggest that the best way to meet those challenges is through intensifying agriculture and increasing yields on the "best" lands. That way, the necessary production can be obtained on the smallest area of land and more land can be "saved for nature" (Wag- goner 1995). Intensification leading to increased yields per hectare provided most of the last doubling of agricultural production—and the potential for another doubling in yields now attracts both debate and research. An alternative pathway by which agricultural production and conservation could be harmonized is wildlife-friendly farming, which involves designing agricultural systems so that they support important components of biological di- versity within the agricultural landscape itself.

Maxted, N., S. Kell, Ã. l. Toledo, E. Dulloo, V. Heywood, T. Hodgkin, D. Hunter, L. Guarino, A. Jarvis and B. Ford-Lloyd (2010). "A global approach to crop wild relative conservation: securing the gene pool for food and agriculture." Kew Bulletin **65**(4): 561-576.

Category: Ecosystem services

Keywords: *Conservation, crop diversity, crop wild relatives, genetic diversity, plant genetic resources for food and agriculture*

Abstract: In light of the growing concern over the potentially devastating impacts on biodiversity and food security of climate change and the massively growing world population, taking action to conserve crop wild relatives (CWR), is no longer an option — it is a priority. Crop wild relatives are species closely related to crops, including their progenitors, many of which have the potential to contribute beneficial traits to crops, such as pest or disease resistance, yield improvement or stability. They are a critical component of plant genetic resources for food and agriculture (PGRFA), have already made major contributions to crop production and are vital for future food security; their systematic conservation in ways that ensure their continuing availability for use is therefore imperative. This is a complex, interdisciplinary, global issue that has been addressed by various national and international initiatives. Drawing on the lessons learnt from these initiatives we can now propose a global approach to CWR conservation, the key elements of which are:

(1) estimating global CWR numbers, (2) assessment of the global importance of CWR diversity, (3) current conservation status, (4) threats to CWR diversity, (5) systematic approaches to CWR conservation, (6) CWR informatics, and (7) enhancing the use of CWR diversity.

Mayers, J., C. Batchelor, I. Bond, R. Hope, E. Morrison and B. Wheeler (2009). Water ecosystem services and poverty under climate change: Key issues and research priorities. London, International Institute for Environment and Development (UK)

Category: Climate change

Keywords: *Water supply, environmental aspects, developing countries, research, Great Britain, climate change*

Introduction: Between October 2006 and July 2007 IIED steered a team that scoped a possible research programme for the UK Department for International Development (DFID) on freshwater ecosystem services and poverty reduction in the context of climate change and other drivers of change. The work identified key research areas and delivery mechanisms. It did this by: developing a drivers–state–impacts–response conceptual framework; seeking views from stakeholders internationally (334 web-survey respondents; 54 in-depth interviews); drawing key lessons from the literature; carrying out policy and practice analyses in key developing countries (Kenya, South Africa, India, Mexico and Bolivia); and capturing the results in this report to DFID.

The challenge addressed by this proposed research programme is a daunting one. Freshwater ecosystem services – the benefits obtained by people from freshwater ecosystems like rivers, swamps, floodplains and groundwater systems – are central to human well-being. But ecosystems are in trouble and the Millennium Ecosystem Assessment, the Comprehensive Assessment of Water Management in Agriculture, and the Intergovernmental Panel on Climate Change have each shown that freshwater ecosystem services are particularly vulnerable. Water problems for poor people are exacerbated by the abuse of ecosystem services and global climate change looks certain to increase the stresses and variability they face. The impacts will vary greatly by region, but the challenges to sustainable development in Africa are particularly acute.

Yet globally, we never destroy water – no matter how we use and abuse it: somewhere, sometime the rains will return. Water ecosystem services are the ultimate renewable resources and many promising solutions to the problems exist. The difficulty is in ensuring that water itself is where we need it, when we need it and of an acceptable quality. This requires efficient and equitable regimes for using the water that is available. In other words, it's all about how decisions are made about water ecosystem services – it's all about governance.

Water as a basic human right, and water left in stream to sustain environmental flows, are both necessary guiding principles yet characterise the tension at the heart of this subject. The adaptive capacity and resilience needed in the face of climate change and other further stressors to livelihoods, and the ever-increasing demand for water for food, fuel and forests, must be better understood and tackled. Key knowledge gaps can be filled by well-targeted research on how to secure regulatory and supporting services of ecosystems while doing most for poverty reduction.

Where river basins are 'closing' – with all water being used and residual flows reduced to a trickle – local conflicts and growing transboundary arguments demand more astute negotiating processes. Payments for water ecosystem services are tools that need further sharpening to be useful here and in other contexts where buyers and sellers become clear. The scale and type of investment needed to secure water ecosystem services is not hopelessly unachievable, but greatly improved governance will be needed to make such investment work. Integrated water resource management incorporating the full range of water ecosystem services remains a fine ideal for governance, but an elusive reality. Yet efforts to achieve higher levels of integration are sensible and innovative forms of research and delivery have great scope to help.

Mayfield, M. M., S. P. Bonser, J. W. Morgan, I. Aubin, S. McNamara and P. A. Vesk (2010). "What does species richness tell us about functional trait diversity? Predictions and evidence for responses of species and functional trait diversity to land-use change." Global Ecology and Biogeography **19**(4): 423-431.

Category: Ecosystem services

Keywords: *Community assembly, community ecology, conservation, diversity, ecosystem function, functional trait diversity, land-use change*

Abstract: In the conservation literature on land-use change, it is often assumed that land-use intensification drives species loss, driving a loss of functional trait diversity and ecosystem function. Modern research, however, does not support this cascade of loss for all natural systems. In this paper we explore the errors in this assumption and present a conceptual model taking a more mechanistic approach to the species–functional trait association in a context of land-use change. We provide empirical support for our model's predictions demonstrating that the association of species and functional trait diversity follows various trajectories in response to land-use change. The central premise of our model is that land-use change impacts upon processes of community assembly, not species per se. From the model, it is clear that community context (i.e. type of disturbance, species pool size) will affect the response trajectory of the relationship between species and functional trait diversity in communities undergoing land-use change. The maintenance of ecosystem function and of species diversity in the face of increasing land-use change are complementary goals. The use of a more ecologically realistic model of responses of species and functional traits will improve our ability to make wise management decisions to achieve both aims in specific at-risk systems.

McConnell, K., N. Bockstael, M. Karl-Gran and R. Jeffrey (2005). Chapter 14 Valuing the environment as a factor of production. Handbook of Environmental Economics, Elsevier. **Volume 2:** 621-669.

Category: Ecosystem services

Keywords: *Environment as an input in production, household production, applied welfare economics, environmental valuation, revealed preference methods*

Abstract: This chapter explores the theory and practice of measuring the economic costs and benefits of environmental changes that influence production, both in the

context of firms and of households. The theory uses models of household and firm decision making to map the influence of environmental changes to changes in human welfare. The goal is to measure, by compensating or equivalent changes in incomes, the welfare effects on people, in their roles as owners of firms, owners of factors of production, and consumers. The developing country context is most common for valuing the environment as an input, because agriculture and natural resource extraction are so much more important than in industrialized countries.

When households or firms produce goods for sale on the market, and the environment influences the costs of production, we show the circumstances when one can use information embodied in the supply curve of the marketed good or the demand curve for an input into the production of the good to extract welfare measures for environmental change. When the environment affects the cost of production of goods households produce and consume, we show the restrictions on production technology that will permit welfare measure for changes in the environment. We also look at circumstances that permit the calculations of bounds for the exact welfare measures. We explore welfare measurement under a variety of institutional structures, including government support for agricultural commodities and open-access fisheries. Exact welfare measurement makes extensive demands for data. Because these demands are not often met in practice, researchers resort to a variety of approximations of welfare measures. We assess these approximations, comparing them with the more exact measures.

McLaughlin, A. and P. Mineau (1995). "The impact of agricultural practices on biodiversity." Agriculture, Ecosystems & Environment **55**(3): 201-212.

Category: Agriculture-induced impacts

Keywords: *Biodiversity, tillage, drainage, intercropping, rotation, grazing, pesticides, fertilizers, pest regulation, soil nutrients/cycling*

Abstract: Agricultural activities such as tillage, drainage, intercropping, rotation, grazing and extensive usage of pesticides and fertilizers have significant implications for wild species of flora and fauna. Species capable of adapting to the agricultural landscape may be limited directly by the disturbance regimes of grazing, planting and harvesting, and indirectly by the abundance of plant and insect foods available. Some management techniques, such as drainage, create such fundamental habitat changes that there are significant shifts in species composition. This paper considers the relative merits of conventional tillage versus reduced, or no-till farming, and reviews the benefits of rest-rotation grazing, crop rotation and intercropping in terms of maintaining wild species populations.

There are a number of undesirable environmental impacts associated with fertilizer and pesticide usage, and in this paper we attempt to provide an account of the ways in which these inputs impact on biodiversity at various levels including plant, invertebrate, and vertebrate groups. Factors which are considered include the mobility, trophic interactions, persistence, and spectrum of toxicity for various pesticides. The ecological virtues of organic and inorganic fertilizers are compared, and the problems arising from excessive use of fertilizer are discussed.

The findings in this review indicate that chemical fertilizer loadings must be better budgeted to not exceed local needs, and that pesticide inputs should be reduced to

a minimum. The types and regimes of disturbance due to mechanical operations associated with agricultural activity may also be modified to help reduce negative impacts on particular groups of species, such as birds. For those plant and insect species which need to be controlled for agronomic reasons, the population decreases brought about by disturbance regimes may be desirable as a form of pest management. The prevalence of agriculture over such a large portion of the Canadian landscape means that it is important that we find solutions to conflicts that arise between agriculture and wild species.

It is important to realize that the impact of agricultural inputs varies greatly among regions and species, and actual effects have generally not been investigated for many species in any one locality; while the focus of this review is on Canada, much Canadian-specific research is lacking, thus, this review also draws from relevant research done elsewhere.

McNeely, J. A. and S. J. Scherr (2003). Ecoagriculture: strategies to feed the world and save wild biodiversity, Island Pr.

Category: Farmer and societal benefits

Keywords: *Wild biodiversity, status of and trends in wild species populations, food security, rural poverty reduction, agriculture and economic development*

Book Description from Amazon.com: Although food production systems for the world's rural poor typically have had devastating effects on the planet's wealth of genes, species and ecosystems, that need not be the case in the future. In this work, two experts on conservation and development examine the idea that agricultural landscapes can be designed more creatively to take the needs of human populations into account while also protecting, or even enhancing, biodiversity. They present a thorough overview of the innovative concept of "ecoagriculture" - the management of landscapes for both the production of food and the conservation of wild biodiversity. The book examines the global impact of agriculture on wild biodiversity; describes the challenge of reconciling biodiversity conservation and agricultural goals; outlines and discusses the ecoagriculture approach; presents diverse case studies that illustrate key strategies; and explores how policies, markets, and institutions can be re-shaped to support ecoagriculture.

Mediene, S., M. Valantin-Morison, J.-P. Sarthou, S. Tourdonnet, M. Gosme, M. Bertrand, J. Roger-Estrade, J.-N. Aubertot, A. Rusch, N. Motisi, C. Pelosi and T. Dore (2011). "Agroecosystem management and biotic interactions: a review." Agronomy for Sustainable Development **31**(3): 491-514.

Category: Ecosystem services

Keywords: *Biodiversity, cropping systems, crop management, diseases, ecosystem engineers organisms, habitats, landscape composition and configuration, natural enemy populations, nutrient cycling, pest control, soil/nutrient cycling, pest regulation*

Abstract: Increasing the use of synthetic fertilisers and pesticides in agroecosystems has led to higher crop yields, accompanied by a decline in biodiversity at the levels of field, cropping system and farm. Biodiversity decline has been favoured by changes at landscape level such as regional farm specialisation, increases in field size, and the

removal of hedgerows and woodlots. The loss of biodiversity in agroecosystems has increased the need for external inputs because beneficial functions are no longer provided by beneficial species as natural enemies of crop pests and ecosystem engineers. This trend has led to a strong reliance on petrochemicals in agroecosystems. However, many scientists have been arguing for more than two decades that this reliance on petrochemicals could be considerably reduced by a better use of biotic interactions. This article reviews options to increase beneficial biotic interactions in agroecosystems and to improve pest management and crop nutrition whilst decreasing petrochemical use. Four agronomic options are presented. First, it has been shown that the choice of cultivar, the sowing date and nitrogen fertilisation practices can be manipulated to prevent interactions between pests and crop, in either time or space. Nevertheless, the efficacy of these manipulations may be limited by pest adaptation. Second, beneficial biotic interactions may result from appropriate changes to the habitats of natural enemies and ecosystem engineers, mediated by soil and weed management. Here, knowledge is scarce, and indirect and complex effects are poorly understood. Third, changes achieved by crop diversification and, fourth, by landscape adaptation are promising. However, these practices also present drawbacks that may not necessarily be outweighed by beneficial effects. Overall, these four management approaches provide a powerful framework to develop sustainable agronomic practices.

Meehan, T., B. Werling, D. Landis and C. Gratton (2011). "Agricultural landscape simplification and insecticide use in the Midwestern United States." Proceedings of the National Academy of Sciences **108**(28): 11500-11505.

Category: Agriculture-induced impacts

Keywords: *Agriculture, biocontrol, crop pests, land cover change, pesticides, pest regulation*

Abstract: Agronomic intensification has transformed many agricultural landscapes into expansive monocultures with little natural habitat. A pervasive concern is that such landscape simplification results in an increase in insect pest pressure, and thus an increased need for insecticides. We tested this hypothesis across a range of cropping systems in the Midwestern United States, using remotely sensed land cover data, data from a national census of farm management practices, and data from a regional crop pest monitoring network. We found that, independent of several other factors, the proportion of harvested cropland treated with insecticides increased with the proportion and patch size of cropland and decreased with the proportion of seminatural habitat in a county. We also found a positive relationship between the proportion of harvested cropland treated with insecticides and crop pest abundance, and a positive relationship between crop pest abundance and the proportion cropland in a county. These results provide broad correlative support for the hypothesized link between landscape simplification, pest pressure, and insecticide use. Using regression coefficients from our analysis, we estimate that, across the seven-state region in 2007, landscape simplification was associated with insecticide application to 1.4 million hectares and an increase in direct costs totaling between $34 and $103 million. Both the direct and indirect environmental costs of landscape simplification should be considered in design of land use policy that balances

multiple ecosystem goods and services.

Merckx, T., L. Marini, R. Feber and D. Macdonald (2012). "Hedgerow trees and extended-width field margins enhance macro-moth diversity: implications for management." Journal of applied ecology **49**(6): 1396-1404.

Category: Ecosystem services

Keywords: *Agri-environment schemes, biodiversity, Action Plan, priority species, conservation status, farmland biodiversity, farmland restoration ecology, farmland rewilding, feeding guild, Lepidoptera, moth mobility, multiple spatial scales, pest regulation, landscape simplification*

Summary

Improving the effectiveness of agri-environment schemes is essential for reversing declines in farmland biodiversity. Crucial to achieving this is identifying management options that are practical and beneficial to biodiversity, and understanding the influence of the surrounding landscape. We used data on abundance and species richness of farmland macro-moths, many of which are declining, and trait-based analyses on their feeding guild, mobility and conservation status, to explore local- and landscape-scale effects of two farmland features (extended-width field margins and hedgerow trees) and surrounding farmland intensification.

Macro-moths were light trapped at 48 fixed sites on 16 farms, over 4 years, within a 1200-km2 area of lowland UK farmland. Sites belonged to one of four experimental groups that differed in their combinations of hedgerow tree presence and field margin width.

Hedgerow trees and extended-width field margins locally increased species richness, but not abundance, of macro-moths, irrespective of each other's presence. Overall, species richness and abundance were not affected by agricultural intensification, as measured by the amount of arable land in the surrounding landscape.

Sedentary moths showed double the species richness, but were half as abundant as mobile moths. Both groups responded positively to extended-width margin and hedgerow tree presence. The effect of hedgerow trees was particularly strong for shrub- and/or tree-feeding species.

Analyses based on the conservation status of moths demonstrated that agricultural intensification lowered the species richness of nationally severely declining UK Biodiversity Action Plan priority species and the abundance of both nationally moderately declining and priority species. These effects were most pronounced at the 0·8-km radius scale.

Synthesis and applications. Our results suggest that the presence of extended-width field margins and hedgerow trees, possibly promoted by agri-environment schemes targeting their implementation at relatively small spatial scales (0·8 km), may help mitigate negative effects of agricultural intensification on macro-moths. A wide range of other taxa feed on macro-moths and may therefore indirectly benefit from these features. Nevertheless, taxa differ widely in their mobility and measures mitigating biodiversity loss may need to be targeted at multiple spatial scales to maximize their effectiveness for multiple taxa.

Meyer, K., M. Vos, W. Mooij, W. Gera Hol, A. Termorshuizen, L. Vet and W. Van Der Putten (2009). "Quantifying the impact of above- and belowground higher trophic levels on plant and herbivore performance by modeling." Oikos **118**(7): 981-990.

Category: Ecosystem services

Keywords: *Succession, sustainable crop protection, invasion, global change, temporal and spatial models, soil/nutrient cycling, pest regulation*

Abstract: Growing empirical evidence suggests that aboveground and belowground multitrophic communities interact. However, investigations that comprehensively explore the impacts of above- and belowground third and higher trophic level organisms on plant and herbivore performance are thus far lacking. We tested the hypotheses that above- and belowground higher trophic level organisms as well as decomposers affect plant and herbivore performance and that these effects cross the soil–surface boundary. We used a well-validated simulation model that is individual-based for aboveground trophic levels such as shoot herbivores, parasitoids, and hyperparasitoids while considering belowground herbivores and their antagonists at the population level. We simulated greenhouse experiments by removing trophic levels and decomposers from the simulations in a factorial design. Decomposers and above- and belowground third trophic levels affected plant and herbivore mortality, root biomass, and to a lesser extent shoot biomass. We also tested the effect of gradual modifications of the interactions between different trophic level organisms with a sensitivity analysis. Shoot and root biomass were highly sensitive to the impact of the fourth trophic level. We found effects that cross the soil surface, such as aboveground herbivores and parasitoids affecting root biomass and belowground herbivores influencing aboveground herbivore mortality. We conclude that higher trophic level organisms and decomposers can strongly influence plant and herbivore performance. We propose that our modelling framework can be used in future applications to quantitatively explore the possible outcomes of complex above- and belowground multitrophic interactions under a range of environmental conditions and species compositions.

Meyling, N. and J. Eilenberg (2007). "Ecology of the entomopathogenic fungi Beauveria bassiana and Metarhizium anisopliae in temperate agroecosystems: Potential for conservation biological control." Biological Control **43**(2): 145-155.

Category: Ecosystem services

Keywords: *Ecosystem services, field margins, functional biodiversity, pest control, population dynamics, natural enemies, pest regulation*

Abstract: It is increasingly recognized that the biodiversity in agroecosystems deliver significant ecosystem services to agricultural production such as biological control of pests. Entomopathogenic fungi, specifically the anamorphic taxa Beauveria bassiana and Metarhizium anisopliae, Hypocreales (Ascomycota), are among the natural enemies of pests in agroecosystems and the fungi are candidates for future conservation biological control in temperate regions. Conservation biological control is a biological control strategy in which farming practices and environmental manipulations are adopted to enhance the living conditions for specific natural enemies of pests. However, in order to manipulate the environment for the benefit of populations of the entomopathogens, knowledge of fundamental aspects of the

ecology of the fungi considered is necessary. This knowledge is still scarce despite the large bulk of recent research into inoculation and inundation biological control with these fungi. Here, we review the current knowledge of the ecology of indigenous populations of B. bassiana and M. anisopliae in agroecosystems of temperate regions, primarily Europe and North America. We suggest anamorphic life cycles of B. bassiana and M. anisopliae in these regions based on the literature of their natural occurrence and distribution in agroecosystems, population dynamics, and interactions with other organisms, environmental factors, and agronomical practices.

Miller, N., A. Estoup, S. Toepfer, D. Bourguet, L. Lapchin, S. Derridj, K. S. Kim, P. Reynaud, L. Furlan and T. Guillemaud (2005). "Multiple Transatlantic Introductions of the Western Corn Rootworm." Science **310**(5750): 992.

Category: Agriculture-induced impacts

Keywords: *Pest, Invertebrata, Arthropoda, Insecta, Coleoptera, Chrysomelidae, Europe, Diabrotica virgifera, invasion, invasive species, animal accidental introduction, wild biodiversity, pest regulation*

Abstract: The invasion of Europe by the western corn rootworm, North America's most destructive corn pest, is ongoing and represents a serious threat to European agriculture. Because this pest was initially introduced in Central Europe, it was believed that subsequent outbreaks in Western Europe originated from this area. Using model-based Bayesian analyses of the genetic variability of the western corn rootworm, we demonstrate that this belief is false: There have been at least three independent introductions from North America during the past two decades. This result raises questions about changing circumstances that have enabled a sudden burst of transatlantic introductions.

Moeskops, B., D. Murphy-Bokern and L. Levidow (2012). Report on EU Commission Conference Organic and Low Input Agriculture: Implementing innovation to respond to EU challenges. Larnaca, TP Organics - The Open University**:** 7.

Category: Ecosystem services

Keywords: *Organic agriculture, low input agriculture, ecofunctional intensification, research and innovation, TP organics, biodiversity, public health, Europe, ecological intensification*

Abstract: This report discusses how the European organic research community might position itself as we move forward into Horizon 2020 and the European Innovation Partnership for Agricultural Productivity and Sustainability (EIP Agriculture). Based on the discussions at the conference in Larnaca, this paper considers how the European Commission could draw on this research community to implement these policy frameworks. The main conclusions drawn from contributions to the conference can be summarised as follows:

The organic sector has grown significantly over the last decades and has become one of the most successful branches of the food and farming sector in the EU. Besides its direct positive impact on the environment, animal welfare and rural development, the organic sector continuously inspires other food systems to become more

sustainable. Therefore the further development of the organic sector is in the interest of the EU. Research & innovation support for the organic sector should be increased.

The organic research community has maintained research capacity in areas that were low priority to the wider agricultural research community over the last twenty years. Many of these research areas are now seen as of wider strategic significance.

Future EU-funded agricultural research & innovation should be guided by the concepts of eco-functional intensification and agro-ecology. Eco-functional intensification means making good use of beneficial ecosystem functions, such as biodiversity and soil fertility, and also maintaining these services. It is part of the wider concept of agro-ecology, which deals with the sustainability of the whole food system. Promoting eco-functional intensification and agro-ecology would significantly reduce the need for external inputs and reduce negative externalities. Such promotion efforts depend on combining four types of innovation – technological, know-how, organisational and social.

Besides the integration of organic principles, such as eco-functional intensification, in the wider agro-food system, EU research funds should also support the further development of specific methods and techniques directly relevant to the EU regulation for organic farming.

A funding line of 5% of the proposed budget for agricultural research & innovation should be established for organic farming research & innovation. This figure corresponds to the 5% of agricultural land organically managed in the EU. The organic sector has the potential to account for 15-20% of agricultural land.

In order to address the real needs of organic and low-input farming, appropriate participatory research approaches should be used. This requires much time on the part of researchers and of practitioners, who should appropriately be rewarded for the time invested.

Knowledge exchange for organic and low-input farming should be improved. The European Commission can support this by establishing a dedicated thematic network under the EIP Agriculture and/or by funding a knowledge management platform for the organic and low-input agriculture sector under Horizon 2020

TP Organics, the research and technology platform for organic food and farming, has been very instrumental over the last years in identifying the research & innovation needs of the sector. It should be officially recognised as a European Technology Platform (ETP) by the European Commission.

Mokany, K., J. Ash and S. Roxburgh (2008). "Functional identity is more important than diversity in influencing ecosystem processes in a temperate native grassland." Journal of Ecology **96**(5): 884-893.

Category: Ecosystem services

Keywords: *Biodiversity, biomass, decomposition, functional traits, light interception, productivity, soil moisture, soil nutrients/cycling*

Abstract:

1. Experimental studies have provided significant knowledge of how biodiversity can influence ecosystem processes. However, there is a growing need to relate these findings to natural communities.

2. Here we identify two major hypotheses for how communities may influence ecosystem processes: the 'diversity hypothesis' (the diversity of organisms in a community influences ecosystem processes through mechanisms such as complementary resource use), and the 'mass ratio hypothesis' (ecosystem processes are determined overwhelmingly by the functional traits of the dominant species). We then test which of these two hypotheses best explain variation in ecosystem properties and processes (biomass pools and fluxes, water use, light interception) in a temperate native grassland. We do this by applying various measures of diversity, functional diversity, and functional identity, whose significant relations with ecosystem processes would support either of the competing hypotheses.
3. Mean trait values best explained variation in five of the eight ecosystem processes examined, supporting Grime's mass ratio hypothesis, which proposes that the functional identities of the dominant species largely determine ecosystem processes.
4. Multi-trait functional diversity indices also explained large amounts of variation in ecosystem processes, while only weak relationships were observed between species richness and ecosystem processes.
5. To explore the mechanistic interactions between variables, we developed structural equation models (SEMs), which indicated that many of the community diversity and trait properties significantly influenced ecosystem processes, even after accounting for co-varying biotic/abiotic factors.
6. Synthesis. Our study is one of the first explicit comparisons of the 'diversity' and 'mass ratio' hypotheses, and our results most strongly support the mass ratio hypothesis, that is, the traits of the dominant species most influenced the ecosystem properties and processes examined. Our results suggest that the management of communities for the maintenance of ecosystem processes should focus on species dominance hierarchies.

Montoya, D., L. Rogers and J. Memmott (2012). "Emerging perspectives in the restoration of biodiversity-based ecosystem services." Trends in ecology & evolution **27**(12): 666-672.
Category: Ecosystem services
Keywords: *Restoration science, landscape scale and meta-communities, ecology, cost-efficient monitoring, ecosystem functionality, pollination*

Abstract: Given the large-scale anthropogenic alteration of natural habitats, ecological restoration is emerging as one of the most important disciplines in environmental science. Once habitats are physically restored, an important goal of restoration is to recover the ecosystem services pro-vided by the diversity of species and their interactions (e.g., seed dispersal, pollination, pest control, and inva- sion resistance). However, current understanding of the ecological processes underlying this recovery is often incomplete and poorly integrated across different ecosystems. Here, we highlight recent conceptual findings in biodiversityecosystem functioning, food-web theory, and metacommunity theory that are relevant to restoration. We also identify knowledge gaps that will contribute to moving restoration from a site- and situation-specific discipline to a more globally applicable science.

Montpellier Panel 2013 (2013). Sustainable intensification: A new paradigm for African

Agriculture. T. M. P. Report. London.
Category: Policy; Ecosystem services
Keywords: *Sustainable intensification, Africa*

Abstract: In a world where natural resources are in short supply at the same time as almost one in four people in Africa suffer from chronic hunger, the Montpellier Panel believes that a new paradigm to tackle food insecurity is urgently needed.

Sustainable Intensification offers a practical pathway towards the goal of producing more food with less impact on the environment, intensifying food production while ensuring the natural resource base on which agriculture depends is sustained, and indeed improved, for future generations.

In sub-Saharan Africa (SSA) a rapidly growing population and increasing food demand, alongside scarcities in resources such as land, water and soil fertility, are compounded by stagnant yields for some crops and alarmingly high rates of hunger and malnutrition. Many of the farming systems in Africa are far from their productive potential while accelerated economic growth in Africa now offers demand-side opportunities for agriculture.

Intensification of production can take many forms. The current model has served us well for a hundred years or more, including its underpinning of the Green Revolution of the 1960s and 1970s that kept food production in pace with population growth. But the context has radically changed. Our current food crisis – recurrent food prices spikes, the existence of about a billion chronically hungry and the need to feed a growing, more prosperous population in the face of threats from climate change – is not a transient affair. Moreover, conventional intensification is not a viable solution if it comes at the expense of the environmental and social resources on which it depends. We need radical measures and new paradigms.

One such paradigm is Sustainable Intensification. This pathway strives to utilise the existing land to produce greater yields, better nutrition and higher net incomes while reducing over reliance on pesticides and fertilisers and lowering emissions of harmful greenhouse gases. It also has to do this in a way that is both efficient and resilient and contributes to the stock of natural environmental capital.

None of the components of this paradigm are new. They comprise techniques of ecological and genetic intensification, within enabling environments created by processes of socio-economic intensification. What is new in this report is the way in which they are combined as a framework to find appropriate solutions to Africa's food and nutrition crisis.

Moore, J. and P. de Ruiter (1991). "Temporal and spatial heterogeneity of trophic interactions within below-ground food webs." Agriculture, Ecosystems & Environment **34**(1-4): 371-397.
Category: Ecosystem services
Keywords: *Food webs, trophic interactions, soil, integrated farming systems, conventional farming systems, soil nutrients/cycling*

Abstract: Real food webs are dynamic multi-dimensional systems, whereas the descriptions of real food webs often do not capture this complexity in that they have been confined to a single habitat (the community web sensu Cohen, 1978) and do not represent changes in time (Paine, 1988). We present an analytical approach that

uses univariate and multivariate statistics and simulation modeling to study pattern within food webs. As an illustration of the approach, we compared below-ground food webs from natural and agricultural ecosystems in terms of their architecture, temporal dynamics of the biomass of functional groups, and the temporal and spatial dynamics of energy channels. The complexity and diversity of below-ground food webs are similar to the detritus-based food webs of other terrestrial and aquatic habitats. The pattern of the flow of nitrogen through the below-ground food webs of the Shortgrass Steppe of North America is similar to that of the food web of agricultural soils of reclaimed marine sediments in The Netherlands. The webs are compartmented along dominant flows of energy (energy channels) originating from primary production and detritus. Comparisons of the connectedness descriptions, and implementations of cluster analysis, canonical discriminant analysis and analysis of variance of temporal biomass of functional groups within food webs of soils from North America and The Netherlands, indicate that the detritus energy channel can be further compartmented into a fungal and bacterial channel. For winter wheat soils in The Netherlands, the degree of compartmentalization appears to depend on management practice. Consumers of fungi were separated in time from consumers of bacteria in the integrated management practice, while little separation was observed in conventional practice. Our study indicates (1) that analyses of food webs should aim to project the web onto the principal niche dimensions food, habitat and time, and (2) that quantitative measures of community structure — identification of functional groups, the biomass and productivity of functional groups, and the flow of nutrients within energy channels — are useful measures of food web structure.

Morris, A., J. Hegarty, A. Baldi and T. Robijns (2011). "Setting aside farmland in Europe: The wider context." Agriculture, Ecosystems & Environment **143**(1): 1-2.

Category: Policy; Ecosystem services

Keywords: *Conservation, farmland*

Editorial, first two paragraphs: There are many reasons why farmers choose, or are obliged, to take sections of land out of production, resulting in different forms of fallow (Kleijn and Baldi, 2005). In the age of inorganic inputs, fallow land plays a lesser role in rebuilding soil fertility and tackling pest and weed problems, but for some, e.g. organic farmers, it is still important.

In recent times, the most well known, perhaps even infamous, form of fallow land is the set-aside scheme under Pillar One (mar- ket support measures and direct subsidies to producers) of the Common Agricultural Policy (CAP). This obliged farmers across the European Union (EU) to take land out of production in an attempt to curb the inevitable crop surpluses that accompanied production linked subsidies. Pillar One set-aside was managed in accordance with rules governing establishment of green covers (by natural regeneration, sowing, or for non-food crops), inputs (pesticides, organic and inorganic fertilizers), cutting and cultivation. Originally introduced in the EU15 countries in 1988 as a voluntary measure, Pillar One set-aside became compulsory, although still financially compensated, after the 1992 CAP reforms. The amount of fallow varied but affected on average 10% of arable land annually. Pil- lar One set-aside was not an environmental measure, and not all such set-aside provided clear environmental benefits (e.g. EU rules allowed the cultivation

of crops for industrial use on set-aside land) but it was able to inject landscape heterogeneity in the form of fal- lows into intensively managed arable landscapes across much of Europe.

Mulder, I. and T. Koellner (2011). "Hardwiring green: how banks account for biodiversity risks and opportunities." Journal of Sustainable Finance & Investment **1**(2): 103-120.
Category: Ecosystem services
Keywords: *Biodiversity, bank, business opportunity, business risks, ecosystem, financial institution, genetic diversity*

Abstract: This article aims at providing better insight into the way in which banks currently deal with biodiversity in their business operations, what their underlying motivations are for doing so, and how the banking sector perceives biodiversity as a business risk or opportunity. Analysis of publicly available information telephone interviews and a questionnaire revealed that only five of the 50 banks have taken considerable steps to account for biodiversity risks and opportunities on an organizational level and within lending portfolios (scores higher than 67%). Most banks, however, remain at the starting grid, with scores to address biodiversity issues on a group or holding level and within lending products and services lower than 33%. In terms of risks related to biodiversity, banks believe that their sector is primarily exposed to reputational risk and, perhaps surprisingly, to credit risk. Motivations for banks to develop policies to account for biodiversity centre on reducing reputational risk and the wish to act ecologically responsible, while being able to differentiate from competitors is seen as a major business opportunity.

Muradian, R. and L. Rival (2013). Governing the provision of ecosystem services. Dordrecht, Springer.
Category: Policy
Keywords: *Ecological Life-cycle Assessment, environmental accounting, ecosystem services, subsidies, bounties, sustainability*

Abstract: Founded on the core notion that we have reached a turning point in the governance, and thus the conservation, of ecosystems and the environment, this edited volume features more than 20 original chapters, each informed by the paradigm shift in the sector over the last decade. Where once the emphasis was on strategies for conservation, enacted through instruments of control such as planning and 'polluter pays' legislation, more recent developments have shown a shift towards incentive-based arrangements aimed at those responsible for providing the environmental services enabled by such ecosystems. Encouraging shared responsibility for watershed management, developed in Costa Rica, is a prime example, and the various interests involved in its instauration in Java are one of the subjects examined here.

Other topics including the interplay between property rights and bioprospecting (a live issue in places where but a small proportion of the insect and plant life has been identified). Other issues explored include the management of marine protected areas, and the controversial issue of payment for ecosystem services. Offering a

comprehensive and worldwide perspective on the burgeoning research being devoted to the topic, the authors show how former divisions and dichotomies between state and market, regulation and incentive, or conservation and development, are being broken down by a growing and urgent sense that solutions must be decentralized, more flexible, and more on polycentric institutional arrangements.

Nascimbene, J., L. Marini and M. Paoletti (2012). "Organic farming benefits local plant diversity in vineyard farms located in intensive agricultural landscapes." Environmental Management **49**(5): 1054-1060.

Category: Agriculture-induced impacts

Keywords: *Conventional farming, disturbance, grassland strip, hedgerow, herbicide, semi-natural habitats, pest regulation, organic agriculture*

Abstract: The majority of research on organic farming has considered arable and grassland farming systems in Central and Northern Europe, whilst only a few studies have been carried out in Mediterranean agro-systems, such as vineyards, despite their economic importance. The main aim of the study was to test whether organic farming enhances local plant species richness in both crop and non-crop areas of vineyard farms located in intensive conventional landscapes. Nine conventional and nine organic farms were selected in an intensively cultivated region (i.e. no gradient in landscape composition) in northern Italy. In each farm, vascular plants were sampled in one vineyard and in two non-crop linear habitats, grass strips and hedgerows, adjacent to vineyards and therefore potentially influenced by farming. We used linear mixed models to test the effect of farming, and species longevity (annual vs. perennial) separately for the three habitat types. In our intensive agricultural landscapes organic farming promoted local plant species richness in vineyard fields, and grassland strips while we found no effect for linear hedgerows. Differences in species richness were not associated to differences in species composition, indicating that similar plant communities were hosted in vineyard farms independently of the management type. This negative effect of conventional farming was probably due to the use of herbicides, while mechanical operations and mowing regime did not differ between organic and conventional farms. In grassland strips, and only marginally in vineyards, we found that the positive effect of organic farming was more pronounced for perennial than annual species.

Nelson, E., G. Mendoza, J. Regetz, S. Polasky, H. Tallis, D. Cameron, K. Chan, G. Daily, J. Goldstein, P. Kareiva, E. Lonsdorf, R. Naidoo, T. Ricketts and M. Shaw (2009). "Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales." Frontiers in Ecology and the Environment **7**(1): 4-11.

Category: Ecosystem services

Keywords: *Modeling, ecosystem services, biodiversity conservation, commodity production, landscape*

Abstract: Nature provides a wide range of benefits to people. There is increasing consensus about the importance of incorporating these “ecosystem services” into resource management decisions, but quantifying the levels and values of these

services has proven difficult. We use a spatially explicit modeling tool, Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), to predict changes in ecosystem services, biodiversity conservation, and commodity production levels. We apply InVEST to stakeholder-defined scenarios of land-use/land-cover change in the Willamette Basin, Oregon. We found that scenarios that received high scores for a variety of ecosystem services also had high scores for biodiversity, suggesting there is little tradeoff between biodiversity conservation and ecosystem services. Scenarios involving more development had higher commodity production values, but lower levels of biodiversity conservation and ecosystem services. However, including payments for carbon sequestration alleviates this tradeoff. Quantifying ecosystem services in a spatially explicit manner, and analyzing tradeoffs between them, can help to make natural resource decisions more effective, efficient, and defensible.

Neumann, K., P. Verburg, E. Stehfest and C. Muler (2010). "The yield gap of global grain production: A spatial analysis." Agricultural Systems **103**(5): 316-326.
Category: Policy; Ecosystem services
Keywords: *Grain production, yield gap, land management, intensification, inefficiency, frontier analysis*

Abstract: Global grain production has increased dramatically during the past 50 years, mainly as a consequence of intensified land management and introduction of new technologies. For the future, a strong increase in grain demand is expected, which may be fulfilled by further agricultural intensification rather than expansion of agricultural area. Little is known, however, about the global potential for intensification and its constraints. In the presented study, we analyze to what extent the available spatially explicit global biophysical and land management-related data are able to explain the yield gap of global grain production. We combined an econometric approach with spatial analysis to explore the maximum attainable yield, yield gap, and efficiencies of wheat, maize, and rice production. Results show that the actual grain yield in some regions is already approximating its maximum possible yields while other regions show large yield gaps and therefore tentative larger potential for intensification. Differences in grain production efficiencies are significantly correlated with irrigation, accessibility, market influence, agricultural labor, and slope. Results of regional analysis show, however, that the individual contribution of these factors to explaining production efficiencies strongly varies between world-regions.

Nielsen, A., J. Dauber, W. E. Kunin, E. Lamborn, B. Jauker, M. Moora, S. G. Potts, T. Reitan, S. Roberts, V. SÃµber, J. Settele, I. Steffan-Dewenter, J. C. Stout, T. Tscheulin, M. Vaitis, D. Vivarelli, J. C. Biesmeijer and T. Petanidou (2012). "Pollinator community responses to the spatial population structure of wild plants: A pan-European approach." Basic and Applied Ecology **13**(6): 489-499.
Category: Ecosystem services
Keywords: *Fragmentation, mutualistic interactions, pollinator assemblages, spatial distribution, spatial scale, bees, hoverflies, hierarchical modelling, Bayesian*

inference, pollination

Abstract: Land-use changes can alter the spatial population structure of plant species, which may in turn affect the attractiveness of flower aggregations to different groups of pollinators at different spatial scales. To assess how pollinators respond to spatial heterogeneity of plant distributions and whether honeybees affect visitation by other pollinators we used an extensive data set comprising ten plant species and their flower visitors from five European countries. In particular we tested the hypothesis that the composition of the flower visitor community in terms of visitation frequencies by different pollinator groups were affected by the spatial plant population structure, viz. area and density measures, at a within-population ('patch') and among-population ('population') scale. We found that patch area and population density were the spatial variables that best explained the variation in visitation frequencies within the pollinator community. Honeybees had higher visitation frequencies in larger patches, while bumblebees and hoverflies had higher visitation frequencies in sparser populations. Solitary bees had higher visitation frequencies in sparser populations and smaller patches. We also tested the hypothesis that honeybees affect the composition of the pollinator community by altering the visitation frequencies of other groups of pollinators. There was a positive relationship between visitation frequencies of honeybees and bumblebees, while the relationship with hoverflies and solitary bees varied (positive, negative and no relationship) depending on the plant species under study. The overall conclusion is that the spatial structure of plant populations affects different groups of pollinators in contrasting ways at both the local ('patch') and the larger ('population') scales and, that honeybees affect the flower visitation by other pollinator groups in various ways, depending on the plant species under study. These contrasting responses emphasize the need to investigate the entire pollinator community when the effects of landscape change on plant–pollinator interactions are studied.

Nielsen, U., E. Ayres, D. Wall and R. Bardgett (2011). "Soil biodiversity and carbon cycling: a review and synthesis of studies examining diversity–function relationships." European Journal of Soil Science **62**(1): 105-116.

Category: Ecosystem services

Keywords: *Soils, soil science, Earth science, carbon cycle, species diversity, soil nutrients/cycling*

Abstract: Biodiversity and carbon (C) cycling have been the focus of much research in recent decades, partly because both change as a result of anthropogenic activities that are likely to continue. Soils are extremely species-rich and store approximately 80% of global terrestrial C. Soil organisms play a key role in C dynamics and a loss of species through global changes could influence global C dynamics. Here, we synthesize findings from published studies that have manipulated soil species richness and measured the response in terms of ecosystem functions related to C cycling (such as decomposition, respiration and the abundance or biomass of decomposer biota) to evaluate the impact of biodiversity loss on C dynamics. We grouped studies where one or more biotic groups had been manipulated to include a richness of ≤10 species or >10 species in order to reflect 'low' and 'high' extents of diversity manipulations. There was a positive relationship between species richness

and C cycling in 77–100% of low-diversity experiments, even when the richness of just one biotic group was manipulated, whereas positive relationships occurred less frequently in studies with greater richness (35–64%). Moreover, when positive relationships were observed, these often indicated functional redundancy at low extents of diversity or that community composition had a stronger influence on C cycling than did species richness. Initial reductions in soil species richness resulting from global changes are unlikely to alter C dynamics significantly unless particularly influential species are lost. However, changes in community composition, and the loss of species with an ability to facilitate specialized soil processes related to C cycling, as a result of global changes, may have larger impacts on C dynamics.

Niemela, J., J. Young, D. Alard, M. Askasibar, K. Henle, R. Johnson, M. Kurttila, T.-B. Larsson, S. Matouch, P. Nowicki, R. Paiva, L. Portoghesi, R. Smulders, A. Stevenson, U. Tartes and A. Watt (2005). "Identifying, managing and monitoring conflicts between forest biodiversity conservation and other human interests in Europe." Forest Policy and Economics **7**(6): 877-890.

Category: Policy

Keywords: *Forest conflicts, conflict management, forest biodiversity*

Abstract: In this paper, circumstances where various human activities and interests clash with the conservation of forest biodiversity are examined, with particular focus on the drivers behind the conflicts. After identifying past and current human-related threats potentially leading to conflicts in forests, the paper will focus on conflict management and monitoring, with an emphasis on inclusionary stakeholder networks and a range of approaches towards sustainable land use. Three dimensions of conflicts are examined: substance ('how things are'), procedure ('how things are done'), and relationships ('how people behave'). These relations will relate to three conflict management approaches: (1) technical, which may contribute to reduce or solve the conflict acting on the 'substance' dimension, (2) political, which may influence the 'procedure' dimension of the conflict establishing principles or rules, and (3) cultural, which may affect the 'relationship' dimension of the conflict. Finally, a general model of adaptive conflict management emphasising communication among the parties and a participatory approach that involves monitoring of the conflict resolution outcomes is proposed. The recognition that strong perceptions among stakeholders have the potential to aggravate conflicts is central to the concept of a inclusionary conflict management framework, improved communication between all stakeholders, and better awareness of the context of the conflicts is emphasised.

Niggli, U., A. Slabe, O. Schmid, N. Halberg and M. Schlüter (2008). Vision for an Organic Food and Farming Research Agenda 2025. Organic Knowledge for the Future, IFOAM-EU and FiBL**:** 48.

Category: Policy

Keywords: *Organic food and farming, EU, research communication, policy, challenges and trends, Technology Platform*

Abstract: Research is one of the most important tools for the further development

and spread of organic food and farming. It is thus important that the EU re- search programme provides adequate support for organic food and farming research. Organic agriculture and food production are innovative learning fields for sustainability and are therefore of special interest to European societies.

This Vision Paper was prepared between June 2007 and August 2008 on the basis of wide- ranging discussions with farmers' organizations, scientists, organic traders and retailers, and EU- wide umbrella organizations representing a variety of commercial, non-commercial and civil interests. The Vision Paper i) shows the strengths and weaknesses of organic food and farming, ii) identifies five global and European challenges and trends on which food and farming research should focus, iii) groups the strategic priorities of future research and iv) highlights a large number of specific research activities for the future.

Norris, K., S. Potts and S. Mortimer (2010). Chapter 3 Ecosystem services and food production. Ecosystem Services, The Royal Society of Chemistry. **30:** 52-69.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Food production systems, ecosystem services, impacts*

Book summary: As human populations grow, so do the resource demands imposed on ecosystems and the impacts of anthropogenic use and abuse are becoming ever more apparent. Consequently, society at large is coming to realize that ecosystem services are not threatened and limited, but that the pressure to evaluate trade-offs between immediate and long-term human needs is urgent. To help inform decision-makers, economic value is increasingly being associated with many ecosystem services and is often based on the replacement with anthropogenic alternatives. The on-going challenge of prescribing economic value to nature, such as through processes like biodiversity banking, is prompting multi-disciplinary shifts in how we recognize and manage the environment, social responsibility, business opportunities, and our future as a species. This comprehensive book brings together emerging topics in environmental science, making an excellent source for policy makers and environmental consultants working in the field or related areas. It also serves as a concise and fully referenced primer for advanced environmental students and researchers.

Chapter Summary: By 2030, the world's human population could rise to 8 billion people and world food demand may increase by 50%. Although food production outpaced population growth in the 20th century, it is clear that the environmental costs of these increases cannot be sustained into the future. This challenges us to re-think the way we produce food. We argue that viewing food production systems within an ecosystems context provides the basis for 21st century food production. An ecosystems view recognises that food production systems depend on ecosystem services but also have ecosystem impacts. These dependencies and impacts are often poorly understood by many people and frequently overlooked. We provide an overview of the key ecosystem services involved in different food production systems, including crop and livestock production, aquaculture and the harvesting of wild nature. We highlight the important ecosystem impacts of food production systems, including habitat loss and degradation, changes to water and nutrient cycles across a range of scales, and biodiversity loss. These impacts often undermine

the very ecosystem services on which food production systems depend, as well as other ecosystem services unrelated to food. We argue that addressing these impacts requires us to re-design food production systems to recognise and manage the limitations on production imposed by the ecosystems within which they are embedded, and increasingly embrace a more multi-functional view of food production systems and associated ecosystems. In this way, we should be able to produce food more sustainably whilst inflicting less damage on other important ecosystem services.

OECD (2001). Environmental Indicators for Agriculture. Methods and Results. Paris. **3:** 400.
Category: Agriculture-induced impacts
Keywords: *Agri-environmental indicators, OECD, agriculture, farm financial resources, environmental impacts, farm management, inputs, natural resources*

Highlights:

The impacts of agriculture on the environment are of major public concern, in the context of agricultural policy reform, trade liberalisation, international environmental agreements and the achievement of sustainable agriculture. Monitoring the environmental performance of agriculture and assessing the environmental effects of policies requires information on agri-environmental interactions.

This Report is a stocktaking of results in measuring the environmental performance of agriculture to address a range of agri-environmental areas considered of policy relevance to OECD member countries. The Report is primarily aimed at policy makers, other stakeholders and the wider public, including non- member OECD countries, interested in recent developments and trends in agri-environmental performance.

An improved capacity to assess agriculture's environmental performance has been a key outcome of the Report. This has been achieved by building on Member countries' experiences and earlier OECD work, and through helping to: establish a common framework, harmonised methodologies and data sets to calculate indicators; advance knowledge of agri-environmental interactions and linkages; and foster an exchange of national and international approaches and experiences in developing indicators.

Some positive developments can be observed. There has been a decrease of over 10 per cent in both nitrogen and pesticide use in many European countries and Japan, and associated improvements in water quality and lowering of greenhouse gas emissions, since the mid-1980s. Soil erosion rates have declined in Australia, Canada, and the United States, and progress has been made in adopting farming practices that enhance environmental performance, such as the shift to using nitrogen management plans, integrated pest management and conservation soil tillage.

The environmental performance of agriculture has deteriorated in some cases. This has been associated with the intensification of farm production in some areas and the regional concentration of activities, such as livestock farming. In turn, this has resulted in higher levels of nutrient surpluses, ammonia and greenhouse gas emissions, with consequent increases in water and air pollution, such as in regions of Canada, Europe, New Zealand and the United States. There is also growing

competition for scarce water resources both between agriculture and other users and also meeting the water needs of aquatic ecosystems for recreational and environmental purposes, particularly in the drier regions of Australia, the United States and Southern Europe.

Overall agri-environmental indicator results over the last 10-15 years have been mixed. The overall indicator results suggest that for many agri-environmental issues, and regions within OECD countries, pollution levels are relatively high (e.g. nitrogen and pesticide loadings in water) and that various environmental risks persist (e.g. soil erosion, water resource depletion). Agriculture, however, does provide certain environmental benefits and services (e.g. providing wildlife habitat, acting as a sink for greenhouse gases, providing landscape amenity).

Interpreting the overall impact of agri-environmental trends can be complex. For example, the increase in agricultural production and total environmental emission levels has been offset, to some extent, by improvements in farm input and natural resource use efficiency. This is the case with the use of fertilisers, pesticides, and water in some countries, where improvements in technology and farm management practices have led to a reduction in the use of these inputs per unit volume of production.

Changes in the environmental performance of agriculture can be attributed to a wide range of factors. These include variations in agricultural production, structural and technological developments, the influence of public pressure and market forces on farming practices and systems, and changes in policy settings and priorities. The linkages between indicators observed in this Report suggest a sequence of causes and effects. Changes in market conditions or policy settings affect the level of financial resources available to farmers, which influence production decisions and farm practices, while agri-environmental measures and environmental regulations may constrain actions taken by farmers. This leads to different environmental outcomes depending on varying agro-ecological conditions.

These results need to be seen in a broader context. For most OECD countries agriculture's role in the national economy is small, but in terms of the use of natural resources is significant, accounting for around 40 per cent of total land use and 45 per cent of water use. Agricultural production has increased by around 15 per cent, resulting mainly from improvements in productivity with capital replacing labour helped by new technologies. The higher production has been achieved from increasing yields as the total agricultural land area has decreased, by 1 per cent, and the use of water has risen, by over 5 per cent. Agricultural employment has declined by about 8 per cent, while the farm population has aged. Farm numbers have declined with a corresponding increase in farm size.

OECD agriculture continues to be characterised by high support, which currently accounts for about 36 per cent of total farm receipts, although there are wide variations in the level, composition and trends in support among countries and commodities. Agricultural and trade policies have caused distortions in market input and output price signals, in some cases this has led to environmental damage. Policy reform should help improve agriculture's environmental performance but in some cases could reduce environmental benefits. As part of the reform process and in response to public pressure, many countries have introduced agri-environmental and environmental measures to help achieve environmental goals.

For some agri-environmental areas there is incomplete knowledge and data to establish trends. Information is incomplete, for example, concerning the degree of groundwater pollution or rate of depletion resulting from agricultural activities, and the human health and environmental risks associated with the use of pesticides. In other cases the linkages between different indicators are understood but are not easy to measure, such as between changes in farm management practices and environmental outcomes, or attributing the relative impact of agriculture and other activities, for example, on water pollution. Also for a number of areas, notably agriculture's impact on biodiversity, habitats and landscape, the understanding and measurement of these impacts is still at a preliminary stage of research, partly because of the high costs associated with monitoring programmes.

The future challenge to developing agri-environmental indicators is to meet the objectives of providing information on the current state and changes in the conditions of the environment in agriculture; and using indicators for policy monitoring, evaluation, and forecasting. This requires improving the analytical soundness and measurability of indicators, especially by overcoming conceptual and data deficiencies, and providing a better interpretation of indicator trends. This could contribute to understanding the linkages between indicators (e.g. water use, management and pricing) and to examining the synergies and trade-offs between the economic, social and environmental dimensions of sustainable agriculture. Developing a core set of integrated OECD agri-environmental indicators, complemented as necessary by other indicators, could help to achieve these objectives.

Oerke, E. (2006). "Crop losses to pests." The Journal of Agricultural Science **144**(01): 31-43.

Category: Agroecology and agroecological practices

Keywords: *Crop losses, weed, general study, cultivated plant, damage, pest and disease control, plant pathogen, pest and disease, pest regulation, yield losses*

Abstract: Productivity of crops grown for human consumption is at risk due to the incidence of pests, especially weeds, pathogens and animal pests. Crop losses due to these harmful organisms can be substantial and may be prevented, or reduced, by crop protection measures. An overview is given on different types of crop losses as well as on various methods of pest control developed during the last century.

Estimates on potential and actual losses despite the current crop protection practices are given for wheat, rice, maize, potatoes, soybeans, and cotton for the period 2001–03 on a regional basis (19 regions) as well as for the global total. Among crops, the total global potential loss due to pests varied from about 50% in wheat to more than 80% in cotton production. The responses are estimated as losses of 26–29% for soybean, wheat and cotton, and 31, 37 and 40% for maize, rice and potatoes, respectively. Overall, weeds produced the highest potential loss (34%), with animal pests and pathogens being less important (losses of 18 and 16%). The efficacy of crop protection was higher in cash crops than in food crops. Weed control can be managed mechanically or chemically, therefore worldwide efficacy was considerably higher than for the control of animal pests or diseases, which rely heavily on synthetic chemicals. Regional differences in efficacy are outlined. Despite a clear increase in pesticide use, crop losses have not significantly decreased during

the last 40 years. However, pesticide use has enabled farmers to modify production systems and to increase crop productivity without sustaining the higher losses likely to occur from an increased susceptibility to the damaging effect of pests.

The concept of integrated pest/crop management includes a threshold concept for the application of pest control measures and reduction in the amount/frequency of pesticides applied to an economically and ecologically acceptable level. Often minor crop losses are economically acceptable; however, an increase in crop productivity without adequate crop protection does not make sense, because an increase in attainable yields is often associated with an increased vulnerability to damage inflicted by pests.

Olsson, O., J. Brown and K. Helf (2008). "A guide to central place effects in foraging." Theoretical Population Biology **74**(1): 22-33.

Category: Ecosystem services

Keywords: *Foraging theory, patch use, GUD, optimality, central place foraging, predation cost of foraging, habitat selection, pollination*

Abstract: We develop a general patch-use model of central place foraging, which subsumes and extends several previous models. The model produces a catalog of central place effects predicting how distance from a central place influences the costs and benefits of foraging, load-size, quitting harvest rates, and giving-up densities. In the model, we separate between costs that are load-size dependent, i.e. a direct effect of the size of the load, and load-size independent effects, such as correlations between distance and patch qualities. We also distinguish between predictions of between- and within-environment comparisons. Foraging costs, giving-up densities and quitting harvest rates should almost always increase with distance with these effects amplified by increases in metabolic costs, predation risk and load-costs. With respect to load-size: when comparing foraging in patches within an environment, we should often expect smaller loads to be taken from distant patches (negative distance–load correlation). However, when comparing between environments, there should be a positive correlation between average distance and load-size.

Omer, A., U. Pascual and N. Russell (2007). "Biodiversity conservation and productivity in intensive agricultural systems." Journal of Agricultural Economics **58**(2): 308-329.

Category: Farmer and societal benefits; Ecosystem services

Keywords: *Agrobiodiversity economics, biodiversity loss, sustainable agricultural intensification, technical change, policy, impacts of intensive agriculture*

Abstract: This paper explores the economic effects of biodiversity loss on marketable agricultural output for intensive agricultural systems, which require an increasing level of artificial capital inputs. A theoretical bio-economic model is used to derive a hypothesis about the effect of the state of biodiversity on the optimal crop output both in the longer run and in the transitional path towards the steady-state equilibrium. The hypothesised positive relationship between biodiversity stock and optimal levels of crop output is empirically tested using a stochastic production frontier approach, based on data from a panel of UK specialised cereal farms for the

period 1989–2000. The results support the theoretical hypothesis. Increases in biodiversity can lead to a continual outward shift in the output frontier (although at a decreasing rate), controlling for the relevant set of labour and capital inputs. Agricultural transition towards biodiversity conservation may be consistent with an increase in crop output in already biodiversity-poor modern agricultural landscapes.

Ostman, O., B. Ekbom and J. Bengtsson (2001). "Landscape heterogeneity and farming practice influence biological control." Basic and Applied Ecology **2**(4): 365-371.

Category: Ecosystem services

Keywords: *Agriculture, aphid-days, conservation predator enhancement, ecosystem service, predator-aphid interaction, pest regulation, landscape features, farming systems*

Abstract: We measured the impact of natural enemies on the population development on the bird cherry-oat aphid (Rhopalosiphum padi) on conventional and organic farms. By pairing farms with similar landscape features but different farming systems, we were able to separate the effects of farming practice and landscape features on the influence of natural enemies on R. padi abundance. Natural enemies had a greater impact on R. padi establishment on organic farms than on conventional farms. Irrespective of farming system, landscapes with abundant field margins and perennial crops were associated with low R. padi establishment. After establishment, there was no difference in ground-living enemy impact on R. padi population growth rate between farming systems, but impact was greater in landscapes where arable land was contiguous.

Ostman, O., B. Ekbom and J. Bengtsson (2003). "Yield increase attributable to aphid predation by ground-living polyphagous natural enemies in spring barley in Sweden." Ecological Economics **45**(1): 149-158.

Category: Farmer and societal benefits; Ecosystem services

Keywords: *Agroecosystems, arthropods, biological control, ecosystem services, farmers, pesticides, pest regulation, yield losses*

Abstract: It has been claimed that natural enemies of pests perform important ecosystem services in agricultural landscapes. These services have rarely been evaluated in yield or monetary terms at farm level. We have examined the degree to which ground-living natural enemies of the bird cherry-oat aphid (Rhopalosiphum padi (L.)) reduced aphid abundance and influenced barley yields on ten commercial farms in central Sweden. On average, ground-living natural enemies of pests increased barley yields by 303 kg/ha. This corresponded to a potential 52% reduction in yield loss from R. padi compared with a scenario where no natural enemies were present. Measured as the percentage increase of actual yield, ground-living natural enemies of aphids increased the yield by 23%. The increase in yields in absolute terms was larger on conventional farms than organic farms, but the percentage increase of yields was larger on organic farms. The study only considered 1 year, with high aphid abundance. However, we also discuss the effects of predators as well as insecticides in the long-term. Our study shows that yield increases attributable to predators can be compared with yield increases from insecticide use for the evaluation of different management strategies.

Pacini, C., A. Wossink, G. Giesen, C. Vazzana and R. Huirne (2003). "Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis." Agriculture, Ecosystems & Environment **95**(1): 273-288.

Category: Farmer and societal benefits; Agriculture-induced impacts

Keywords: *Sustainability, farming systems, organic agriculture, pedo-climatic impact, Tuscany, soil nutrients/cycling, watershed services, soil erosion*

Abstract: Agricultural researchers widely recognise the importance of sustainable agricultural production systems and the need to develop appropriate methods to measure sustainability. The principal purpose of this paper is to evaluate the financial and environmental aspects of sustainability of organic, integrated and conventional farming systems (OFS, IFS and CFS, respectively) at farm level and on more detailed spatial scales. This was achieved by applying an integrated economic-environmental accounting framework to three case study farms in Tuscany (Italy) covering different farming systems (FSs) and different spatial scales. The environmental performances of the FSs were measured through the application of an environmental accounting information system (EAIS) at field, site and farm level. The EAIS indicators were then integrated with: (1) a set of financial indicators to evaluate the economic and environmental trade-offs between different FSs and (2) with information on the regional and site-specific soil and climate conditions to study the impact of different pedo-climates on the environmental performances of the FSs. The gross margins of steady-state OFSs were found to be higher than the corresponding CFS gross margins. The OFSs perform better than IFSs and CFSs with respect to nitrogen losses, pesticide risk, herbaceous plant biodiversity and most of the other environmental indicators. However, on hilly soils, erosion was found to be higher in OFSs than in CFSs. The pesticide and the nitrogen indicators in this study showed a similar environmental impact caused by integrated and conventional farming practices. Regional pedo-climatic factors were found to have a considerable impact on nutrient losses, soil erosion, pesticide risk and herbaceous plant biodiversity, site-specific factors on nutrient losses and soil erosion. Results at field level suggest that herbaceous plant biodiversity and crop production are not always conflicting variables. Results of the case study farms are discussed and compared with environmental sustainability thresholds reported from EU Directives on nitrate and pesticides in groundwater and the literature.

Padulosi, S., N. Bergamini and T. Lawrence (2012). On-farm conservation of neglected and underutilized species: status, trends and novel approaches to cope with climate change. International Conference International Conference, 14-16 June, 2011., Frankfurt.

Category: Ecosystem services

Keywords: *On farm conservation, traditional crops, landraces, climate change, underutilized crops, agrobiodiversity, food security, nutrition, India, Bolivia, Nepal, community biodiversity registers, China, West Africa, Red List for cultivated crops, custodian farmers, slow food, Italy, Greece, Switzeland, genetic diversity*

Welcoming address:

Adaptation of agriculture to changing climatic conditions including utilization and

promotion of suitable crops and tree species (underutilized and neglected species, wild relatives of crops, etc.) will be one of the central tasks of future agricultural activities. It will be especially important in view of the need for securing the food basis and providing balanced nutrition for the rural population of many developing countries. The inclusion of agrobiodiversity measures in the project setup is already gaining increased attention as "risk insurance".

Important components of agrobiodiversity are neglected and underutilized plants that have a lot of traits and properties important for our future nutrition base. These species are often traditionally used, or are wild species that contribute to nutrition and a balanced diet for poor and underprivileged folks. In addition, these plants may have a variety of additional properties, such as potential for future adaptation to climate change (heat or salt tolerance), medicinal properties, as well as resistance genes against pests and diseases, thus helping us to reduce use of pesticides.

Neglected and underutilized species (NUS) comprise a broad variety of agricultural and wild crops in different countries. Many of them are traditional crops that are still cultivated by farmers; others include wild vegetables and wild relatives of crops. Farmers have an increasing role as guardians of traditional as well as neglected and underutilized crops, vegetables and tree species. This responsibility should be valued, not only by the government but also by private industry and other stakeholders who up to now have benefited from farmers' traditional knowledge of plants and biodiversity resources. I would like to refer to the Nagoya Agreement and the International Treaty on Plant Genetic Resources for Food and Agriculture (2001) which acknowledges "Farmers Rights" as guardians and users of the genetic resources and traditional knowledge and demands equitable sharing of access to and benefits from plant and animal genetic resources.

We should not forget that many NUS have an economic potential and in future we have to tap this potential because farmers will only maintain and promote those species if they have an economic benefit. Hopefully, international discussions on the Economics of Ecosystems and Biodiversity (TEEB), Payment for Ecosystem Services (PES) and increasing orientation towards a green economy has to include the promotion and use of NUS. Here it is our task to emphasize inclusion of those species into those discussions and to promote their conservation and use

Paloniemi, R., E. Apostolopoulou, E. Primmer, M. Grodzinska-Jurcak, K. Henle, I. Ring, M. Kettunen, J. Tzanopoulos, S. G. Potts and S. van den Hove (2012). "Biodiversity conservation across scales: lessons from a science-policy dialogue." Nature Conservation **2**: 7-19.

Category: Policy

Keywords: *Biodiversity conservation, environmental policy, governance, scale sensitivity, scale challenge, stakeholders, academia, EU*

Abstract: One of the core challenges of biodiversity conservation is to better understand the interconnectedness and interactions of scales in ecological and governance processes. These interrelationships constitute not only a complex analytical challenge but they also open up a channel for deliberative discussions and knowledge exchange between and among various societal actors which may themselves be operating at various scales, such as policy makers, land use planners, members of NGOs, and researchers. In this paper, we discuss and integrate the

perspectives of various disciplines academics and stakeholders who participated in a workshop on scales of European biodiversity governance organised in Brussels in the autumn of 2010. The 23 participants represented various governmental agencies and NGOs from the European, national, and sub-national levels. The data from the focus group discussions of the workshop were analysed using qualitative content analysis. The core scale-related challenges of biodiversity policy identified by the participants were cross-level and cross-sector limitations as well as ecological, social and social-ecological complexities that potentially lead to a variety of scale-related mismatches. As ways to address these cha- llenges the participants highlighted innovations, and an aim to develop new interdisciplinary approaches to support the processes aiming to solve current scale challenges.

Pan, G., P. Smith and W. Pan (2009). "The role of soil organic matter in maintaining the productivity and yield stability of cereals in China." Agriculture, Ecosystems & Environment **129**(1-3): 344-348.

Category: Ecosystem services

Keywords: *C sequestration, cereal production, cropland productivity, food security of China, soil organic matter, soil nutrients/cycling*

Abstract: The role of soil organic matter (SOM) in agricultural systems has been widely studied in conjunction with the potential for greenhouse gas mitigation. However, the link between SOM accumulation in croplands, crop productivity and yield stability has not yet been clearly established. In this paper, we collected data on provincial yearly crop productivity (yields, total cropland area) during 1949–1998 and the average SOM contents in croplands sampled and determined from the National Soil Survey in 1979–1982 of mainland China. The cereal productivity was assessed both with an overall mean of 1949–1998 and with the mean values for different time periods within this overall time, respectively. The yield variability within a single stabilizing stage, and between the fluctuating years, was calculated as a negative measure of yield stability. The correlation between SOM and cereal productivity was very significant for most provinces, but the relationship has become less significant as we approach the present. Moreover, the average yield variability was very significantly and negatively correlated with the cropland SOM level. The findings support our previous hypothesis from case studies, that C sequestration in China's croplands may provide win–win benefits, by enhancing crop productivity and stabilizing yield. This offers a sound basis as a greenhouse gas mitigation strategy by promoting C sequestration in croplands, and enhancing food security in China's agriculture.

Pannell, D. J. and N. A. Glenn (2000). "A framework for the economic evaluation and selection of sustainability indicators in agriculture." Ecological Economics **33**(1): 135-149.

Category: Agriculture-induced impacts

Keywords: *Sustainability indicators, economic valuation, bayesian decision theory, management decisions*

Abstract: In recent years, the concept of ‘sustainability indicators’ has become prominent in agricultural science. The idea is that particular characteristics of

resources are monitored and recorded, with the intention that this information serves as an aid for decision making by farmers and/or policy makers. A great many sustainability indicators have been proposed by agricultural scientists. However, there is no guidance currently available as to which of the possible sustainability indicators provide information of economic value. In this paper we present a conceptual framework for the economic valuation and prioritisation of sustainability indicators. The framework is based on Bayesian decision theory, particularly its use to calculate the value of information under conditions of uncertainty. We present an illustrative numerical example. Based on this example and the theoretical framework, we identify a number of important insights about the practical use of sustainability indicators.

Parmesan, C. (2006). "Ecological and evolutionary responses to recent climate change." Annual review of ecology, evolution, and systematics: 637-669.

Category: Climate change

Keywords: *Aquatic, global warming, phenology, range shift, terrestrial, trophic, asynchrony, climate change, pest regulation, pollination*

Abstract: Ecological changes in the phenology and distribution of plants and animals are occurring in all well-studied marine, freshwater, and terrestrial groups. These observed changes are heavily biased in the directions predicted from global warming and have been linked to local or regional climate change through correlations between climate and biological variation, field and laboratory experiments, and physiological research. Range-restricted species, particularly polar and mountaintop species, show severe range contractions and have been the first groups in which entire species have gone extinct due to recent climate change. Tropical coral reefs and amphibians have been most negatively affected. Predator-prey and plant-insect interactions have been disrupted when interacting species have responded differently to warming. Evolutionary adaptations to warmer conditions have occurred in the interiors of species' ranges, and resource use and dispersal have evolved rapidly at expanding range margins. Observed genetic shifts modulate local effects of climate change, but there is little evidence that they will mitigate negative effects at the species level.

Paul, E. (1997). Soil organic matter in temperate agroecosystems: Long-term experiments in North America, CRC Press.

Category: Ecosystem services

Keywords: *Soil organic matter, temperate agroecosystems, North America, humus, soil fertility, soil biology, ecology, soil nutrients/cycling*

Abstract: The presence - or absence - of soil organic matter (SOM) has important implications for agricultural productivity. It could also have significant implications for global climate due to its role as a source/sink of carbon. Therefore, it is important to understand the issues related to the accumulation or loss of SOM, to use what we have learned from experiments to make sound decisions about soil and crop management, and to test models and future concepts concerning SOM management. A database is included with the book, presenting tabular data for 34

sites in North America.

Pearson, D., J. Henryks and H. Jones (2011). "Organic food: What we know (and do not know) about consumers." Renewable agriculture and food systems **26**(02): 171-177.
Category: Agroecology and agroecological practices; Policy
Keywords: *Organic food, consumers, research, purchases, segmentation, policy*

Abstract: This paper reports on the latest contributions to over 20 years of research on organic food consumers. There is a general consensus in the literature on the reasons why people buy organic food. However, there is also a gap between consumers' generally positive attitude toward organic food and their relatively low level of actual purchases. Product differentiation based on intangible features, such as credence attributes such as organic, in fast-moving consumer goods categories is enjoying rapid growth. However, there are many difficulties with research in this area, including the errors inherent in research that relies on consumer self-reporting methodologies. Further, in relation to organic food, there is a divergence between consumers' perception of its superior health features and scientific evidence. Fresh fruits and vegetables are of vital importance to the organic sector as they are the entry point for many customers and account for one-third of sales. Further, although there is a small proportion of dedicated organic food buyers, most sales come from the majority of buyers who switch between conventional and organic food purchases. This paper identifies the practical implications for generic organic food marketing campaigns, as well as for increasing sales of specific products. It concludes with suggested priorities for further research.

Perfecto, I. and J. Vandermeer (2010). "The agroecological matrix as alternative to the land-sparing/agriculture intensification model." PNAS **107**(13): 5786-5791.
Category: Ecosystem services; Policy
Keywords: *Food crisis, biodiversity, fragmented landscapes, matrix quality, small-scale farmers, wild biodiversity, policy*

Abstract: Among the myriad complications involved in the current food crisis, the relationship between agriculture and the rest of nature is one of the most important yet remains only incompletely analyzed. Particularly in tropical areas, agriculture is frequently seen as the antithesis of the natural world, where the problem is framed as one of minimizing land devoted to agriculture so as to devote more to conservation of biodiversity and other ecosystem services. In particular, the "forest transition model" projects an overly optimistic vision of a future where increased agricultural intensification (to produce more per hectare) and/or increased rural-to-urban migration (to reduce the rural population that cuts forest for agriculture) suggests a near future of much tropical aforestation and higher agricultural production. Reviewing recent developments in ecological theory (showing the importance of migration between fragments and local extinction rates) coupled with empirical evidence, we argue that there is little to suggest that the forest transition model is useful for tropical areas, at least under current sociopolitical structures. A model that incorporates the agricultural matrix as an integral component of conservation programs is proposed. Furthermore, we suggest that this model will be

most successful within a framework of small-scale agroecological production.

The current food crisis calls attention to the need for construction of sustainable ecosystems more generally. As Robert Watson, the cochair of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) stated in a press conference when the report was released in 2008, "Business as usual is not an option." Although the particulars are variable, the underlying sense is clear—the longue durée of economic, social, and political development in which environmental variables are regarded as externalities has come to a close. Within this awakening, the loss of biodiversity is regarded as one of the more important environmental issues related to both sustainability and food production. With extinction rates currently at greater levels than natural background, some have suggested that we are in the midst of another mass extinction comparable to the one that occurred at the end of the Cretaceous (1), except this time it is driven by humans rather than a natural catastrophic event, and the major human activity involved is agriculture, which clearly links the biodiversity crisis with the current food crisis.

In this article, we focus on one aspect of these crises—the debate about the application of the traditional forest transition (FT) model to the tropics in general, a debate that has subtle but important relations with the world food system. We contrast this model with what we refer to as the "matrix quality" model, in which agriculture is seen as an intimate and inextricable component of the biodiversity conservation agenda.

Perrings, C., A. Duraiappah, A. Larigauderie and H. Mooney (2011). "The biodiversity and ecosystem services science-policy interface." Science **331**(6021): 1139-1140.

Category: Policy

Keywords: *Anthropogenic ecosystem change, global biodiversity, Busan outcome, assessment, science*

Abstract: In recognition of our inability to halt damaging ecosystem change (1–4), the United Nations Environment Pro-gramme (UNEP) was asked in December 2010 to convene a meeting "to determine modalities and institutional arrangements" of a new assessment body, akin to the Inter- governmental Panel on Climate Change (IPCC), to track causes and consequences of anthropogenic ecosystem change (5). The "blueprint" for this body, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES), lies in recommen-dations of an intergovernmental conference held in the Republic of Korea in June 2010: the Busan outcome (6). But it is a blueprint for governance rather than science. Using the experience from past assessments of global biodiversity and ecosystem services change (1, 7, 8) and from the IPCC (9–11), we ask what the policy-oriented charges in the Busan outcome imply for the science of the assessment process.

Persson, A., O. Olsson, M. Rundlof and H. G. Smith (2010). "Land use intensity and landscape complexity: Analysis of landscape characteristics in an agricultural region in Southern Sweden." Agriculture, Ecosystems & Environment **136**(1-2): 169-176.

Category: Ecosystem services; Policy

Keywords: *Agriculture, farmland, landscape complexity, landscape heterogeneity, land use intensity, wild diversity*

Abstract: It is generally recognised that agricultural intensification has lead to simplification of landscape structure, but it has not been clarified if this is a ubiquitous relationship. That is, it has been an open question whether agricultural intensity and landscape simplicity should be regarded as one single or as two separate dimensions. To evaluate this we analysed landscape data in 136 different 1 km × 1 km study sites and within a buffer zone of 2 km around each site (i.e. approximately 5 km × 5 km). The sites were distributed over a large part of the region of Scania, southernmost Sweden, an area dominated by agriculture but with large variation in both intensity and complexity. We used spatially explicit digital data on land use, digitised aerial photographs, field surveys of landscape elements and agricultural statistics. Two separate factor analyses, one for each scale of measurements (1 km and 5 km), suggest that there are five and three relevant factors for each scale respectively. At the 1 km scale, the first factor can be interpreted as describing the intensity of land use in the form of proportion arable land which is highly correlated to crop yield. The second and third factors are more connected to landscape structure and amount of small patches of semi-natural habitats. The fourth and fifth factors contain one major variable each: proportion pasture and leys respectively. The division of intensity and complexity related variables is less clear at a larger spatial scale. At the 5 km scale, factor 1 is defined almost identically as at the 1 km scale. However, factors 2 and 3 are interpreted as descriptors of dairy and livestock farming systems but also include structural variables. Our analyses suggest that land use intensity and structural complexity of landscapes are more or less separate landscape level factors, at least at smaller spatial scales. This is important to bear in mind, especially when trying to explain patterns of biodiversity change in agricultural landscapes.

Petchey, O. and K. Gaston (2006). "Functional diversity: back to basics and looking forward." Ecology Letters **9**(6): 741-758.

Category: Ecosystem services

Keywords: *Context dependence, ecosystems, functional classification, indirect use value, phenetics, redundancy, species, species richness, traits, functional diversity*

Abstract: Functional diversity is a component of biodiversity that generally concerns the range of things that organisms do in communities and ecosystems. Here, we review how functional diversity can explain and predict the impact of organisms on ecosystems and thereby provide a mechanistic link between the two. Critical points in developing predictive measures of functional diversity are the choice of functional traits with which organisms are distinguished, how the diversity of that trait information is summarized into a measure of functional diversity, and that the measures of functional diversity are validated through quantitative analyses and experimental tests. There is a vast amount of trait information available for plant species and a substantial amount for animals. Choosing which traits to include in a particular measure of functional diversity will depend on the specific aims of a particular study. Quantitative methods for choosing traits and for assigning weighting to traits are being developed, but need much more work before we can be

confident about trait choice. The number of ways of measuring functional diversity is growing rapidly. We divide them into four main groups. The first, the number of functional groups or types, has significant problems and researchers are more frequently using measures that do not require species to be grouped. Of these, some measure diversity by summarizing distances between species in trait space, some by estimating the size of the dendrogram required to describe the difference, and some include information about species' abundances. We show some new and important differences between these, as well as what they indicate about the responses of assemblages to loss of individuals. There is good experimental and analytical evidence that functional diversity can provide a link between organisms and ecosystems but greater validation of measures is required. We suggest that non-significant results have a range of alternate explanations that do not necessarily contradict positive effects of functional diversity. Finally, we suggest areas for development of techniques used to measure functional diversity, highlight some exciting questions that are being addressed using ideas about functional diversity, and suggest some directions for novel research.

Phalan, B., A. Balmford, R. Green and J. Scharlemann (2011). "Minimising the harm to biodiversity of producing more food globally." Food Policy **36, Supplement 1**(0): S62-S71.
Category: Policy; Ecosystem services
Keywords: *Biodiversity conservation, agriculture, land sparing, wildlife-friendly farming, organic farming, land-use policy*

Abstract: Should farming and conservation policies aim broadly to separate land for nature and land for production (land sparing) or integrate production and conservation on the same land (wildlife-friendly farming)? Most studies that try to address this question suffer from flaws in sampling design, inappropriate metrics, and/or failure to measure biodiversity baselines. We discuss how these failings can be addressed, and what existing information tells us about the key debates on this topic. The evidence available suggests that trade-offs between biodiversity and yield are prevalent. While there are some wildlife-friendly farming systems that support high species richness, a large proportion of wild species cannot survive in even the most benign farming systems. To conserve those species, protection of wild lands will remain essential. Sustainable intensification could help to facilitate sparing of such lands, provided that as much attention is given to protecting habitats as to raising yields. We discuss the general circumstances under which yield increases can facilitate land sparing, recognising that policies and social safeguards will need to be context-specific. In some situations, bringing degraded lands into production could help reduce pressure on wild lands, but much more information is needed on the biodiversity implications of using degraded lands. We conclude that restricting human requirements for land globally will be important in limiting the impacts on biodiversity of increasing food production. To achieve this, society will need to integrate explicit conservation objectives into local, regional and international policies affecting the food system.

Phalan, B., M. Onial, A. Balmford and R. E. Green (2011). "Reconciling food production and

biodiversity conservation: land sharing and land sparing compared." Science **333**(6047): 1289-1291.

Category: Ecosystem services; Policy

Keywords: *Land sharing, land sparing, crop yield, biodiversity conservation, Ghana, India, population density, birds, trees, wild biodiversity*

Abstract: The question of how to meet rising food demand at the least cost to biodiversity requires the evaluation of two contrasting alternatives: land sharing, which integrates both objectives on the same land; and land sparing, in which high-yield farming is combined with protecting natural habitats from conversion to agriculture. To test these alternatives, we compared crop yields and densities of bird and tree species across gradients of agricultural intensity in southwest Ghana and northern India. More species were negatively affected by agriculture than benefited from it, particularly among species with small global ranges. For both taxa in both countries, land sparing is a more promising strategy for minimizing negative impacts of food production, at both current and anticipated future levels of production.

Pinke, G., R. Pal and Z. Botta-Dukat (2010). "Effects of environmental factors on weed species composition of cereal and stubble fields in western Hungary." Central European Journal of Biology **5**(2): 283-292.

Category: Agriculture-induced impacts; Ecosystem services

Keywords: *Arable fields, Central-Europe, gradient analysis, seasonal changes, weed ecology, weed vegetation, pest regulation*

Abstract: Multivariate analysis of data obtained from 184 cereal and stubble fields in low-input agricultural systems located in western Hungary was undertaken in order to asses environmental factors affecting weed species composition. For each variable, the gross and net effect on weed species composition was calculated. All variables considered in this study had a significant effect on weed species composition and explained 26.99% of the total variation. Most variation in species composition was explained by the aspect (cereal vs. stubble), followed by soil pH, mean annual precipitation, soil texture, mean annual temperature, and altitude. Separating the cereals and stubbles soil pH became the most important factor. Our results suggest that during the long vegetation period, cereal weed communities dominated by winter annuals are replaced by stubble-field weed communities dominated by summer annuals. This seasonal change may also have the same important effect on weed species composition as crop types.

Pinke, G., R. Pal, Z. Botta-Dukat and M. Chytry (2009). "Weed vegetation and its conservation value in three management systems of Hungarian winter cereals on base-rich soils." Weed Research **49**(5): 544-551.

Category: Agriculture-induced impacts; Ecosystem services

Keywords: *Arable weeds, biodiversity, farmland birds, pollinators, rare species, weed flora, pest regulation, pollination*

Abstract: Floristic composition and conservation value of the weed vegetation of winter cereal fields on base-rich soils in western Hungary was compared among three management systems: (i) small, extensively managed fields; (ii) small,

intensively managed fields and (iii) large, intensively managed fields. Data were analysed by principal components analysis (PCA) and redundancy analysis (RDA). Most variation in species composition was explained by the differences between the three field types, particularly by the difference between the extensively managed fields and the two types of intensively managed fields and by crop cover. There were several species positively associated with small extensively managed fields, but no species associated with either of the two types of intensively managed fields. Logistic regression was made of the occurrence of species groups important for nature conservation on the first RDA axis, representing the distinction between the extensively and intensively managed fields. This showed that Red List and insect-pollinated plant species occurred more frequently in small extensively managed fields, but there was no difference between fields in the frequency of bird seed-food species.

Plummer, M. (2009). "Assessing benefit transfer for the valuation of ecosystem services." Frontiers in Ecology and the Environment **7**(1): 38-45.

Category: Ecosystem services; Farmer and societal benefits

Keywords: *Ecosystem services, conservation planning, ecosystem-based, benefit transfer*

Abstract: The valuation of ecosystem services can play an important role in conservation planning and ecosystem-based management. Unfortunately, gathering primary, site-specific data is costly. As a result, a popular alternate method is to conduct a “benefit transfer” (applying economic value estimates from one location to a similar site in another location). Among the potential pitfalls of such an approach, the correspondence (or lack thereof) between the locations is probably the most important for evaluating the probable validity of the benefit transfer. A common type of benefit transfer in ecosystem service valuation applies an estimate of value per hectare to all areas having the same land-cover or habitat type, and is particularly susceptible to errors resulting from lack of correspondence. Enhancing the use of benefit transfers in this and other ecosystem service applications requires paying closer attention to simple guidelines, developed by economists, for improving validity and accuracy.

Polasky, S., E. Nelson, J. Camm, B. Csuti, P. Fackler, E. Lonsdorf, C. Montgomery, D. White, J. Arthur, B. Garber-Yonts, R. Haight, J. Kagan, A. Starfield and C. Tobalske (2008). "Where to put things? Spatial land management to sustain biodiversity and economic returns." Biological Conservation **141**(6): 1505-1524.

Category: Agroecology and agroecological practices

Keywords: *Conservation planning, efficiency frontier, land use, tradeoffs, terrestrial vertebrates, survival probability*

Abstract: Expanding human population and economic growth have led to large-scale conversion of natural habitat to human-dominated landscapes with consequent large-scale declines in biodiversity. Conserving biodiversity, while at the same time meeting expanding human needs, is an issue of utmost importance. In this paper we develop a spatially explicit landscape-level model for analyzing the biological and economic consequences of alternative land-use patterns. The spatially explicit

biological model incorporates habitat preferences, area requirements and dispersal ability between habitat patches for terrestrial vertebrate species to predict the likely number of species that will be sustained on the landscape. The spatially explicit economic model incorporates site characteristics and location to predict economic returns for a variety of potential land uses. We apply the model to search for efficient land-use patterns that maximize biodiversity conservation objectives for given levels of economic returns, and vice versa. We apply the model to the Willamette Basin, Oregon, USA. By thinking carefully about the arrangement of activities, we find land-use patterns that sustain high levels of biodiversity and economic returns. Compared to the 1990 land-use pattern, we show that both biodiversity conservation and the value of economic activity could be increased substantially.

Polishchuk, Y. and F. Rauschmayer (2012). "Beyond "benefits"? Looking at ecosystem services through the capability approach." Ecological Economics **81**(0): 103-111.
Category: Farmer and societal benefits; ecosystem services
Keywords: *Ecosystem services, human well-being, capability approach*

Abstract: Current conceptual debates on the impacts of ecosystem services (ESS) on human well-being often boil down to discussing the application and limitations of monetisation approaches. Meanwhile we argue that ESS can be understood in a richer and more nuanced way if we revisit the human well-being dimension of the ESS concept, going beyond the widely cited notion of “benefits” as put forward by the Millennium Ecosystem Assessment (MA, 2005) and transcending the currently prevalent utilitarian framing. Hence, we examine ESS through the lens of the capability approach, which offers a multidimensional framework for human well-being as an alternative to mainstream utilitarian and opulence perspectives. Within this framework, ESS can be effectively viewed as contributing – in a diversity of ways – to people's capabilities, i.e., their freedoms to lead lives they have reason to value. Such a view opens up a richer debate on the human dimension of ESS and points to new potential areas and ways of application of the ESS concept.

Porter, P., J. Lauer, W. Lueschen, J. Ford, T. Hoverstad, E. Oplinger and R. Crookston (1997). "Environment affects the corn and soybean rotation effect." Agron. J. **89**(3): 442-448.
Category: Agriculture-induced impacts
Keywords: *Environmental effect, yield, crop rotation, stress, Glycine max, Zea mays, Leguminosae, Dicotyledones, Angiospermae, Spermatophyta, Gramineae, Monocotyledones, United States, cropping system, grain legume, cereal crop, oil plant(vegetal)*

Abstract: Corn (Zea mays L.) and soybean [Glycine max (L.) Merr.], the backbone of Midwesterncrop production, respond to rotation, but how growing conditions affect this is not well documented. Our objectives were to determinethe effect of various corn and soybean cropping patterns on yields and to evaluate environmental effects on the rotation effect. The study began in 1981 at Lamberton,MN, on a Webster clay loam (fine-loamy, mixed, mesic Typic Endoaquoll), in 1982 at Waseca, MN, on a Nicollet clay loam (fine-loamy, mixed, mesic Aquic Hapludoll), and in 1983 at

Arlington, WI, on a Plano silt loam (fine-silty, mixed, mesic Typic Argiudoll). Cropping sequences were (i) continuous monocultureof each crop; (it) annual rotation of the two crops; and (iii) I, 2, 3, 4, and 5 yr of each crop following 5 yr of the other crop. Results are based on II yr of data at Lamberton, 8 yr (soybean) or 9 yr (corn) at Waseca, 9 yr at Arlington. Corn rotated annually with soybean yielded 13% more, and Ist-yr corn following multiple years of soybean yielded 15 %more than continuous corn. Soybean annually rotated with corn yielded 10% more, and Ist-yr soybean following multiple years of corn yielded 18% more than continuous soybean. The crops differed in response to increasing years of consecutive planting: 2nd-yr to 5th-yr corn yields were no different fromcontinuous corn yields; 2nd-yr soybean yielded 8% more than continuous soybean, 3rd-yr soybean yielded 3% more, and 4th- and 5th-yr soybean yielded the same as continuous soybean. Relative increase in yields of both crops in annual rotation compared with monoculture was approximately two-fold greater in low-yielding than in high-yielding environments. In low-yielding environments, the yield advantage of an annual rotation of corn and soybean compared with monoculture was frequently greater than 25%. The commonly practiced annual rotation of corn and soybean maximized corn yields, but not soybean yields, relative to the other sequences studied.

Postma-Blaauw, M., R. de Goede, J. Bloem, J. Faber and L. Brussaard (2010). "Soil biota community structure and abundance under agricultural intensification and extensification." Ecology **91**(2): 460-473.

Category: Ecosystem services

Keywords: *Body size, crop rotation, enchytraeids, feeding groups, land use change, life history, microarthropods, microbial biomass, protozoa, soil biodiversity, soil nutrients/cycling*

Abstract: Understanding the impacts of agricultural intensification and extensification on soil biota communities is useful in order to preserve and restore biological diversity in agricultural soils and enhance the role of soil biota in agroecosystem functioning. Over four consecutive years, we investigated the effects of agricultural intensification and extensification (including conversion of grassland to arable land and vice versa, increased and decreased levels of mineral fertilization, and monoculture compared to crop rotation) on major soil biota group abundances and functional diversity. We integrated and compared effects across taxonomic levels to identify sensitive species groups.

Conversion of grassland to arable land negatively affected both abundances and functional diversity of soil biota. Further intensification of the cropping system by increased fertilization and reduced crop diversity exerted smaller and differential effects on different soil biota groups. Agricultural intensification affected abundances of taxonomic groups with larger body size (earthworms, enchytraeids, microarthropods, and nematodes) more negatively than smaller-sized taxonomic groups (protozoans, bacteria, and fungi). Also functional group diversity and composition were more negatively affected in larger-sized soil biota (earthworms, predatory mites) than in smaller-sized soil biota (nematodes). Furthermore, larger soil biota appeared to be primarily affected by short-term consequences of conversion (disturbance, loss of habitat), whereas smaller soil biota were

predominantly affected by long-term consequences (probably loss of organic matter). Reestablishment of grassland resulted in increased abundances of soil biota groups, but since not all groups increased in the same measure, the community structure was not completely restored.

We concluded that larger-sized soil biota are more sensitive to agricultural intensification than smaller-sized soil biota. Furthermore, since larger-sized soil biota groups had lower taxonomic richness, we suggest that agricultural intensification exerts strongest effects on species-poor soil biota groups, thus supporting the hypothesis that biodiversity has an "insurance" function. As soil biota play an important role in agroecosystem functioning, altered soil biota abundances and functional group composition under agricultural intensification are likely to affect the functioning of the agroecosystem.

Potts, S., J. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger and W. Kunin (2010). "Global pollinator declines: trends, impacts and drivers." Trends in ecology & evolution **25**(6): 345-353.

Category: Ecosystem services

Keywords: *Pollinators, wild, domesticated, decline, biodiversity, ecosystem services, pollination*

Abstract: Pollinators are a key component of global biodiversity, providing vital ecosystem services to crops and wild plants. There is clear evidence of recent declines in both wild and domesticated pollinators, and parallel declines in the plants that rely upon them. Here we describe the nature and extent of reported declines, and review the potential drivers of pollinator loss, including habitat loss and fragmentation, agrochemicals, pathogens, alien species, climate change and the interactions between them. Pollinator declines can result in loss of pollination services which have important negative ecological and economic impacts that could significantly affect the main- tenance of wild plant diversity, wider ecosystem stability, crop production, food security and human welfare.

Potts, S. G., J. C. Biesmeijer, R. Bommarco, A. Felicioli, M. Fischer, P. Jokinen, D. Kleijn, A. M. Klein, W. E. Kunin and P. Neumann (2011). "Developing European conservation and mitigation tools for pollination services: approaches of the STEP (Status and Trends of European Pollinators) project." Journal of Apicultural Research **50**(2): 152.

Category: Ecosystem services

Keywords: *Bees, crops, environmental pressures, flowering plants, pollinators, pollination services, crop selection, animal pollination, pollination*

Abstract: Pollinating insects form a key component of European biodiversity, and provide a vital ecosystem service to crops and wild plants. There is growing evidence of declines in both wild and domesticated pollinators, and parallel declines in plants relying upon them. The STEP project (Status and Trends of European Pollinators, 2010-2015, www.step-project.net) is documenting critical elements in the nature and extent of these declines, examining key functional traits associated with pollination deficits, and developing a Red List for some European pollinator groups. Together these activities are laying the groundwork for future pollinator monitoring

programmes. STEP is also assessing the relative importance of potential drivers of pollinator declines, including climate change, habitat loss and fragmentation, agrochemicals, pathogens, alien species, light pollution, and their interactions. We are measuring the ecological and economic impacts of declining pollinator services and floral resources, including effects on wild plant populations, crop production and human nutrition. STEP is reviewing existing and potential mitigation options, and providing novel tests of their effectiveness across Europe. Our work is building upon existing and newly developed datasets and models, complemented by spatially-replicated campaigns of field research to fill gaps in current knowledge. Findings are being integrated into a policy-relevant framework to create evidence-based decision support tools. STEP is establishing communication links to a wide range of stakeholders across Europe and beyond, including policy makers, beekeepers, farmers, academics and the general public. Taken together, the STEP research programme aims to improve our understanding of the nature, causes, consequences and potential mitigation of declines in pollination services at local, national, continental and global scales.

Power, A. (2010). "Ecosystem services and agriculture: tradeoffs and synergies." Philosophical Transactions of the Royal Society B: Biological Sciences **365**(1554): 2959-2971.
Category: Ecosystem services
Keywords: *Ecosystem services, agroecosystems, pollination, biological control, valuation of ecosystem services, soil carbon sequestration*

Abstract: Agricultural ecosystems provide humans with food, forage, bioenergy and pharmaceuticals and are essential to human wellbeing. These systems rely on ecosystem services provided by natural ecosystems, including pollination, biological pest control, maintenance of soil structure and fertility, nutrient cycling and hydrological services. Preliminary assessments indicate that the value of these ecosystem services to agriculture is enormous and often underappreciated. Agroecosystems also produce a variety of ecosystem services, such as regulation of soil and water quality, carbon sequestration, support for biodiversity and cultural services. Depending on management practices, agriculture can also be the source of numerous disservices, including loss of wildlife habitat, nutrient runoff, sedimentation of waterways, greenhouse gas emissions, and pesticide poisoning of humans and non-target species. The tradeoffs that may occur between provisioning services and other ecosystem services and disservices should be evaluated in terms of spatial scale, temporal scale and reversibility. As more effective methods for valuing ecosystem services become available, the potential for 'win–win' scenarios increases. Under all scenarios, appropriate agricultural management practices are critical to realizing the benefits of ecosystem services and reducing disservices from agricultural activities.

Power, E., D. Kelly and J. Stout (2013). "Impacts of organic and conventional dairy farmer attitude, behaviour and knowledge on farm biodiversity in Ireland." Journal for Nature Conservation **21**(5): 272-278.
Category: Agriculture-induced impacts; Ecosystem services

Keywords: *Achievement, agri-environmental scheme, grassland, intensive agriculture, plant diversity, production*

Abstract: Agricultural intensification has caused significant declines in biodiversity. Agri-environmental schemes (AES), including organic farming, are thought to benefit biodiversity. However, under similar production conditions and in comparable locations and schemes, farms are not managed in the same way, with variable consequences for production and the environment. Understanding farmer attitude, behaviour and knowledge of the environment and their impacts on biodiversity may help us understand the variable impacts of AES on biodiversity. We combined a sociological survey of nine organic and eight conventional dairy farmers (measuring environmental and achievement attitudes; environmental and production-orientated behaviours and environmental knowledge), in Ireland, with a biodiversity (using plant richness as an indicator) assessment of their farms. We found higher plant richness on organic farms than conventional. Organic and conventional farmers had similar attitudes to farming achievement and the environment but organic farmers were better informed about environmental issues and carried out more environmentally orientated behaviours. Biodiversity was positively related to the amount of environmentally orientated behaviours and negatively related to production-orientated behaviours carried out on farms. Organic farmers who had more positive attitudes to the environment and were better informed about it had higher biodiversity on their farms compared to less positively inclined, less informed organic farmers. We show disparities between attitude and actual behaviour in relation to the environment, with organic farmers sharing similar attitudes to conventional farmers, but more prepared to inform themselves about and carry out environmentally friendly farming. Results indicate that organic farming and environmentally orientated behaviours benefit biodiversity and that there is an important link between farmer environmental attitudes and knowledge and the beneficial effects of organic farming on biodiversity. We encourage conservation orientated thinking and better environmental education among farmers, including those who already participate in an AES. This way, the benefits of the AES for the environment may be maximised.

Prather, C., S. Pelini, A. Laws, E. Rivest, M. Woltz, C. Bloch, I. Del Toro, C.-K. Ho, J. Kominoski, T. Newbold, S. Parsons and A. Joern (2013). "Invertebrates, ecosystem services and climate change." Biological Reviews **88**(2): 327-348.

Category: Climate change

Keywords: *Climate change, insects, invertebrates, ecosystem services, sustainability, biodiversity, ecosystem engineers, bioindicator species, pollination, pest regulation, soil nutrients/cycling*

Abstract: The sustainability of ecosystem services depends on a firm understanding of both how organisms provide these services to humans and how these organisms will be altered with a changing climate. Unquestionably a dominant feature of most ecosystems, invertebrates affect many ecosystem services and are also highly responsive to climate change. However, there is still a basic lack of understanding of the direct and indirect paths by which invertebrates influence ecosystem services, as well as how climate change will affect those ecosystem services by altering

invertebrate populations. This indicates a lack of communication and collaboration among scientists researching ecosystem services and climate change effects on invertebrates, and land managers and researchers from other disciplines, which becomes obvious when systematically reviewing the literature relevant to invertebrates, ecosystem services, and climate change. To address this issue, we review how invertebrates respond to climate change. We then review how invertebrates both positively and negatively influence ecosystem services. Lastly, we provide some critical future directions for research needs, and suggest ways in which managers, scientists and other researchers may collaborate to tackle the complex issue of sustaining invertebrate-mediated services under a changing climate.

Pretty, J. (2008). "Agricultural sustainability: concepts, principles and evidence."
Philosophical Transactions of the Royal Society B: Biological Sciences **363**(1491): 447-465.
Category: Ecosystem services; Agroecology and agroecological practices
Keywords: *Environmental goods and services, natural capital, social capital, agroecology, carbon sequestration, pesticides*

Abstract: Concerns about sustainability in agricultural systems centre on the need to develop technologies and practices that do not have adverse effects on environmental goods and services, are accessible to and effective for farmers, and lead to improvements in food productivity. Despite great progress in agricultural productivity in the past half-century, with crop and livestock productivity strongly driven by increased use of fertilizers, irrigation water, agricultural machinery, pesticides and land, it would be over-optimistic to assume that these relationships will remain linear in the future. New approaches are needed that will integrate biological and ecological processes into food production, minimize the use of those non-renewable inputs that cause harm to the environment or to the health of farmers and consumers, make productive use of the knowledge and skills of farmers, so substituting human capital for costly external inputs, and make productive use of people's collective capacities to work together to solve common agricultural and natural resource problems, such as for pest, watershed, irrigation, forest and credit management. These principles help to build important capital assets for agricultural systems: natural; social; human; physical; and financial capital. Improving natural capital is a central aim, and dividends can come from making the best use of the genotypes of crops and animals and the ecological conditions under which they are grown or raised. Agricultural sustainability suggests a focus on both genotype improvements through the full range of modern biological approaches and improved understanding of the benefits of ecological and agronomic management, manipulation and redesign. The ecological management of agroecosystems that addresses energy flows, nutrient cycling, population-regulating mechanisms and system resilience can lead to the redesign of agriculture at a landscape scale. Sustainable agriculture outcomes can be positive for food productivity, reduced pesticide use and carbon balances. Significant challenges, however, remain to develop national and international policies to support the wider emergence of more sustainable forms of agricultural production across both industrialized and developing countries.

Pullin, A., A. Baldi, O. Can, M. Dieterich, V. Kati, B. Livoreil, G. Lovei, B. Mihok, O. Nevin, N. Selva and I. Sousa-Pinto (2009). "Conservation focus on Europe: Major conservation policy issues that need to be informed by conservation science." Conservation Biology **23**(4): 818-824.

Category: Policy

Keywords: *Evidence-based conservation, knowledge exchange, policy-relevant science, science–policy interface*

Abstract: Europe is one of the world's most densely populated continents and has a long history of human-dominated land- and seascapes. Europe is also at the forefront of developing and implementing multinational conservation efforts. In this contribution, we describe some top policy issues in Europe that need to be informed by high-quality conservation science. These include evaluation of the effectiveness of the Natura 2000 network of protected sites, implications of rapid economic and subsequent land-use change in Central and Eastern Europe, conservation of marine biodiversity and sustainability of fisheries, the effect of climate change on movement of species in highly fragmented landscapes, and attempts to assess the economic value of ecosystem services and biodiversity. Broad policy issues such as those identified are not easily amenable to scientific experiment. A key challenge at the science–policy interface is to identify the research questions underlying these problem areas so that conservation science can provide evidence to underpin future policy development.

Quijas, S. and P. Balvanera (2013). Biodiversity and ecosystem services. Encyclopedia of Biodiversity (Second Edition). Waltham, Academic Press**:** 341-356.

Category: Ecosystem services

Keywords: *Ecosystem process, ecosystem service, ecosystem service provider, experimental manipulations, food, functional diversity, human health, human well-being, meta-analysis, observational studies, pollination, spatial scale, species composition, species richness*

Abstract: Biodiversity is tightly linked to ecosystem services and thus to the human well-being in complex ways. The roles played by biodiversity in key ecosystem services such as agricultural food production, regulation of soil productive potential, crop pollination, and human disease regulation have been intensively studied and show very different patterns and mechanisms. Experimental manipulations of biodiversity at local spatial scales, observational studies at landscape scales, and the development of spatially explicit models at regional to global scales have also contributed to test hypotheses, develop models, and inform management of the role played by biodiversity in ecosystem service delivery.

Ramirez, K., C. Lauber, R. Knight, M. Bradford and N. Fierer (2010). "Consistent effects of nitrogen fertilization on soil bacterial communities in contrasting systems." Ecology **91**(12): 3463-3470.

Category: Agriculture-induced impacts

Keywords: *16S rRNA genes, microbial ecology, N fertilization, nitrogen, pyrosequencing, soil*

bacteria, soil bacterial diversity, soil microbiology, soil nutrients/cycling

Abstract: Ecosystems worldwide are receiving increasing amounts of reactive nitrogen (N) through anthropogenic activities. Although the effects of increased N inputs on plant communities have been reasonably well studied, few comparable studies have examined impacts on whole soil bacterial communities, though they play critical roles in ecosystem functioning. We sampled soils from two long-term ecological research (LTER) experimental N gradients, both of which have been amended with NH4NO3; a grassland at Cedar Creek (27 years of N additions) and an agricultural field at Kellogg Biological Station (8 years of N additions). By examining shifts in bacterial communities across these contrasting ecosystem types, we could test competing hypotheses about the direct and indirect factors that might drive bacterial responses to elevated N inputs. Bacterial community structure was highly responsive to N additions. We observed predictable and consistent changes in the structure of the bacterial communities across both ecosystem types. Our results suggest that bacterial communities across these gradients are more structured by N and/or soil carbon availability than by shifts in the plant community or soil pH associated with the elevated nitrogen inputs. In contrast to the pronounced shifts in bacterial community composition and in direct contrast to the patterns often observed in plant communities, increases in N availability did not have consistent effects on the richness and diversity of soil bacterial communities.

Rand, T., J. Tylianakis and T. Tscharntke (2006). "Spillover edge effects: the dispersal of agriculturally subsidized insect natural enemies into adjacent natural habitats." Ecology Letters **9**(5): 603-614.

Category: Ecosystem services

Keywords: *Agroecosystem, biological control, consumer, cross-boundary, cross-system, edge effects, fragmentation, herbivore, spatial subsidies, spillover predation, pest regulation*

Abstract: The cross-edge spillover of subsidized predators from anthropogenic to natural habitats is an important process affecting wildlife, especially bird, populations in fragmented landscapes. However, the importance of the spillover of insect natural enemies from agricultural to natural habitats is unknown, despite the abundance of studies examining movement in the opposite direction. Here, we synthesize studies from various ecological sub-disciplines to suggest that spillover of agriculturally subsidized insect natural enemies may be an important process affecting prey populations in natural habitat fragments. This contention is based on (1) the ubiquity of agricultural–natural edges in human dominated landscapes; (2) the substantial literature illustrating that crop and natural habitats share important insect predators; and (3) the clear importance of the landscape matrix, specifically distance to ecological edges, in influencing predator impacts in agroecosystems. Further support emerges from theory on the importance of cross-boundary subsidies for within site consumer–resource dynamics. In particular, high productivity and temporally variable resource abundance in agricultural systems are predicted to result in strong spillover effects. More empirical work examining the prevalence and significance of such natural enemy spillover will be critical to a broader understanding of fragmentation impacts on insect predator–prey interactions.

Rantalainen, M., J. Haimi, H. Fritze, T. Pennanen and H. Setala (2008). "Soil decomposer community as a model system in studying the effects of habitat fragmentation and habitat corridors." Soil Biology and Biochemistry **40**(4): 853-863.

Category: Ecosystem services

Keywords: *Soil fauna, soil microbes, below-ground habitat, ecological model system, habitat size, ecosystem functioning, scale, below-ground biodiversity, soil nutrients/cycling*

Abstract: Due to the practical difficulties of experimental study of habitat fragmentation and habitat corridors at the landscape scale, the use of smaller-scale model systems has been offered as a feasible alternative to uncover the ecological phenomena taking place in fragmented environments. In this mini-review, we consider the applicability of the soil decomposer community as such a model system. For the most part, this article is based on the few studies that have explicitly addressed this question by experimental manipulations of the natural habitat of soil decomposer community. However, to broaden the view, we also capitalize upon studies focusing on the effects of isolation and soil use changes on soil organisms and on dispersal of soil fauna, all of these being considered as factors determining the sensitivity of organisms to habitat fragmentation. Since usability of a model system by definition depends on the possibility of applying the results to other (usually larger scale) systems, we discuss the characteristics of the soil decomposer community also from this point of view.

The existing data suggest that soil organisms, in general, are not sensitive to habitat fragmentation even in small scale. Because of this, and the unique features of the belowground environment and its biota combined with gaps in the knowledge of the life history characteristics of soil organisms, the soil decomposer community is not ideal for predicting the implications of habitat fragmentation and habitat corridors on threatened species. Despite this, we still believe that there are lessons to be learned by studying the effects of habitat fragmentation on this important community of organisms, especially in combination with the consequences of ongoing climate change.

Raudsepp-Hearne, C., G. D. Peterson and E. M. Bennett (2010). "Ecosystem service bundles for analyzing tradeoffs in diverse landscapes." Proceedings of the National Academy of Sciences **107**(11): 5242-5247.

Category: Ecosystem services

Keywords: *Ecosystem services, landscape, spatial analysis, agriculture*

Abstract: A key challenge of ecosystem management is determining how to manage multiple ecosystem services across landscapes. Enhancing important provisioning ecosystem services, such as food and timber, often leads to tradeoffs between regulating and cultural ecosystem services, such as nutrient cycling, flood protection, and tourism. We developed a framework for analyzing the provision of multiple ecosystem services across landscapes and present an empirical demonstration of ecosystem service bundles, sets of services that appear together repeatedly. Ecosystem service bundles were identified by analyzing the spatial patterns of 12 ecosystem services in a mixed-use landscape consisting of 137 municipalities in

Quebec, Canada. We identified six types of ecosystem service bundles and were able to link these bundles to areas on the landscape characterized by distinct social–ecological dynamics. Our results show landscape-scale tradeoffs between provisioning and almost all regulating and cultural ecosystem services, and they show that a greater diversity of ecosystem services is positively correlated with the provision of regulating ecosystem services. Ecosystem service-bundle analysis can identify areas on a landscape where ecosystem management has produced exceptionally desirable or undesirable sets of ecosystem services.

Rauschmayer, F., S. van den Hove and T. Koetz (2009). "Participation in EU biodiversity governance: how far beyond rhetoric?" Environment and planning. C, Government & policy **27**(1): 42.

Category: Policy

Keywords: *EU biodiversity governance, Birds and Habitat directives, Natura 2000, France, Germany, rhetoric on participation, real-life implementation*

Abstract: We explore the theory and practice of participation in EU biodiversity governance, focusing on the implementation of the Birds and Habitat directives and Natura 2000 at the EU and member- state levels in the cases of France and Germany. We identify three shifts in EU biodiversity governance which potentially lead to intensifying participatory processes, but which may also be induced by more participation: (i) a shift from a top-down state-centred administrative understanding of policy making towards more flexible and bottom-up approaches; (ii) a shift towards more democratic, `postnormal', types of science; and (iii) a shift from a conservation focus towards a more anthropocentric ecosystems goods-and-services approach framed in a normative context of sustainability. We look at whether these shifts happen in practice and also look at the link with participation. At all political levels a big gap remains between the rhetoric on participation and the real-life implementation of participatory processes.

Reinhard, S. and V. Linderhof (2012). Does the EU environment benefit from agri-environmental measures? A spatial econometric analysis. ERSA conference papers. ERSA. **12:** 1136.

Category: Farmer and societal benefits

Keywords: *Rural Development Program, spatial data analyses, spatial econometrics, environmental economics, agriculture*

Abstract: This paper analyses the impact of agri-environmental measures (AEM), the most important measure of the EU Rural Development Program (RDP) measures. Of the total public RDP budget, almost a quarter is allocated to this measure (35 billion euro including EU and national contribution). The measure is offered in all 27 EU Member States. Highest farmer uptake is found in extensive agricultural regions (mountainous areas, grassland areas), whereas low implementation occurs in prime agricultural regions. AEM are contracts between farmers and the governing authority, in which farmers commit themselves to adopt environmentally friendly farming practices that go beyond usual good agricultural practice. EU-wide environmental impact indicators are not readily available therefore we constructed

two indicators (i) High Natural Value (HNV) farmland indicator at NUTS2 level, (capturing agricultural biodiversity change) and (ii) nitrogen balance (capturing change in water quality). These indicators are used in a joint production function that resembles the joint production of agricultural produce and biodiversity/landscape, incorporating the environmentally detrimental emissions of nutrients. Data were collected from Eurostat and other sources. The spending on the agri-environmental measures is not uniformly distributed over the NUTS 2 regions in the EU. The spatial analyses of nitrogen surplus and HNV- farmland showed the presence of spatial dependencies. Based on the spatial dependency tests of the classical regression model, a spatial error model is estimated. In the current version we relate the entire array of AEM to one impact indicators. Data on spending disaggregated to the various activities would improve the econometric estimation.

Renting, H., W. Rossing, J. Groot, J. D. Van der Ploeg, C. Laurent, D. Perraud, D. Stobbelaar and M. Van Ittersum (2009). "Exploring multifunctional agriculture. A review of conceptual approaches and prospects for an integrative transitional framework." Journal of Environmental Management **90, Supplement 2**(0): S112-S123.

Category: Farmer and societal benefits; Policy

Keywords: *Multifunctional agriculture, sustainability, farm household strategies, land-use change, governance, interdisciplinarity*

Abstract: In the last decade the multifunctional agriculture (MFA) concept has emerged as a key notion in scientific and policy debates on the future of agriculture and rural development. Broadly speaking, MFA refers to the fact that agricultural activity beyond its role of producing food and fibre may also have several other functions such as renewable natural resources management, landscape and biodiversity conservation and contribution to the socio-economic viability of rural areas. The use of the concept can be traced to a number of wider societal and political transformation processes, which have influenced scientific and policy approaches in different ways amongst countries and disciplines. This paper critically discusses various existing research approaches to MFA, both from natural and social sciences. To this aim different strands of literature are classified according to their focus on specific governance mechanisms and levels of analysis into four main categories of research approaches (market regulation, land-use approaches, actor-oriented and public regulation approaches). For each category an overview of the state-of-the-art of research is given and an assessment is made of its strengths and weaknesses. The review demonstrates that the multifunctionality concept has attracted a wealth of scientific contributions, which have considerably improved our understanding of key aspects of MFA. At the same time approaches in the four categories have remained fragmented and each has limitations to understand MFA in all its complexity due to inherent constraints of applied conceptualizations and associated disciplinary backgrounds. To go beyond these limitations, we contend, new meta-level frameworks of analysis are to be developed that enable a more integrated approach. The paper concludes by presenting the main lines of an integrative, transitional framework for the study of MFA, which analyses multifunctional agriculture against the background of wider societal change processes towards sustainability and identifies a number of key elements and

research challenges for this.

Ricketts, T. (2001). "The matrix matters: effective isolation in fragmented landscapes." Am Nat **158**: 87-99.
Category: Agriculture-induced impacts
Keywords: *Fragmentation, landscape ecology, matrix, dispersal, butterflies, maximum likelihood*

Abstract: Traditional approaches to the study of fragmented landscapes invoke an island-ocean model and assume that the nonhabitat matrix surrounding remnant patches is uniform. Patch isolation, a crucial parameter to the predictions of island biogeography and metapopulation theories, is measured by distance alone. To test whether the type of interpatch matrix can contribute significantly to patch isolation, I conducted a mark-recapture study on a butterfly community inhabiting meadows in a naturally patchy landscape. I used maximum likelihood to estimate the relative resistances of the two major matrix types (willow thicket and conifer forest) to butterfly movement between meadow patches. For four of the six butterfly taxa (subfamilies or tribes) studied, conifer was 3–12 times more resistant than willow. For the two remaining taxa (the most vagile and least vagile in the community), resistance estimates for willow and conifer were not significantly different, indicating that responses to matrix differ even among closely related species. These results suggest that the surrounding matrix can significantly influence the "effective isolation" of habitat patches, rendering them more or less isolated than simple distance or classic models would indicate. Modification of the matrix may provide opportunities for reducing patch isolation and thus the extinction risk of populations in fragmented landscapes.

Ricketts, T., G. Daily, P. Ehrlich and C. D. Michener (2004). "Economic value of tropical forest to coffee production." Proceedings of the National Academy of Sciences of the United States of America **101**(34): 12579-12582.
Category: Ecosystem services
Keywords: *Bees, ecosystem service, landscape, pollination*

Abstract: Can economic forces be harnessed for biodiversity conservation? The answer hinges on characterizing the value of nature, a tricky business from biophysical, socioeconomic, and ethical perspectives. Although the societal benefits of native ecosystems are clearly immense, they remain largely unquantified for all but a few services. Here, we estimate the value of tropical forest in supplying pollination services to agriculture. We focus on coffee because it is one of the world's most valuable export commodities and is grown in many of the world's most biodiverse regions. Using pollination experiments along replicated distance gradients, we found that forest-based pollinators increased coffee yields by 20% within ≈1 km of forest. Pollination also improved coffee quality near forest by reducing the frequency of "peaberries" (i.e., small misshapen seeds) by 27%. During 2000–2003, pollination services from two forest fragments (46 and 111 hectares) translated into ≈$60,000 (U.S.) per year for one Costa Rican farm. This value is

commensurate with expected revenues from competing land uses and far exceeds current conservation incentive payments. Conservation investments in human-dominated landscapes can therefore yield double benefits: for biodiversity and agriculture.

Ricketts, T. H., J. Regetz, I. Steffan-Dewenter, S. A. Cunningham, C. Kremen, A. Bogdanski, B. Gemmill-Herren, S. S. Greenleaf, A. M. Klein, M. M. Mayfield, L. A. Morandin, A. Ochieng and B. F. Viana (2008). "Landscape effects on crop pollination services: are there general patterns?" Ecology Letters **11**(5): 499-515.

Category: Ecosystem services

Keywords: *Agriculture, bees, ecosystem services, habitat fragmentation, hierarchical Bayesian model, land use, pollinators, above-ground biodiversity, pollination*

Abstract: Pollination by bees and other animals increases the size, quality, or stability of harvests for 70% of leading global crops. Because native species pollinate many of these crops effectively, conserving habitats for wild pollinators within agricultural landscapes can help maintain pollination services. Using hierarchical Bayesian techniques, we synthesize the results of 23 studies – representing 16 crops on five continents – to estimate the general relationship between pollination services and distance from natural or semi-natural habitats. We find strong exponential declines in both pollinator richness and native visitation rate. Visitation rate declines more steeply, dropping to half of its maximum at 0.6 km from natural habitat, compared to 1.5 km for richness. Evidence of general decline in fruit and seed set – variables that directly affect yields – is less clear. Visitation rate drops more steeply in tropical compared with temperate regions, and slightly more steeply for social compared with solitary bees. Tropical crops pollinated primarily by social bees may therefore be most susceptible to pollination failure from habitat loss. Quantifying these general relationships can help predict consequences of land use change on pollinator communities and crop productivity, and can inform landscape conservation efforts that balance the needs of native species and people.

Robertson, N. and S. Wunder (2005). Fresh tracks in the forest. Assessing incipient Payments for Environmental Services initiatives in Bolivia, CIFOR.

Category: Ecosystem services

Keywords: *Nature conservation, incentives, economic evaluation, watershed, management, carbon sequestration, environmental impact, biodiversity, nature tourism, social impact, Bolivia, case studies*

Executive Summary

As threats to the world's ecosystems grow and change, increasing attention has been focused on the important services that ecosystems provide to humans. These services include carbon sequestration and storage, watershed protection, and landscape beauty and biodiversity conservation. Worldwide, a new generation of conservation initiatives aims at creating systems in which the users of one or more environmental services compensate resource managers for improved conservation of these services. Such systems, termed 'payments for environmental services' (PES), may have the potential to protect environmental services while at the same time

improving local livelihoods. This study provides an overview and assessment of environmental, economic and social effects of various PES-related initiatives as well as an overview of challenges and promoting factors to PES in Bolivia. We use five criteria to define PES systems: a voluntary agreement, a well-defined service, at least one buyer, at least one seller, and a conditional (quid pro quo) transaction.

We examined 17 initiatives that were either ongoing or under preparation in various parts of Bolivia. We were able to closely analyse nine of these, which we consider our primary case studies. Most of these initiatives are still fairly young, and the analyses of their effects remain preliminary. Conceptually, we found that none of the existing initiatives in Bolivia satisfies all the above-mentioned criteria. Thus, no 'pure' PES scheme currently exists in Bolivia. However, several experiences use direct economic incentives and satisfy several of the criteria. There is thus a broader family of 'PES-like' projects exhibiting some important PES elements.

Five of the nine initiatives that we analysed closely were community-based tourism initiatives that focus on landscape beauty, profiting from the growing ecotourism market in Bolivia and existing tour operations near protected areas. Watershed PES systems were the second most common (three cases) and have received substantial attention, both because of a growing scarcity of water and because of the ideological–political controversies in Bolivia about using any type of market-based system to manage watersheds. There has only been one carbon project (Noel Kempff) in Bolivia, while others are in the pipeline. Biodiversity PES systems have basically all remained incipient initiatives without taking off, probably primarily because of uncertain markets in the case of biodiversity premiums for products and uncertain land-tenure systems for conservation concessions. However, biodiversity protection is 'bundled' with six of the nine initiatives; conservation organisations with a primary interest in biodiversity protection use other services (particularly ecotourism) as an entry and leverage point for pursuing biodiversity conservation.

Our analysis of the environmental effects, which we estimated by assessing changes in environmental threats, showed generally net positive protection effects in the nine PES-like initiatives, but also a large variation in environmental protection efficiency. This is to some extent explained by the short lifespan of some of the initiatives, but otherwise mostly to be blamed on case-by-case design factors. The economic effects also varied in size, but were generally positive: all major groups participating as environmental-service sellers were made better off in economic terms—there were no trends of people being 'trapped' by PES in a negative livelihood outcome. The magnitude of gains varied according to the project age, the amount of external support and the management of the system. Some groups other than PES recipients proper could lose out from PES-like initiatives, e.g. landless labourers who had hoped to colonise land being protected in a PES system. This can also cause equity concerns and social tensions. On the other hand, we also found a series of community-wide positive social effects, such as improved organisation and articulation vis-à-vis outside actors, and training.

Several of the PES-like initiatives could be transformed into full PES systems; certainly in some cases this is a necessity, as when sellers of environmental services exist, but donors are bridging the current lack of buyers willing to pay for these services. Our recommendations for the future design of successful PES systems

include, among others, trust-building among participants and a thorough understanding of future PES demand, supply and future transaction costs. For initiatives currently underway, more efforts should be made to monitor environmental impacts, directly reward those environmental-service providers that comply with the contingent PES agreements, and keep all stakeholders well informed of the goals, challenges and progress of the PES initiative. The prospects for PES success warrant future exploration and support.

Rockström, J., M. Falkenmark, L. Karlberg, H. Hoff, S. Rost and D. Gerten (2009). "Future water availability for global food production: The potential of green water for increasing resilience to global change." Water Resources Research **45**(7): W00A12.

Category: Climate change; Policy

Keywords: *Climate change, global water resources, agricultural water management, resilience, food production, integrated green-blue water analysis, water cycles, eco-hydrology, water budgets, climate impacts*

Abstract: While past strategies for agricultural water management have focused on irrigation (use of blue water), this paper demonstrates the dominance of green water in food production. A global, yet spatially disaggregated, green-blue analysis of water availability and requirement, using the LPJmL dynamic vegetation and water balance model, indicates that many countries currently assessed as severely water short are able to produce enough food for their populations if green water is considered and is managed well. The need to integrate green and blue water management is highlighted in a future scenario of water availability under climate change and population growth (HadCM2 A2). For 2050, the scenario indicates that 59% of the world population will face blue water shortage, and 36% will face green and blue water shortage. Even under climate change, good options to build water resilience exist without further expansion of cropland, particularly through management of local green water resources that reduces risks for dry spells and agricultural droughts.

Roder, W., S. Mason, M. Clegg and K. Kniep (1989). "Yield-soil water relationships in sorghum-soybean cropping systems with different fertilizer regimes." Agron. J. **81**(3): 470-475.

Category: Agroecology and agroecological practices

Keywords: *Monoculture, soil fertility, fertilization, oil plant(vegetal), field experiment, Nebraska, nitrogen fertilization, manure, yield, soil plant relation, soil water properties, crop rotation, mineral fertilization, organic fertilization, Cultivated soil, mollisols, glycine max, silty clay loam soils, United States, Leguminosae, dicotyledones, angiospermae, apermatophyta, soil nutrients/cycling*

Abstract: Crop rotation of soybean [Glycine max (L.) Merr.] with grain sorghum [Sorghum bicolor (L.) Moench], and application of N fertilizer or manure generally increases grain sorghum yield. Little is known about rotation and fertilization effects on soybean yield in the Great Plains. Grain yields were measured from 1981 to 1987 in a cropping experiment started in 1980 on a Sharpsburg silty clay loam (fine, montmorillonitic, mesic Typic Argiudoll). The cropping treatments included

continuous soybean, continuous grain sorghum, and grain sorghum-soybean rotation. Fertilizer treatments consisted of control, manure (15.8 Mg dry matter ha−1 yr−1l) and N (45 kg ha−1 for soybean and 90 kg N ha−1 for sorghum). Volumetric soil water content was determined with a neutron probe in 1985, 1986, and 1987. Soil water content was unaffected by fertilizer treatment. Water content in the upper 30 cm was generally greatest with continuous grain sorghum and least with continuous soybean. Soil water depletion to 120 cm in September was 10 to 36 mm greater with soybean than with grain sorghum. Crop rotation increased soybean yield, but N application did not. Manure application reduced soybean yield in 1986, but had no effect in the other years. Rotation and fertilization increased sorghum grain yield. The soybean yield advantage from crop rotation decreased as 1 April to 31 May rainfall increased. Cropping-system induced differences in soil water content early in the growing season may be partly responsible for higher soybean yield with crop rotation.

Rodriguez, J., E. Bennett, G. Cumming, S. Cork, J. Agard, A. Dobson and G. Peterson (2006). "Trade-offs across space, time, and ecosystem services." Ecology and Society **11**(1): 28.

Category: Ecosystem services

Keywords: *Ecosystem services, Millennium Ecosystem Assessment, space, time, synergisms, trade-offs*

Abstract: Ecosystem service (ES) trade-offs arise from management choices made by humans, which can change the type, magnitude, and relative mix of services provided by ecosystems. Trade-offs occur when the provision of one ES is reduced as a consequence of increased use of another ES. In some cases, a trade-off may be an explicit choice; but in others, trade-offs arise without premeditation or even awareness that they are taking place. Trade-offs in ES can be classified along three axes: spatial scale, temporal scale, and reversibility. Spatial scale refers to whether the effects of the trade-off are felt locally or at a distant location. Temporal scale refers to whether the effects take place relatively rapidly or slowly. Reversibility expresses the likelihood that the perturbed ES may return to its original state if the perturbation ceases. Across all four Millennium Ecosystem Assessment scenarios and selected case study examples, trade-off decisions show a preference for provisioning, regulating, or cultural services (in that order). Supporting services are more likely to be “taken for granted.” Cultural ES are almost entirely unquantified in scenario modeling; therefore, the calculated model results do not fully capture losses of these services that occur in the scenarios. The quantitative scenario models primarily capture the services that are perceived by society as more important—provisioning and regulating ecosystem services—and thus do not fully capture trade-offs of cultural and supporting services. Successful management policies will be those that incorporate lessons learned from prior decisions into future management actions. Managers should complement their actions with monitoring programs that, in addition to monitoring the short-term provisions of services, also monitor the long-term evolution of slowly changing variables. Policies can then be developed to take into account ES trade-offs at multiple spatial and temporal scales. Successful strategies will recognize the inherent complexities of ecosystem management and will work to develop policies that minimize the effects of ES trade-offs.

Rodríguez-Labajos, B. (2013). "Climate change, ecosystem services, and costs of action and inaction: scoping the interface." Wiley Interdisciplinary Reviews: Climate Change: n/a-n/a.
Category: Climate change
Keywords: *Climate change, ecosystem service provision, ecosystem change, damages, mitigation costs. human wellbeing*

Abstract: Cost calculations related to climate change have accrued much intellectual effort. However, few works approach the assessment from the point of view of the effects of climate variability and change in ecosystem service provision. Failure to act plausibly leads to ecological, social, and economic damages as a result of ecosystem change. The necessary actions to cope with unavoidable damages from such change generate adaptation costs, while mitigation costs are associated with actions to tackle undesired future changes in the ecosystems. Examples of these effects and related costs, based on representative studies, are reviewed following the organizing scheme of the ecosystem services approach. The examination of case examples reveals the potential and limits of monetary versus non-monetary estimations of impacts in human wellbeing from climate change-related changes in the ecosystems, trade-offs between types of ecosystem service provision and implications of timing in action. This article further discusses the necessary steps to advance in an inclusive scrutiny of the costs associated with the effects of climate change on ecosystem service provision.

Rosa, H., D. Barry, S. Kandel and L. Dimas (2004). Compensation for Environmental Services and Rural Communities: Lessons from the Americas. Working paper series, Political Economy Research Institute.
Category: Ecosystem services
Keywords: *compensation for environmental services, rural communities, America*

Abstract: In principle, payments for environmental services – such as watershed management, biodiversity conservation, and carbon sequestration – can advance the goals of both environmental protection and poverty reduction. A review of recent initiatives in the Americas suggests, however, that this desirable combination is not automatic. If payments for environmental services (PES) schemes are to be an effective vehicle for strengthening livelihoods in poor rural communities, they must be designed with that objective firmly in mind. This paper draws key lessons from diverse experiences in Costa Rica, Mexico, Brazil, El Salvador, and New York.

Rosenzweig, C., D. Karoly, M. Vicarelli, P. Neofotis, Q. Wu, G. Casassa, A. Menzel, T. Root, N. Estrella, B. Seguin, P. Tryjanowski, C. Liu, S. Rawlins and A. Imeson (2008). "Attributing physical and biological impacts to anthropogenic climate change." Nature **453**(7193): 353-357.
Category: Climate change
Keywords: *Dynamical climatology, spatial analysis regional scope, planetary scale, biosphere, Cryosphere, hydrosphere, environment impact, change detection, observation data ; greenhouse gas, air pollution, human activity, anthropogenic*

factor, man environment interface, climate warming, climate change, global change

Abstract: Significant changes in physical and biological systems are occurring on all continents and in most oceans, with a concentration of available data in Europe and North America. Most of these changes are in the direction expected with warming temperature. Here we show that these changes in natural systems since at least 1970 are occurring in regions of observed temperature increases, and that these temperature increases at continental scales cannot be explained by natural climate variations alone. Given the conclusions from the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report that most of the observed increase in global average temperatures since the mid-twentieth century is very likely to be due to the observed increase in anthropogenic greenhouse gas concentrations, and furthermore that it is likely that there has been significant anthropogenic warming over the past 50 years averaged over each continent except Antarctica, we conclude that anthropogenic climate change is having a significant impact on physical and biological systems globally and in some continents.

Rossing, W. A. H., J. M. Meynard and M. K. van Ittersum (1997). Model-based explorations to support development of sustainable farming systems: case studies from France and the Netherlands. Developments in Crop Science, Elsevier. **Volume 25:** 339-351.

Category: Agroecology and agroecological practices

Keywords: *Sustainable agriculture, farming systems, cropping systems, prototyping, model-based learning, participatory research*

Abstract: Sustainable land use requires development of agricultural production systems that, in adidtion to economic objectives, contribute to objectives in areas such as environment, health and well-being, rural scenery and nature. Since these objectives are at least partially conflicting, development of sustainable farming systems is characterized by negotiation about acceptable compromises among objectives. Four phases can be distinguished in the course of farming systems development: diagnosis, design, testing and improvement, and dissemination. During the last decade an approach coined 'prototyping' has emerged as a promising method for empirical farming systems development in Western Europe. Limitations of the approach include: (1) the limited number of systems that can be evaluated, resulting in a lack of perspective on conflicts among objectives, and (2) the expertise-based nature of rules used during systems design which unduly narrows the range of available options and obscures understanding of systems behaviour. In the paper, explorative studies based on transparent models of agronomy and management are put forward to supplement empirical prototyping and to remedy its shortcomings. To illustrate the potential of model-based explorations, two case studies are presented. The first case study deals with diagnosis and design of wheatbased rotations in the Paris Basin of France, aimed at alleviating tactical problems of poor resource-use efficiency within the constrainst imposed by existing crop rotations. The second case study addresses design of sustainable bulb-based farming systems in the Netherlands with the purpose of investigating strategic options at crop rotation and farm level to resolve conflicts between economic and environmental objectives. In the discussion, methodological elements of model-based explorations and interaction with stakeholders are addressed, and opportunities for enhanced

development of sustainable farming systems are identified.

Rounsevell, M. D. A., F. Ewert, I. Reginster, R. Leemans and T. R. Carter (2005). "Future scenarios of European agricultural land use: II. Projecting changes in cropland and grassland." Agriculture, Ecosystems & Environment **107**(2-3): 117-135.
Category: Policy; Climate change; Agriculture-induced impacts
Keywords: *Land use scenarios, special Report on Emission Scenarios (SRES), climate change*

Abstract: This paper presents the development of quantitative, spatially explicit and alternative scenarios of future agricultural land use in Europe (the 15 European Union member states, Norway and Switzerland). The scenarios were constructed to support analyses of the vulnerability of ecosystem services, but the approach also provides an exploration of how agricultural land use might respond to a range of future environmental change drivers, including climate and socio-economic change. The baseline year was 2000 and the scenarios were constructed for 3 years (2020, 2050 and 2080) at a spatial resolution of 10 min latitude and longitude. Time slices were defined for the climate scenarios as the 10 years before 2020, 2050 and 2080. The scenarios were based on an interpretation of the four storylines of the Special Report on Emission Scenarios (SRES) of the Intergovernmental Panel on Climate Change (IPCC) using a simple supply/demand model of agricultural area quantities at the European scale and the disaggregation of these quantities using scenario-specific, spatial allocation rules. The scenarios demonstrate the importance of assumptions about technological development for future agricultural land use in Europe. If technology continues to progress at current rates then the area of agricultural land would need to decline substantially. Such declines will not occur if there is a correspondingly large increase in the demand for agricultural goods, or if political decisions are taken either to reduce crop productivity through policies that encourage extensification or to accept widespread overproduction. For the set of parameters assumed here, cropland and grassland areas (for the production of food and fibre) decline by as much as 50% of current areas for some scenarios. Such declines in production areas would result in large parts of Europe becoming surplus to the requirement of food and fibre production. Although it is difficult to anticipate how this land would be used in the future, it seems that continued urban expansion, recreational areas (such as for horse riding) and forest land use would all be likely to take up at least some of the surplus. Furthermore, whilst the substitution of food production by energy production was considered in these scenarios, surplus land would provide further opportunities for the cultivation of bioenergy crops.

Rounsevell, M. D. A., I. Reginster, M. B. Araujo, T. R. Carter, N. Dendoncker, F. Ewert, J. I. House, S. Kankaanpaa, R. Leemans, M. J. Metzger, C. Schmit, P. Smith and G. Tuck (2006). "A coherent set of future land use change scenarios for Europe." Agriculture, Ecosystems & Environment **114**(1): 57-68.
Category: Climate change
Keywords: *Land use scenarios, special report on emission scenarios (IPCC SRES), climate change, spatial allocation rules, PELCOM land cover data set, land use modelling*

Abstract: This paper presents a range of future, spatially explicit, land use change

scenarios for the EU15, Norway and Switzerland based on an interpretation of the global storylines of the Intergovernmental Panel on Climate Change (IPCC) that are presented in the special report on emissions scenarios (SRES). The methodology is based on a qualitative interpretation of the SRES storylines for the European region, an estimation of the aggregate totals of land use change using various land use change models and the allocation of these aggregate quantities in space using spatially explicit rules. The spatial patterns are further downscaled from a resolution of 10 min to 250 m using statistical downscaling procedures. The scenarios include the major land use/land cover classes urban, cropland, grassland and forest land as well as introducing new land use classes such as bioenergy crops.

The scenario changes are most striking for the agricultural land uses, with large area declines resulting from assumptions about future crop yield development with respect to changes in the demand for agricultural commodities. Abandoned agricultural land is a consequence of these assumptions. Increases in urban areas (arising from population and economic change) are similar for each scenario, but the spatial patterns are very different. This reflects alternative assumptions about urban development processes. Forest land areas increase in all scenarios, although such changes will occur slowly and largely reflect assumed policy objectives. The scenarios also consider changes in protected areas (for conservation or recreation goals) and how these might provide a break on future land use change. The approach to estimate new protected areas is based in part on the use of models of species distribution and richness. All scenarios assume some increases in the area of bioenergy crops with some scenarios assuming a major development of this new land use.

Several technical and conceptual difficulties in developing future land use change scenarios are discussed. These include the problems of the subjective nature of qualitative interpretations, the land use change models used in scenario development, the problem of validating future change scenarios, the quality of the observed baseline, and statistical downscaling techniques.

Royal Society. (2009). Reaping the benefits: science and the sustainable intensification of global agriculture. RS Policy document 11/09. London**:** 86.

Category: Policy; Ecosystem services

Keywords: *UK, agricultural sustainable intensification, agricultural sustainability, food production, constraints, biological science, research and technology, innovation*

Abstract: Food security is one of this century's key global challenges. By 2050 the world will require increased crop production in order to feed its predicted 9 billion people. This must be done in the face of changing consumption patterns, the impacts of climate change and the growing scarcity of water and land. Crop production methods will also have to sustain the environment, preserve natural resources and support livelihoods of farmers and rural populations around the world. There is a pressing need for the 'sustainable intensification' of global agriculture in which yields are increased without adverse environmental impact and without the cultivation of more land.

Addressing the need to secure a food supply for the whole world requires an urgent international effort with a clear sense of long-term challenges and possibilities.

Biological science, especially publicly funded science, must play a vital role in the sustainable intensification of food crop production. The UK has a responsibility and the capacity to take a leading role in providing a range of scientific solutions to mitigate potential food shortages. This will require significant funding of cross-disciplinary science for food security.

The constraints on food crop production are well understood, but differ widely across regions. The availability of water and good soils are major limiting factors. Significant losses in crop yields occur due to pests, diseases and weed competition. The effects of climate change will further exacerbate the stresses on crop plants, potentially leading to dramatic yield reductions. Maintaining and enhancing the diversity of crop genetic resources is vital to facilitate crop breeding and thereby enhance the resilience of food crop production.

Addressing these constraints requires technologies and approaches that are underpinned by good science. Some of these technologies build on existing knowledge, while others are completely radical approaches, drawing on genomics and high-throughput analysis.

Novel research methods have the potential to contribute to food crop production through both genetic improvement of crops and new crop and soil management practices. Genetic improvements to crops can occur through breeding or genetic modification to introduce a range of desirable traits. The application of genetic methods has the potential to refine existing crops and provide incremental improvements. These methods also have the potential to introduce radical and highly significant improvements to crops by increasing photosynthetic efficiency, reducing the need for nitrogen or other fertilisers and unlocking some of the unrealised potential of crop genomes.

The science of crop management and agricultural practice also needs to be given particular emphasis as part of a food security grand challenge. These approaches can address key constraints in existing crop varieties and can be applied widely. Current approaches to maximising production within agricultural systems are unsustainable; new methodologies that utilise all elements of the agricultural system are needed, including better soil management and enhancement and exploitation of populations of beneficial soil microbes. Agronomy, soil science and agroecology—the relevant sciences—have been neglected in recent years.

Past debates about the use of new technologies for agriculture have tended to adopt an either/or approach, emphasising the merits of particular agricultural systems or technological approaches and the downsides of others. This has been seen most obviously with respect to genetically modified (GM) crops, the use of pesticides and the arguments for and against organic modes of production. These debates have failed to acknowledge that there is no technological panacea for the global challenge of sustainable and secure global food production. There will always be trade-offs and local complexities. This report considers both new crop varieties and appropriate agroecological crop and soil management practices and adopts an inclusive approach. No techniques or technologies should be ruled out. Global agriculture demands a diversity of approaches, specific to crops, localities, cultures and other circumstances. Such diversity demands that the breadth of relevant scientific enquiry is equally diverse, and that science needs to be combined with social, economic and political perspectives.

In addition to supporting high-quality science, the UK needs to maintain and build its capacity to innovate, in collaboration with international and national research centres. UK scientists and agronomists have in the past played a leading role in disciplines relevant to agriculture, but training in agricultural sciences and related topics has recently suffered from a lack of policy attention and support. Agricultural extension services, connecting farmers with new innovations, have been similarly neglected in the UK and elsewhere. There is a major need to review the support for and provision of extension services, particularly in developing countries.

The governance of innovation for agriculture needs to maximise opportunities for increasing production, while at the same time protecting societies, economies and the environment from negative side effects. Regulatory systems need to improve their assessment of benefits. Horizon scanning will ensure proactive consideration of technological options by governments. Assessment of benefits, risks and uncertainties should be seen broadly, and should include the wider impacts of new technologies and practices on economies and societies. Public and stakeholder dialogue—with NGOs, scientists and farmers in particular—needs to be a part of all governance frameworks.

Rucker, R., W. Thurman and M. Burgett (2012). "Honey bee pollination markets and the internalization of reciprocal benefits." American Journal of Agricultural Economics **94**(4): 956-977.

Category: Ecosystem services

Keywords: *Pollination services, market, United Staes, bee, pollination fees, pollination*

Abstract: The world's most extensive markets for pollination services are those for honey bee pollination in the United States. These markets play important roles in coordinating the behavior of migratory beekeepers, who both produce honey and provide substitutes for ecosystem pollination services. We analyze the economic forces that drive migratory beekeeping and theoretically and empirically analyze the determinants of pollination fees in a larger and richer data set than has been studied before. Our empirical results expand our understanding of pollination markets and market-supporting institutions that internalize external effects.

Rudel, T., L. Schneider, M. Uriarte, B. Turner, R. DeFries, D. Lawrence, J. Geoghegan, S. Hecht, A. Ickowitz, E. Lambin, T. Birkenholtz, S. Baptista and R. Grau (2009). "Agricultural intensification and changes in cultivated areas, 1970-2005." Proceedings of the National Academy of Sciences **106**(49): 20675-20680.

Category: Policy; Agriculture-induced impacts; Ecosystem services

Keywords: *Agriculture intensification, land sparing, land use*

Abstract: Does the intensification of agriculture reduce cultivated areas and, in so doing, spare some lands by concentrating production on other lands? Such sparing is important for many reasons, among them the enhanced abilities of released lands to sequester carbon and provide other environmental services. Difficulties measuring the extent of spared land make it impossible to investigate fully the hypothesized causal chain from agricultural intensification to declines in cultivated areas and then to increases in spared land. We analyze the historical circumstances in which rising

yields have been accompanied by declines in cultivated areas, thereby leading to land-sparing. We use national-level United Nations Food and Agricultural Organization data on trends in cropland from 1970–2005, with particular emphasis on the 1990–2005 period, for 10 major crop types. Cropland has increased more slowly than population during this period, but paired increases in yields and declines in cropland occurred infrequently, both globally and nationally. Agricultural intensification was not generally accompanied by decline or stasis in cropland area at a national scale during this time period, except in countries with grain imports and conservation set-aside programs. Future projections of cropland abandonment and ensuing environmental services cannot be assumed without explicit policy intervention.

Rundlof, M., J. Bengtsson and H. Smith (2008). "Local and landscape effects of organic farming on butterfly species richness and abundance." Journal of applied ecology **45**(3): 813-820.

Category: Agriculture-induced impacts

Keywords: *Additive partitioning, agri-environment schemes, conservation, diversity, farming practice, landscape ecology, Lepidoptera, spatial distribution, spatial scales*

Abstract:

1. Agri-environmental schemes (AES) are commonly adopted in Europe to reduce the loss of farmland biodiversity. These schemes have, however, been criticized as not fulfilling this goal, partly because their effectiveness is thought to differ depending on external factors such as landscape heterogeneity, the focal organism and scale of application.

2. We used one AES, organic farming, as a landscape-scale experiment to test whether its effect on butterflies depends on the spatial scale at which it is applied. Our study system consisted of organically and conventionally managed fields within eight pairs of matched landscapes, differing in the proportion of land under organic management at the landscape scale. Butterflies and their nectar and host-plant resources were surveyed along the fields and adjacent field borders.

3. Butterfly species richness and abundance were significantly increased by organic farming at the local scale. However, local butterfly species richness was also positively affected by a large proportion of organic farming in the surrounding landscape, independent of the local farming practice. Local and landscape farming practices interacted such that the farming practice within fields had a larger effect on butterfly abundance if surrounded by conventionally rather than organically managed fields. These results could only partly be explained by variation in local availability of nectar and host-plant resources.

4. The total observed species richness (γ-diversity) was higher in organically managed landscapes, mainly because of higher within-field diversity (α-diversity), whereas the between-field diversity (β-diversity) tended to be similar in both landscape types.

5. Synthesis and applications. Butterflies were positively affected by organic farming at a local scale, but the amount of organic farming in the surrounding landscape had either an additive (species richness) or interactive (abundance) effect. Therefore, the spatial distribution of AES must be taken into account to maximize their potential to

increase farmland biodiversity. We have shown that organic farming affected butterfly species richness on nearby conventionally managed land. This suggests a landscape effect of organic farming that may indicate a wider benefit of AES for biodiversity conservation.

Rundlof, M., M. Edlund and H. Smith (2010). "Organic farming at local and landscape scales benefits plant diversity." Ecography **33**(3): 514-522.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Pesticides, Sweden, forb, farmland, herbicide, mass, annual plant, dispersion, habitat, local effect, farming, herbaceous plant, hypothesis test, uptake, agroecosystem, intensification, agri-environmental measure, biodiversity, landscape, organic agriculture*

Abstract: Agri-environment schemes (AES) have been suggested to counter negative effects of agricultural intensification and enhance farmland biodiversity, but evaluations have produced inconsistent results. We suggest that this is partly a consequence of scale-dependence, i.e. that the consequence of organic farming will differ depending on the scale of uptake in a particular landscape. To test our hypothesis on diversity of forbs, we designed a landscape scale study using spatially explicit information about the Swedish AES for organic farming. The study system consisted of uncultivated field borders along paired fields (organic and conventional) in matched landscapes with either a high or a low proportion of organic faming, allowing separate tests of the effects of farming practice at the local and the landscape scale. The local effect of organic farming was consistently strong, with higher diversity in borders adjoining organic fields, most likely due to the lack of herbicide use on organically managed farmland. Thus, we show that not only the proportion of semi-natural habitat is important for farmland biodiversity, but that also the management of cropland can influence the diversity in semi-natural habitats. Furthermore, forb richness was also higher in borders situated in landscapes with a high proportion of organic land, irrespectively of local management, possibly as a result of dispersal of mainly annual plant species from the organically managed fields into the borders (mass effect). Our results demonstrate that farming practice at a local and a landscape scale independently can influence plant species richness, indicating that organic farming can influence diversity also at larger spatial scales and outside the organically managed land. Our study highlight the importance of studying multiple scales, including both local and landscape factors to provide a better understanding of biodiversity patterns.

Rundlof, M. and H. Smith (2006). "The effect of organic farming on butterfly diversity depends on landscape context." Journal of applied ecology **43**(6): 1121-1127.

Category: Agriculture-induced impacts; Policy

Keywords: *Agriculture, agri-environment schemes, biodiversity, conservation, farming practice, farmland, landscape heterogeneity, lepidoptera*

Abstract:

1. The recent dramatic decline in farmland biodiversity is often attributed to agricultural intensification and structural changes in the agricultural landscape. One

suggested farm practice seen to benefit biodiversity and reverse declines is organic farming. Because organic farming is viewed as a more sustainable form of agriculture it is currently subsidized by European agri-environment schemes. However, the efficiency of agri-environment schemes to preserve biodiversity has recently been questioned, partly because their uptake has been highest in extensively farmed more heterogeneous landscapes.

2. We investigated the effect of farming practice on butterfly species richness and abundance along cereal field headlands and margins on 12 matched pairs of organic and conventional farms in contrasting landscapes (homogeneous and heterogeneous landscape diversity).

3. Both organic farming and landscape heterogeneity significantly increased butterfly species richness and abundance. There was also a significant interaction between farming practice and landscape heterogeneity, because organic farming only significantly increased butterfly species richness and abundance in homogeneous rather than heterogeneous landscapes.

4. An analysis of the distribution of organic farming in Sweden in relation to productivity of the arable land (yield of spring barley, kg ha−1) indicated that the distribution of organic farms was skewed towards extensively farmed agricultural areas.

5. Synthesis and applications. The species richness and abundance of butterflies can be enhanced by actions aimed at both promoting organic farming and increasing landscape heterogeneity. However, the beneficial effect of organic farming was only evident in intensively farmed homogeneous landscapes. Currently, the majority of organic arable land in Sweden is located in heterogeneous landscapes where changing the type of farming practice adds little to the existing biodiversity. We therefore propose that the interaction between landscape heterogeneity and farming practice must be considered when promoting farmland biodiversity, for example in Europe by developing context-based agri-environment schemes to increase the amount of organic farming in intensively farmed landscapes. We also propose that in homogeneous agricultural landscapes, organic farming could be used as a more efficient tool to restore landscape heterogeneity if the creation of semi-natural landscape elements was mandatory in the regulations associated with organic agri-environment schemes.

Rusch, A., R. Bommarco, M. Jonsson, H. G. Smith and B. Ekbom (2013). "Flow and stability of natural pest control services depend on complexity and crop rotation at the landscape scale." Journal of applied ecology **50**(2): 345-354.

Category: Ecosystem services

Keywords: *Biological control, crop diversity, crop rotation, ecosystem services, farming practices, landscape complexity, stability, pest regulation*

Summary

Increasing landscape complexity can enhance biodiversity and ecosystem services in agroecosystems. However, policies based on conversion of arable land into semi-natural habitats to increase landscape complexity and ecosystem services can be difficult to implement. Although it appears to be a promising management option, nothing is known about the effect of increasing landscape diversity through crop

rotations on the delivery of ecosystem services.
In this study, we examined how landscape complexity and crop rotation intensity in the landscape at different spatial scales affect the flow and the stability of natural pest control services in barley fields using manipulative cage experiments.
Exclusion experiments revealed that natural enemies can have a strong impact on aphid population growth and that the delivery of pest control services is strongly dependent on the landscape context.
We found that the overall level of pest control increased with landscape complexity and that this effect was independent of crop rotation intensity. In addition, the within-field stability in pest control services increased with crop rotation intensity in the landscape, although stability in parasitism rates decreased.
Multiple spatial scales analyses showed that the mean level of natural pest control was best predicted by landscape complexity at the 0·5-km and the 1-km spatial scales. The stability in overall pest control decreased with proportion of ley at the 2·5-km and the 3-km spatial scales.
Synthesis and applications. Our study disentangled, for the first time, the relative effects of landscape complexity and crop rotation intensity on the delivery of an ecosystem service. We show that combined management of semi-natural habitat and crop rotation can stabilize and enhance natural pest control in agricultural landscapes. Our findings have important implications in terms of management options to maintain and enhance ecosystem services in agroecosystems. They suggest that conservation of heterogeneous landscapes, characterized by a higher proportion of semi-natural habitats such as pastures and relatively small fields, is essential for maintaining and enhancing effective biological control in agroecosystems.

Rusch, A., M. Valantin-Morison, J.-P. Sarthou and J. Roger-Estrade (2010). Biological control of insect pests in agroecosystems: effects of crop management, farming systems, and seminatural habitats at the landscape scale: a review.
Category: Ecosystem services
Keywords: *Biological Control, insect Pests, agroecosystems, farming Systems, seminatural habitats, landscape, pest regulation*
Abstract: There is a growing body of evidence to suggest that the simplification of land uses associated with a strong dependence on agrochemical inputs is decreas- ing environmental quality, threatening biodiversity, and increasing the likeli- hood of pest outbreaks. The development of farming systems with greater reliance on ecosystem services, such as biological control of insect pests, should increase the sustainability of agroecosystems. However, the factors responsible for the maintenance or enhancement of natural pest control remain unclear. The goal of this review is, therefore, to expose which elements, from the field to the landscape scale, influence natural enemy populations and pest regulation. We present here the principal effects of seminatural habitats, farm- ing systems, and crop management on the abundance of insect pests and their biological control, with a view to evaluating their relative importance and identifying key elements that regulate natural pest control interactions. Because of the range of spatial and temporal scales experienced by these organisms, we advocate, in studies investigating trophic

relations and biological pest control, a clear description of cropping systems and an explicit consideration of seminatural habitats and more generally of the surrounding landscape. Through this review, we also indicate gaps in knowledge and demonstrate the interest of linking agronomy and landscape ecology to understand trophic interactions, maximize natural pest control, and limit pesticide applica- tions. Quantifying the relative importance of both local and landscape scales is a fundamental step in the design and assessment of ecologically sound integrated pest management strategies for farmers.

Saad, R., T. Koellner and M. Margni (2013). "Land use impacts on freshwater regulation, erosion regulation, and water purification: a spatial approach for a global scale level." The International Journal of Life Cycle Assessment **18**(6): 1253-1264.

Category: Ecosystem services

Keywords: *Characterization factors, ecosystem quality, ecosystem services, global scale, land use, Life cycle impact assessment, regionalization, spatial differentiation*

Abstract:

Purpose Rarely considered in environmental assessment methods, potential land use impacts on a series of ecosystem services must be accounted for in widely used decision-making tools such as life cycle assessment (LCA). The main goal of this study is to provide an operational life cycle impact assessment characterization method that addresses land use impacts at a global scale by developing spatially differentiated characterization factors (CFs) and assessing the extent of their spatial variability using different regionalization levels.

Methods

The proposed method follows the recommendations of previous work and falls within the framework and principles for land use impact assessment established by the United Nations Environment Programme/Society of Environmental Toxicology and Chemistry Life Cycle Initiative. Based on the spatial approach suggested by Saad et al. (Int J Life Cycle Assess 16: 198–211, 2011), the intended impact pathways that are modeled pertain to impacts on ecosystem services damage potential and focus on three major ecosystem services: (1) erosion regulation potential, (2) freshwater regulation potential, and (3) water purification potential. Spatially-differentiated CFs were calculated for each biogeographic region of all three regionalization scale (Holdridge life regions, Holdridge life zones, and terrestrial biomes) along with a nonspatial world average level. In addition, seven land use types were assessed considering both land occupation and land transformation interventions.

Results and discussion

A comprehensive analysis of the results indicates that, when compared to all resolution schemes, the world generic averaged CF can deviate for various ecosystem types. In the case of groundwater recharge potential impacts, this range varied up to factors of 7, 4.7, and 3 when using the Holdridge life zones, the Holdridge regions, and the terrestrial biomes regionalization levels, respectively. This validates the importance of introducing a regionalized assessment and highlights how a finer scale increases the level of detail and consequently the discriminating power across several biogeographic regions, which could not have been captured

using a coarser scale. In practice, the implementation of such regionalized CFs suggests that an LCA practitioner must identify the ecosystem in which land occupation or transformation activities occur in addition to the traditional inventory data required—namely, the land use activity and the inventory flow.

Conclusions

The variability of CFs across all three regionalization levels provides an indication of the uncertainty linked to nonspatial CFs. Among other assumptions and value choices made throughout the study, the use of ecological borders over political boundaries was deemed more relevant to the interpretation of environmental issues related to specific functional ecosystem behaviors.

Saad, R., M. Margni, T. Koellner, B. Wittstock and L. Deschenes (2011). "Assessment of land use impacts on soil ecological functions: development of spatially differentiated characterization factors within a Canadian context." The International Journal of Life Cycle Assessment **16**(3): 198-211.

Category: Ecosystem services

Keywords: *Characterization factors, ecosystem services, land use, Life Cycle Impact Assessment (LCIA), regionalization, soil ecological functions, soil ecological quality, spatial differentiation*

Abstract:

Purpose

Among other regional impact categories in LCA, land use still lacks a suitable assessment method regarding the least developed “soil ecological quality” impact pathway. The goals of this study are to scope the framework addressing soil ecological functions and to improve the development of regionalized characterization factors (CFs). A spatially explicit approach was developed and illustrated for the Canadian context using three different regional scales and for which the extent of spatial variability was assessed.

Materials and methods

A model framework based on the multifunctional character of soil and the ecosystem services defined by the Millennium Ecosystem Assessment is suggested. This framework includes land use impacts on soil ecological quality evaluated regarding the change in soil capacity to fulfill a range of soil ecological functions. Four impact indicators, namely erosion resistance, groundwater recharge, mechanical, and physicochemical filtration, proposed by the functional method of Baitz (2002), were used to assess three major degraded regulating services: erosion regulation, freshwater regulation, and water purification. Spatially differentiated CFs were calculated based on the principles proposed by the UNEP/SETAC Life Cycle Initiative for two Canadian spatial models (15 ecozones, 193 ecoregions) along with a non-spatial one (one generic). Seven representative land use types were tested.

Results and discussion

Using the ecozone-based scale, an overall result comparison between the non-spatial and spatial models indicates significant differences between ranges across land use types and results up to four times larger than what the generic scale can capture. This highlights the importance of introducing a regionalized assessment. When considering the impacts from a specific land use type, such as urban land use,

generic CFs fail to adequately represent spatial CFs because they tend to be highly dependent on the biogeographical conditions of the location. When comparing all three resolution scales, CF results calculated using the ecoregions spatial scale generally show a larger spread across each land use type. Interesting variations and extreme scenarios are revealed which could not be observed using a coarser scale-based model such as the ecozone resolution scheme.

Conclusions

This work demonstrates the accomplishment of developing spatially differentiated CFs addressing impacts of different land use types on soil ecological functions. For a large territorial area spreading over many biomes, such as Canada, accounting for ecological unit boundaries proves to be necessary since the generic scale is not sufficiently representative. An evaluation of the extent of spatial differentiation emphasized the influence on the variability of regionalized CFs.

Saether, B.-E., R. Lande, S. Engen, H. Weimerskirch, M. Lillegaard, R. Altwegg, P. Becker, T. Bregnballe, J. Brommer, R. McCleery, E. Nyholm, W. Rendell, R. Robertson, P. Tryjanowski and M. Visser (2005). "Generation time and temporal scaling of bird population dynamics." Nature **436**(7047): 99-102.

Category: Ecosystem services

Keywords: *Vertebrata, life history trait, models, parameter estimation, population regulation, generation time, density dependence, population dynamics, pest regulation*

Abstract: Theoretical studies have shown that variation in density regulation strongly influences population dynamics1, yet our understanding of factors influencing the strength of density dependence in natural populations still is limited2. Consequently, few general hypotheses have been advanced to explain the large differences between species in the magnitude of population fluctuations3–6. One reason for this is that the detection of density regulation in population time series is complicated by time lags induced by the life history of species7,8 that make it difficult to separate the relative contributions of intrinsic and extrinsic factors to the population dynamics. Here we use population time series for 23 bird species to estimate parameters of a stochastic density- dependent age-structured model. We show that both the strength of total density dependence in the life history and the magnitude of environmental stochasticity, including transient fluctuations in age structure, increase with generation time. These results indicate that the relationships between demographic and life- history traits in birds9,10 translate into distinct population dynamical patterns that are apparent only on a scale of generations.

Samnegard, U., A. Persson and H. Smith (2011). "Gardens as sources of pollinators in intensively managed farmland." Biological Conservation.

Category: Ecosystem services

Keywords: *Pollinators, gardens, conservation, pollination*

Abstract: The recent loss of pollinating insects and out-crossing plants in agricultural landscapes has raised concern for the maintenance of ecosystem services. Wild bees

have been shown to benefit from garden habitats in urban and suburban areas. We investigated the effects of distance from garden habitats on wild bees and seed set of a native out-crossing plant Campanula persicifolia, in intensively managed agricultural landscapes in Southern Sweden. Bee abundance and species richness, as well as plant seed set, were higher closer to gardens (<15 m) than further away (>140 m). This highlights private gardens as a landscape wide resource for pollinators but also the lack of sufficient pollination of wild plants in contemporary agricultural landscapes.

Sandhu, H., S. Wratten, R. Cullen and B. Case (2008). "The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach." Ecological Economics **64**(4): 835-848.

Category: Agroecology and agroecological practices; Ecosystem services

Keywords: *Arable land, avoided cost, economic value, ecosystem services, engineered ecosystems, organic farming*

Abstract: First, the role of land management practices in the maintenance and enhancement of ES in agricultural land was investigated by quantifying the economic value of ES at the field level under organic and conventional arable systems. This quantification was based on an experimental approach in contrast with earlier value transfer methods. Total economic value of ES in organic fields ranged from US $1610 to US $19,420 ha− 1 yr− 1 and that of conventional fields from US $1270 to US $14,570 ha− 1 yr− 1. The non-market value of ES in organic fields ranged from US $460 to US $5240 ha− 1 yr− 1. The range of non-market values of ES in conventional fields was US $50 — 1240 ha− 1 yr− 1. There were significant differences between organic and conventional fields for the economic values of some ES. Next, this economic information was used to extrapolate and to calculate the total and non-market value of ES in Canterbury arable land. The total annual economic and non-market values of ES for the conventional arable area in Canterbury (125,000 ha) were US $332 million and US $71 million, respectively. If half the arable area under conventional farming shifted to organic practices, the total economic value of ES would be US $192 million and US $166 million annually for organic and conventional arable area, respectively. In this case, the non-market value of ES for the organic area was US $65 million and that of conventional area was US $35 million annually. This study demonstrated that arable farming provides a range of ES which can be measured using field experiments based on ecological principles by incorporating a 'bottom-up' approach. The work also showed that conventional New Zealand arable farming practices can severely reduce the financial contribution of some of these services in agriculture whereas organic agricultural practices enhance their economic value.

Scheper, J., A. Holzschuh, M. Kuussaari, S. G. Potts, M. Rundlöf, H. G. Smith and D. Kleijn (2013). "Environmental factors driving the effectiveness of European agri-environmental measures in mitigating pollinator loss – a meta-analysis." Ecology Letters **16**(7): 912-920.

Category: Policy; Ecosystem services

Keywords: *Agri-environmental schemes, ecological contrast, ecosystem services, landscape*

context, land-use intensity, pollinators, pollination

Abstract: In Europe, agri-environmental schemes (AES) have been introduced in response to concerns about farmland biodiversity declines. Yet, as AES have delivered variable results, a better understanding of what determines their success or failure is urgently needed. Focusing on pollinating insects, we quantitatively reviewed how environmental factors affect the effectiveness of AES. Our results suggest that the ecological contrast in floral resources created by schemes drives the response of pollinators to AES but that this response is moderated by landscape context and farmland type, with more positive responses in croplands (vs. grasslands) located in simple (vs. cleared or complex) landscapes. These findings inform us how to promote pollinators and associated pollination services in species-poor landscapes. They do not, however, present viable strategies to mitigate loss of threatened or endangered species. This indicates that the objectives and design of AES should distinguish more clearly between biodiversity conservation and delivery of ecosystem services.

Scherr, S. J. and J. A. McNeely (2008). "Biodiversity conservation and agricultural sustainability: towards a new paradigm of ecoagriculture landscapes." Philosophical Transactions of the Royal Society B: Biological Sciences **363**(1491): 477-494.

Category: Ecosystem services; Policy

Keywords: *Ecoagriculture, landscape, biodiversity conservation, agricultural production, rural livelihoods*

Abstract: The dominant late twentieth century model of land use segregated agricultural production from areas managed for biodiversity conservation. This module is no longer adequate in much of the world. The Millennium Ecosystem Assessment confirmed that agriculture has dramatically increased its ecological footprint. Rural communities depend on key components of biodiversity and ecosystem services that are found in non-domestic habitats. Fortunately, agricultural landscapes can be designed and managed to host wild biodiversity of many types, with neutral or even positive effects on agricultural production and livelihoods. Innovative practitioners, scientists and indigenous land managers are adapting, designing and managing diverse types of 'ecoagriculture' landscapes to generate positive co-benefits for production, biodiversity and local people. We assess the potentials and limitations for successful conservation of biodiversity in productive agricultural landscapes, the feasibility of making such approaches financially viable, and the organizational, governance and policy frameworks needed to enable ecoagriculture planning and implementation at a globally significant scale. We conclude that effectively conserving wild biodiversity in agricultural landscapes will require increased research, policy coordination and strategic support to agricultural communities and conservationists.

Schiappacasse, I., L. Nahuelhual, F. Vasquez and C. Echeverria (2012). "Assessing the benefits and costs of dryland forest restoration in central Chile." Journal of Environmental Management **97**(0): 38-45.

Category: Ecosystem services; Farmer and societal benefits

Keywords: *Dryland forests, ecosystem services, economic valuation, ecological restoration, contingent valuation*

Abstract: Investment in natural capital restoration is increasing as a response to the widespread ecological degradation of dryland forests. However, finding efficient mechanisms to promote restoration among private landowners is a significant challenge for policy makers with limited financial resources. Furthermore, few attempts have been made to evaluate the costs and benefits of restoration interventions even though this information is relevant to orient decision making. Hence, our goal was to estimate the benefits and costs of dryland forest restoration by means of reforestation with native trees in a study area in central Chile. To determine benefits we applied a Contingent Valuation questionnaire that allowed for the calculation of willingness to pay measures. Restoration costs were calculated based on market prices following existing technical recommendations developed for the study area. The results showed that the restoration project had a negative NPV irrespective of the discount rate applied in the analysis. Thus, the NPV varied between –US$71,000 and –US$258,000. The NPV attained positive results only for negative discount rates (US$15,039 for −2%) and only when the national subsidy available for forest restoration was taken into account. This shows that landowners in Colliguay do not have incentives for carrying out restoration interventions due to a classic market failure: that in which ecosystems are mismanaged because many of their benefits are externalities from the perspective of landowners. Overall, these results stress the need for developing new compensation mechanisms and enhancing those in existence, with the aim of making restoration competitive with other land uses.

Schweiger, O., J. Biesmeijer, R. Bommarco, T. Hickler, P. Hulme, S. Klotz, I. Kühn, M. Moora, A. Nielsen, R. Ohlemüller, T. Petanidou, S. Potts, P. Pyšek, J. Stout, M. Sykes, T. Tscheulin, M. Vilà, G.-R. Walther, C. Westphal, M. Winter, M. Zobel and J. Settele (2010). "Multiple stressors on biotic interactions: how climate change and alien species interact to affect pollination." Biological Reviews **85**(4): 777-795.

Category: Climate change; Ecosystem services

Keywords: *Biological invasions, competition, ecosystem functions, ecosystem services, global change, higher order effects, multiple drivers, pollination, species interactions*

Abstract: Global change may substantially affect biodiversity and ecosystem functioning but little is known about its effects on essential biotic interactions. Since different environmental drivers rarely act in isolation it is important to consider interactive effects. Here, we focus on how two key drivers of anthropogenic environmental change, climate change and the introduction of alien species, affect plant–pollinator interactions. Based on a literature survey we identify climatically sensitive aspects of species interactions, assess potential effects of climate change on these mechanisms, and derive hypotheses that may form the basis of future research. We find that both climate change and alien species will ultimately lead to the creation of novel communities. In these communities certain interactions may no longer occur while there will also be potential for the emergence of new relationships. Alien species can both partly compensate for the often negative effects of climate change but also amplify them in some cases. Since potential

positive effects are often restricted to generalist interactions among species, climate change and alien species in combination can result in significant threats to more specialist interactions involving native species.

Semenov, M. (2009). "Impacts of climate change on wheat in England and Wales." Journal of The Royal Society Interface **6**(33): 343-350.

Category: Climate change

Keywords: *Drought and heat stress, wheat simulation model, stochastic weather generator, UKCIP02, LARS-WG, Sirius*

Abstract: The frequency and magnitude of extreme weather events are likely to increase with global warming. However, it is not clear how these events might affect agricultural crops and whether yield losses resulting from severe droughts or heat stress will increase in the future. The aim of this paper is to analyse changes in the magnitude and spatial patterns of two impact indices for wheat: the probability of heat stress around flowering and the severity of drought stress. To compute these indices, we used a wheat simulation model combined with high-resolution climate scenarios based on the output from the Hadley Centre regional climate model at 18 sites in England and Wales. Despite higher temperature and lower summer precipitation predicted in the UK for the 2050s, the impact of drought stress on simulated wheat yield is predicted to be smaller than that at present, because wheat will mature earlier in a warmer climate and avoid severe summer drought. However, the probability of heat stress around flowering that might result in considerable yield losses is predicted to increase significantly. Breeding strategies for the future climate might need to focus on wheat varieties tolerant to high temperature rather than to drought.

Settle, W., H. Ariawan, E. Astuti, W. Cahyana, A. Hakim, D. Hindayana and A. Lestari (1996). "Managing tropical rice pests through conservation of generalist natural enemies and alternative prey." Ecology **77**(7): 1975-1988.

Category: Ecosystem services

Keywords: *Pest, pest management, biological control, integrated pest management, agroecosystem, Planktonophagous, Saprophagous, insecticide, animal community, Indonesia, Java, tropical zone, Oryza sativa, Arthropoda, Chironomidae, Asia, Gramineae, Monocotyledones, Angiospermae, Spermatophyta, Cereal crop, Invertebrata, Diptera, Insecta, pest regulation*

Abstract: The cultivation of tropical Asian rice, which may have originated 9000 yr ago, represents an agricultural ecosystem of unrivaled ecological complexity. We undertook a study of the community ecology of irrigated tropical rice fields on Java, Indonesia, as a supporting study for the Indonesian National Integrated Pest Management Programme, whose purpose is to train farmers to be better agronomists and to employ the principles of integrated pest management (IPM). Two of our study objectives, reported on here, were (1) to explore whether there exist general and consistent patterns of arthropod community dynamics related to natural or intrinsic levels of biological control, and (2) to understand how the existing levels of biological control are affected by insecticide use, as well as by large-scale

habitat factors relating to differing patterns for vegetational landscapes, planting times, and the length of dry fallow periods.

We performed a series of observational studies and two experimental studies. Abundant and well-distributed populations of generalist predators can be found in most early-season tropical rice fields. We took samples from plants and water surface using a vacuum-suction device, and from the subsurface using a dip net. Our results show that high populations of generalist predators are likely to be supported, in the early season, by feeding on abundant populations of detritus- feeding and plankton-feeding insects, whose populations consistently peak and decline in the first third of the season. We hypothesize that since this abundance of alternative prey gives the predator populations a "head start" on later-developing pest populations, this process should strongly suppress pest populations and generally lend stability to rice ecosystems by decoupling predator populations from a strict dependence on herbivore populations.

We experimentally tested our hypothesis of trophic linkages among organic matter, detritivores and plankton feeders, and generalist predators and showed that by increasing organic matter in test plots we could boost populations of detritivores and plankton-feeders, and in turn significantly boost the abundance of generalist predators. These results hold for populations found on the plant, on the water surface, and below the water surface. We also demonstrated the link between early-season natural enemy populations and later-season pest populations by experimentally reducing early-season predator populations with insecticide applications, causing pest populations to resurge later in the season.

Overall, these results demonstrate the existence of a mechanism in tropical irrigated rice systems that supports high levels of natural biological control. This mechanism depends on season- long successional processes and interactions among a wide array of species, many of which have hitherto been ignored as important elements in a rice ecosystem. Our results support a management strategy that promotes the conservation of existing natural biological control through a major reduction in insecticide use, and the corresponding increase in habitat heterogeneity.

Shackelford, G., P. Steward, T. Benton, W. Kunin, S. Potts, J. Biesmeijer and S. Sait (2013). "Comparison of pollinators and natural enemies: a meta-analysis of landscape and local effects on abundance and richness in crops." Biological Reviews: n/a-n/a.

Category: Ecosystem services

Keywords: *Ecosystem service, pollination, pest control, pest regulation, biological control, abundance, richness, diversity, stability, complexity*

Abstract: To manage agroecosystems for multiple ecosystem services, we need to know whether the management of one service has positive, negative, or no effects on other services. We do not yet have data on the interactions between pollination and pest-control services. However, we do have data on the distributions of pollinators and natural enemies in agroecosystems. Therefore, we compared these two groups of ecosystem service providers, to see if the management of farms and agricultural landscapes might have similar effects on the abundance and richness of both. In a meta-analysis, we compared 46 studies that sampled bees, predatory beetles, parasitic wasps, and spiders in fields, orchards, or vineyards of food crops.

These studies used the proximity or proportion of non-crop or natural habitats in the landscapes surrounding these crops (a measure of landscape complexity), or the proximity or diversity of non-crop plants in the margins of these crops (a measure of local complexity), to explain the abundance or richness of these beneficial arthropods. Compositional complexity at both landscape and local scales had positive effects on both pollinators and natural enemies, but different effects on different taxa. Effects on bees and spiders were significantly positive, but effects on parasitoids and predatory beetles (mostly Carabidae and Staphylinidae) were inconclusive. Landscape complexity had significantly stronger effects on bees than it did on predatory beetles and significantly stronger effects in non-woody rather than in woody crops. Effects on richness were significantly stronger than effects on abundance, but possibly only for spiders. This abundance-richness difference might be caused by differences between generalists and specialists, or between arthropods that depend on non-crop habitats (ecotone species and dispersers) and those that do not (cultural species). We call this the 'specialist-generalist' or 'cultural difference' mechanism. If complexity has stronger effects on richness than abundance, it might have stronger effects on the stability than the magnitude of these arthropod-mediated ecosystem services. We conclude that some pollinators and natural enemies seem to have compatible responses to complexity, and it might be possible to manage agroecosystems for the benefit of both. However, too few studies have compared the two, and so we cannot yet conclude that there are no negative interactions between pollinators and natural enemies, and no trade-offs between pollination and pest-control services. Therefore, we suggest a framework for future research to bridge these gaps in our knowledge.

Simoncini, R. (2010). Developing an integrated monitoring system to assess agri-environmental measures effectiveness in Tuscany, OECD**:** 16.

Category: Ecosystem services; Policy

Keywords: *Eu, policy instruments, environmental goods and services, effectiveness, efficiency, agri-environmental measures assessment, Tuscany*

Abstract: The rationale of the method proposed to monitor agri-environmental measures is based on a revised version of the methodology on how to develop effective, scientifically and economically verifiable local Agri-Environmental Measures (AEMs) developed by the AEMBAC project (2001-2004) of the EU 5th Framework Programme (Contract Ref. QLRT-1999- 31666) (Simoncini et al., 2004, Simoncini, 2009).

The overall objective of the AEMBAC methodology was to set up the design and development of agri-environmental measures (AEMs) that ensure the effective conservation of biodiversity and the environment by improving the sustainability of local agricultural practices.

In order to monitor and assess the effectiveness and efficiency of agri-environmental measures the proposed approach will focus on two sets of indicators and on the analyses of their relationships as defined by the AEMBAC analytical framework. These indicators analyse:

• the state of each agro-ecosystem and its ability to perform selected environmental functions for the delivering of environmental goods and services;

• the local agricultural land use and practices; and
• the impacts of agri-environmental measures upon the ability of agro-ecosystems to deliver environmental goods and services

The proposed method develops in a process of sequential steps that start with the identification of real or potential environmental functions performed by agro-ecosystems and the selection of indicators with which to analyse these functions. These indicators are then used to identify the Environmental Minimum Requirements (EMRs) for the successful performance of environmental functions and, in reference to these, to analyse the sustainability of local agricultural practices in terms of delivering environmental goods and services. By factoring in the analysis the expected results of agri-environmental measures in lessening/eliminating agricultural negative impacts or improving positive ones, it is then possible to monitor and assess the effectiveness and efficiency of agri-environmental measures at the end of their implementation period.

This process enables objective analysis of the effects of agricultural practices on the environment, the identification of scientifically and economically justified agri-environmental goals and, ultimately, the monitoring and assessment of effectiveness and efficiency of agri-environmental measures in achieving those goals.

Smail, R. (2009). Forest land conversion, ecosystem services, and economic issues for policy: a review. Portland, DIANE Publishing.

Category: Policy

Keywords: *Forest, forest fragmentation, ecosystem services, land use, conversion, forest policy, ecosystem services, economic analysis*

Abstract: The continued conversion and development of forest land pose a serious threat to the ecosystem services derived from forested landscapes. We argue that developing an understanding of the full range of consequences from forest conversion requires understanding the effects of such conversion on both components of ecosystem services: products and processes. However, there are unavoidable challenges involved in quantifying the threats from forest conversion and their related costs to human well-being. First, most attempts to quantify the costs of forest conversion on ecosystem services will necessarily rely on specific ecological science that is often emerging, changing, or simply nonexistent. For example, the role that many species play in ecosystem processes is poorly understood. Second, given the interconnected nature of ecosystem products and processes, any attempt to quantify the effects of forest conversion must grapple with jointness in production. For example, the cost of losing a species from forest conversion must account for that species' role as both (1) a product that directly contributes to human well-being, and (2) as a component in an ecosystem process. Finally, the ecology and the human dimensions of ecosystems are highly specific to spatial-temporal circumstances. Consequently, the effects of forest conversion in one spatial-temporal context are likely to be quite different than effects elsewhere.

Smith, H. G., J. Danhardt, A. Lindstrom and M. Rundlof (2010). "Consequences of organic farming and landscape heterogeneity for species richness and abundance of farmland

birds." Oecologia **162**(4): 1071-1079.
Category: Agriculture-induced impacts
Keywords: *Biodiversity, farmland birds, agri-environment schemes, landscape ecology, organic agriculture*

Abstract: It has been suggested that organic farming may benefit farmland biodiversity more in landscapes that have lost a significant part of its former landscape heterogeneity. We tested this hypothesis by comparing bird species richness and abundance during the breeding season in organic and conventional farms, matched to eliminate all differences not directly linked to the farming practice, situated in either homogeneous plains with only a little semi-natural habitat or in heterogeneous farmland landscapes with abundant field borders and semi-natural grasslands. The effect of farm management on species richness interacted with landscape structure, such that there was a positive relationship between organic farming and diversity only in homogeneous landscapes. This pattern was mainly dependent on the species richness of passerine birds, in particular those that were invertebrate feeders. Species richness of non-passerines was positively related to organic farming independent of the landscape context. Bird abundance was positively related to landscape heterogeneity but not to farm management. This was mainly because the abundance of passerines, particularly invertebrate feeders, was positively related to landscape heterogeneity. We suggest that invertebrate feeders particularly benefit from organic farming because of improved foraging conditions through increased invertebrate abundances in otherwise depauperate homogeneous landscapes. Although many seed-eaters also benefit from increased insect abundance, they may also utilize crop seed resources in homogeneous landscapes and conventional farms. The occurrence of an interactive effect of organic farming and landscape heterogeneity on bird diversity will have consequences for the optimal allocation of resources to restore the diversity of farmland birds.

Smith, P. (2013). "Delivering food security without increasing pressure on land." Global Food Security **2**(1): 18-23.
Category: Ecosystem services, policy
Keywords: *Sustainable intensification, food security, ecosystem services, food demand, diet change, food production*

Abstract: The challenge of feeding 9 to 10 Billion people by 2050 may seem like a big enough challenge in itself, but we also need to achieve this feat whilst, at the same time, reducing adverse impacts of food production on a whole range of ecosystem services. One suggested response is “sustainable intensification” which entails delivering safer, nutritious food from the same area whilst maintaining ecosystem service provision. In this review, I examine sustainable intensification and consider alternatives such as management of food demand and waste reduction. I conclude that sustainable intensification has a role to play, but this must be accompanied by fundamental change in global food systems.
Highlights
Food production can increase by expanding agricultural area or increasing per-area productivity.

Expanding agriculture into forests and natural areas is environmentally damaging.
To meet future food demand per-area productivity must increase, through "sustainable intensification".
Sustainable intensification will be challenging, and will not be without environmental impact.
The need for sustainable intensification can be reduced by managing demand and reducing food waste.

Snapp, S., M. Blackie, R. Gilbert, R. Bezner-Kerr and G. Kanyama-Phiri (2010). "Biodiversity can support a greener revolution in Africa." Proceedings of the National Academy of Sciences **107**(48): 20840-20845.
Category: Ecosystem services; Agriculture-induced impacts
Keywords: *Ecosystem services, nitrogen, rural development, sustainable agriculture, soil nutrients/cycling*

Abstract: The Asian green revolution trebled grain yields through agro- chemical intensification of monocultures. Associated environmental costs have subsequently emerged. A rapidly changing world necessitates sustainability principles be developed to reinvent these technologies and test them at scale. The need is particularly urgent in Africa, where ecosystems are degrading and crop yields have stagnated. An unprecedented opportunity to reverse this trend is unfolding in Malawi, where a 90% subsidy has ensured access to fertilization and improved maize seed, with substantive gains in productivity for millions of farmers. To test if economic and ecological sustainability could be improved, we preformed manipulative experimentation with crop diversity in a countrywide trial (n = 991) and at adaptive, local scales through a decade of participatory research (n = 146). Spatial and temporal treatments compared monoculture maize with legume-diversified maize that included annual and semiperennial (SP) growth habits in temporal and spatial combinations, including rotation, SP rotation, inter- crop, and SP intercrop systems. Modest fertilizer intensification doubled grain yield compared with monoculture maize. Biodiversity improved ecosystem function further: SP rotation systems at half-fertilizer rates produced equivalent quantities of grain, on a more stable basis (yield variability reduced from 22% to 13%) compared with monoculture. Across sites, profitability and farmer preference matched: SP rotations provided twofold superior returns, whereas diversification of maize with annual legumes provided more modest returns. In this study, we provide evidence that in Africa, crop diversification can be effective at a countrywide scale, and that shrubby, grain legumes can enhance environmental and food security.

Snapp, S., L. Gentry and R. Harwood (2010). "Management intensity - not biodiversity - the driver of ecosystem services in a long-term row crop experiment." Agriculture, Ecosystems & Environment **138**(3â€"4): 242-248.
Category: Agroecology and agroecological practices
Keywords: *Sustainable agriculture, organic, crop diversity, soil carbon, nitrogen cycle, soil nutrients/cycling*

Abstract: A positive role for biodiversity is assumed for managed ecosystems. We

conducted a 12-year study of this sustainability principle, through separate manipulation of management intensity and crop diversity. The site was located in southwest Michigan, representative of rain-fed production, with high climate variability and well-drained soils. Provisioning services of grain and protein yield were monitored, simultaneous with supporting services of soil fertility, C and N, and regulating services associated with water quality (N-use efficiency and nitrate-N leached in gravimetric lysimeters). Surprisingly, a strong role for management was shown, and almost nil for crop diversity. Organic management (ORG) sustained soil fertility, augmented soil C (36% increase), enhanced N retention (50% decrease in nitrate-N leaching) and improved N-use efficiency, compared to conventional, integrated (INT) management. Provisioning of grain – quantity, quality and temporal yield stability – was highest in INT continuous maize (monoculture and biculture) with an annual yield of 6.4 Mg ha−1, compared to ORG of 5.1 Mg ha−1. Biodiverse rotational systems (three and six species) produced 25% lower yield, but the grain was of high quality. A focus on ORG management rather than crop diversity is suggested as a means to sequester C, and produced grain in a semi-closed system.

Sparks, T. H., A. Langowska, A. GŁAzaczow, Z. Wilkaniec, M. BieŃKowska and P. Tryjanowski (2010). "Advances in the timing of spring cleaning by the honeybee Apis mellifera in Poland." Ecological Entomology **35**(6): 788-791.

Category: Ecosystem services

Keywords: *Cleansing, honeybee, phenology, Poland, pollinators, pollination*

Abstract:

1. The honeybee Apis mellifera is of huge worldwide economic importance in the pollination of crops for human consumption. In recent years, honeybee populations have declined under pressure from diseases and pests. Climate change is increasingly being viewed as an additional threat to honeybees and yet only limited research has been carried out in this area.
2. This paper reports the advance of the first cleansing flight ('spring cleaning') of the honeybee in Poznań, Poland, i.e. flights to excrete faeces, over a month in the period 1985–2009. The timing of this flight is advanced not only by higher late winter/spring temperatures but also by higher temperatures in the previous summer and autumn.
3. This earlier activity gives hope that the reported earlier flowering of many native and cultivated species will not cause a pollination synchrony crisis.

Steffan-Dewenter, I., M. Kessler, J. Barkmann, M. Bos, D. Buchori, S. Erasmi, H. Faust, G. Gerold, K. Glenk, S. Gradstein, E. Guhardja, M. Harteveld, D. Hertel, P. Hohn, M. Kappas, S. Kohler, C. Leuschner, M. Maertens, R. Marggraf, S. Migge-Kleian, J. Mogea, R. Pitopang, M. Schaefer, S. Schwarze, S. Sporn, A. Steingrebe, S. Tjitrosoedirdjo, S. Tjitrosoemito, A. Twele, R. Weber, L. Woltmann, M. Zeller and T. Tscharntke (2007). "Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification." Proceedings of the National Academy of Sciences **104**(12): 4973-4978.

Category: Ecosystem services

Keywords: *Agricultural economics, agroforestry management, land use change, plant–animal interactions, ecosystem goods and services*

Abstract: Losses of biodiversity and ecosystem functioning due to rainforest destruction and agricultural intensification are prime concerns for science and society alike. Potentially, ecosystems show nonlinear responses to land-use intensification that would open management options with limited ecological losses but satisfying economic gains. However, multidisciplinary studies to quantify ecological losses and socioeconomic tradeoffs under different management options are rare. Here, we evaluate opposing land use strategies in cacao agroforestry in Sulawesi, Indonesia, by using data on species richness of nine plant and animal taxa, six related ecosystem functions, and on socioeconomic drivers of agroforestry expansion. Expansion of cacao cultivation by 230% in the last two decades was triggered not only by economic market mechanisms, but also by rarely considered cultural factors. Transformation from near-primary forest to agroforestry had little effect on overall species richness, but reduced plant biomass and carbon storage by 75% and species richness of forest-using species by 60%. In contrast, increased land use intensity in cacao agroforestry, cou- pled with a reduction in shade tree cover from 80% to 40%, caused only minor quantitative changes in biodiversity and maintained high levels of ecosystem functioning while doubling farmers' net income. However, unshaded systems further increased income by 40%, implying that current economic incentives and cultural preferences for new intensification practices put shaded systems at risk. We conclude that low-shade agroforestry provides the best available compromise between economic forces and ecological needs. Certification schemes for shade-grown crops may provide a market-based mechanism to slow down current intensification trends.

Steffan-Dewenter, I., A.-M. Klein, V. Gaebele, T. Alfert and T. Tscharntke (2006). "Bee diversity and plant-pollinator interactions in fragmented landscapes." Specialization and Generalization in Plant-Pollinator Interactions: 387-410.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Bee diversity, pollinator, fragmented landscapes, pollination limitation, plant reproduction, pollination*

(no abstract)

Steffan-Dewenter, I., U. Munzenberg, C. Buerger, C. Thies and T. Tscharntke (2002). "Scale-dependent effects of landscape context on three pollinator guilds." Ecology **83**(5): 1421-1432.

Category: Ecosystem services; Agriculture-induced impacts

Keywords: *Bees, biotic interactions, community structure, connectivity, habitat fragmentation, landscape ecology, pollination, spatial scales, species diversity*

Abstract: Most ecological processes and interactions depend on scales much larger than a single habitat, and therefore it is important to link spatial patterns and ecological processes at a landscape scale. Here, we analyzed the effects of landscape context on the distribution of bees (Hymenoptera: Apoidea) at multiple spatial scales with respect to the following hypotheses: (1) Local abundance and diversity of bees

increase with increasing proportion of the surrounding seminatural habitats. (2) Solitary wild bees, bumble bees, and honey bees respond to landscape context at different spatial scales. We selected 15 landscape sectors and determined the percentage of seminatural habitats and the diversity of habitat types at eight spatial scales (radius 250–3000 m) by field inspections and analyses of vegetation maps using two Geographic Information Systems. The percentage of seminatural habitats varied between 1.4% and 28%. In the center of each landscape sector a patch of potted flowering plants (four perennial and two annual species) was placed in the same habitat type, a grassy field margin adjacent to cereal fields. In all, 865 wild bee individuals and 467 honey bees were observed and an additional 475 individuals were caught for species identification. Species richness and abundance of solitary wild bees showed a close positive correlation with the percentage of seminatural habitats at small scales up to 750 m, whereas bumble bees and honey bees did not respond to landscape context at these scales. In contrast, honey bees were correlated with landscape context at large scales. The densities of flower-visiting honey bees even increased with decreasing proportion of seminatural habitats at a radius of 3000 m. We are not aware of any empirical studies showing contrasting foraging patterns related to landscape context at different spatial scales. We conclude (1) that local landscape destruction affects solitary wild bees more than social bees, possibly changing mutualistic plant–pollinator and competitive wild bees–honey bees interactions and (2) that only analyses of multiple spatial scales may detect the importance of the landscape context for local pollinator communities.

Steffan-Dewenter, I. and S. Schiele (2008). "Do resources or natural enemies drive bee population dynamics in fragmented habitats?" Ecology **89**(5): 1375-1387.

Category: Ecosystem services

Keywords: *Habitat fragmentation, orchard meadows, Osmia rufa, pollinators, population ecology, red mason bee, resource limitation, solitary bees, time series, top-down or bottom-up control, pollination*

Abstract: The relative importance of bottom-up or top-down forces has been mainly studied for herbivores but rarely for pollinators. Habitat fragmentation might change driving forces of population dynamics by reducing the area of resource-providing habitats, disrupting habitat connectivity, and affecting natural enemies more than their host species. We studied spatial and temporal population dynamics of the solitary bee Osmia rufa (Hymenoptera: Megachilidae) in 30 fragmented orchard meadows ranging in size from 0.08 to 5.8 ha in an agricultural landscape in central Germany. From 1998 to 2003, we monitored local bee population size, rate of parasitism, and rate of larval and pupal mortality in reed trap nests as an accessible and standardized nesting resource. Experimentally enhanced nest site availability resulted in a steady increase of mean local population size from 80 to 2740 brood cells between 1998 and 2002. Population size and species richness of natural enemies increased with habitat area, whereas rate of parasitism and mortality only varied among years. Inverse density-dependent parasitism in three study years with highest population size suggests rather destabilizing instead of regulating effects of top-down forces. Accordingly, an analysis of independent time series showed on

average a negative impact of population size on population growth rates but provides no support for top-down regulation by natural enemies. We conclude that population dynamics of O. rufa are mainly driven by bottom-up forces, primarily nest site availability.

Stoate, C., A. Baldi, P. Beja, N. Boatman, I. Herzon, A. van Doorn, G. de Snoo, L. Rakosy and C. Ramwell (2009). "Ecological impacts of early 21st century agricultural change in Europe: A review." Journal of Environmental Management **91**(1): 22-46.

Category: Ecosystem services; Agriculture-induced impacts; Policy

Keywords: *Aquatic ecology, arable ecology, biodiversity, climate change, common agricultural policy, ecosystem services, grassland, multifunctionality, soil*

Abstract: The impacts of agricultural land use are far-reaching and extend to areas outside production. This paper provides an overview of the ecological status of agricultural systems across the European Union in the light of recent policy changes. It builds on the previous review of 2001 devoted to the impacts of agricultural intensification in Western Europe. The focus countries are the UK, The Netherlands, Boreal and Baltic countries, Portugal, Hungary and Romania, representing a geographical spread across Europe, but additional reference is made to other countries. Despite many adjustments to agricultural policy, intensification of production in some regions and concurrent abandonment in others remain the major threat to the ecology of agro-ecosystems impairing the state of soil, water and air and reducing biological diversity in agricultural landscapes. The impacts also extend to surrounding terrestrial and aquatic systems through water and aerial contamination and development of agricultural infrastructures (e.g. dams and irrigation channels). Improvements are also documented regionally, such as successful support of farmland species, and improved condition of watercourses and landscapes. This was attributed to agricultural policy targeted at the environment, improved environmental legislation, and new market opportunities. Research into ecosystem services associated with agriculture may provide further pressure to develop policy that is targeted at their continuous provisioning, fostering motivation of land managers to continue to protect and enhance them.

Suding, K., S. Lavorel, F. S. Chapin, J. H. C. Cornelissen, S. Díaz, E. Garnier, D. Goldberg, D. Hooper, S. Jackson and M.-L. Navas (2008). "Scaling environmental change through the community-level: a trait-based response-and-effect framework for plants." Global Change Biology **14**(5): 1125-1140.

Category: Ecosystem services

Keywords: *Community dynamics, diversity, ecosystem responses, effect and response framework, functional traits, global change, leaf-level scaling, physiology*

Abstract: Predicting ecosystem responses to global change is a major challenge in ecology. A critical step in that challenge is to understand how changing environmental conditions influence processes across levels of ecological organization. While direct scaling from individual to ecosystem dynamics can lead to robust and mechanistic predictions, new approaches are needed to appropriately translate questions through the community level. Species invasion, loss, and

turnover all necessitate this scaling through community processes, but predicting how such changes may influence ecosystem function is notoriously difficult. We suggest that community-level dynamics can be incorporated into scaling predictions using a trait-based response–effect framework that differentiates the community response to environmental change (predicted by response traits) and the effect of that change on ecosystem processes (predicted by effect traits). We develop a response-and-effect functional framework, concentrating on how the relationships among species' response, effect, and abundance can lead to general predictions concerning the magnitude and direction of the influence of environmental change on function. We then detail several key research directions needed to better scale the effects of environmental change through the community level. These include (1) effect and response trait characterization, (2) linkages between response-and-effect traits, (3) the importance of species interactions on trait expression, and (4) incorporation of feedbacks across multiple temporal scales. Increasing rates of extinction and invasion that are modifying communities worldwide make such a research agenda imperative.

Sutherland, W., S. Armstrong-Brown, P. Armsworth, B. Tom, J. Brickland, C. Campbell, D. Chamberlain, A. Cooke, N. Dulvy, N. Dusic, M. Fitton, R. Freckleton, H. Godfray, N. Grout, H. Harvey, C. Hedley, J. Hopkins, N. B. Kift, J. Kirby, W. Kunin, D. Macdonald, B. Marker, M. Naura, A. Neale, T. Oliver, D. Osborn, A. Pullin, M. Shardlow, D. Showler, P. Smith, R. Smithers, J.-L. Solandt, J. Spencer, C. Spray, C. Thomas, J. Thompson, S. Webb, D. Yalden and A. Watkinson (2006). "The identification of 100 ecological questions of high policy relevance in the UK." Journal of applied ecology **43**(4): 617-627.

Category: Policy

Keywords: *Agricultural reform, biodiversity, conservation, fisheries, land management, restoration ecology, UK*

Abstract:

1. Evidence-based policy requires researchers to provide the answers to ecological questions that are of interest to policy makers. To find out what those questions are in the UK, representatives from 28 organizations involved in policy, together with scientists from 10 academic institutions, were asked to generate a list of questions from their organizations.

2. During a 2-day workshop the initial list of 1003 questions generated from consulting at least 654 policy makers and academics was used as a basis for generating a short list of 100 questions of significant policy relevance. Short-listing was decided on the basis of the preferences of the representatives from the policy-led organizations.

3. The areas covered included most major issues of environmental concern in the UK, including agriculture, marine fisheries, climate change, ecosystem function and land management.

4. The most striking outcome was the preference for general questions rather than narrow ones. The reason is that policy is driven by broad issues rather than specific ones. In contrast, scientists are frequently best equipped to answer specific questions. This means that it may be necessary to extract the underpinning specific question before researchers can proceed.

5. Synthesis and applications. Greater communication between policy makers and scientists is required in order to ensure that applied ecologists are dealing with issues in a way that can feed into policy. It is particularly important that applied ecologists emphasize the generic value of their work wherever possible.

Swallow, B., M. Kallesoe, U. Iftikhar, M. van Noordwijk, C. Bracer, S. Scherr, K. V. Raju, S. Poats, A. Duraiappah, B. Ochieng, H. Mallee and R. Rumley (2007). Environmental services in the developing World: Framing Pan-Tropical analysis and comparison. Working Paper no. 32. Nairobi, World Agroforestry Centre: 59.

Category: Ecosystem services

Keywords: *Environmental services, conservation, compensation and reward mechanisms, ecosystem services, ecosystem stewards, environmental service beneficiaries, payment for environmental services*

Abstract: This is the first of a series of nine papers exploring the state of the science and practice of compensation and rewards for environmental services in the developing world. This study has been undertaken to address key questions about the impact and future prospects of compensation and rewards for ecosystem services, and the potential role of research and policy engagement in helping to make these instruments more beneficial to the poor in the developing world. The papers resulting from this study have been prepared by an international group of authors as part of a pan-tropical scoping study for the Rural Poverty and Environment Programme of the International Development Research Centre of Canada. All of the papers focus on the frontiers between the ecosystems that underlie rural livelihoods, the environmental services that those ecosystems generate, and the human well-being of rural populations.

This introductory paper begins with a review of the recent historical development of compensation and reward mechanisms within a broader context of changing approaches to conservation and environmental policy. Conservation approaches have moved from a sole focus on protected areas, to integrated conservation and development projects, to landscape management approaches, and now, consideration of conservation contracts. At roughly the same time, there has been a general relaxation of government enforcement of environmental regulations towards more multi-stakeholder forms of governance in which non-governmental and international organizations play roles and a variety of market-based and negotiation approaches have come to the fore. That dynamic context is fostering greater interest in mechanisms for compensation and reward for environmental services in the developing regions of the world. Later sections of the paper clarify key concepts and present a conceptual framework for characterizing different types of mechanisms and the internal and external factors affecting those mechanisms. The penultimate section summarizes experience and perceptions of compensation and reward for environmental services. The concluding section postulates the alternative motivations that are shaping compensation and reward mechanisms in the developing world.

Swift, M. J., A. Izac and M. van Noordwijk (2004). "Biodiversity and ecosystem services in

agricultural landscapes: are we asking the right questions?" Agriculture, Ecosystems & Environment **104**(1): 113-134.

Category: Ecosystem services

Keywords: *Agricultural landscapes, biodiversity, ecosystem services, functional groups, resilience*

Abstract: The assumed relationship between biodiversity or local richness and the persistence of 'ecosystem services' (that can sustain productivity on-site as well as off-site, e.g. through regulation of water flow and storage) in agricultural landscapes has generated considerable interest and a range of experimental approaches. The abstraction level aimed for, however, may be too high to yield meaningful results. Many of the experiments on which evidence in favour or otherwise are based are artificial and do not support the bold generalisations to other spatial and temporal scales that are often made. Future investigations should utilise co-evolved communities, be structured to investigate the distinct roles of clearly defined functional groups, separate the effects of between- and within-group diversity and be conducted over a range of stress and disturbance situations. An integral part of agricultural intensification at the plot level is the deliberate reduction of diversity. This does not necessarily result in impairment of ecosystem services of direct relevance to the land user unless the hypothesised diversity–function threshold is breached by elimination of a key functional group or species. Key functions may also be substituted with petro-chemical energy in order to achieve perceived efficiencies in the production of specific goods. This can result in the maintenance of ecosystem services of importance to agricultural production at levels of biodiversity below the assumed 'functional threshold'. However, it can also result in impairment of other services and under some conditions the de-linking of the diversity–function relationship. Avoidance of these effects or attempts to restore non-essential ecosystem services are only likely to be made by land users at the plot scale if direct economic benefit can be thereby achieved. At the plot and farm scales biodiversity is unlikely to be maintained for purposes other than those of direct use or 'utilitarian' benefits and often at levels lower than those necessary for maintenance of many ecosystem services. The exceptions may be traditional systems where intrinsic values (social customs) continue to provide reasons for diversity maintenance. High levels of biodiversity in managed landscapes are more likely to be maintained for reasons of intrinsic, serependic ('option' or 'bequest') values or utilitarian ('direct use') than for functional or ecosystem service values. The major opportunity for both maintaining ecosystem services and biodiversity outside conservation areas lies in promoting diversity of land-use at the landscape and farm rather than field scale. This requires, however, an economic and policy climate that favours diversification in land uses and diversity among land users.

Swinton, S. M., F. Lupi, G. P. Robertson and S. K. Hamilton (2007). "Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits." Ecological Economics **64**(2): 245-252.

Category: Ecosystem services

Keywords: *Ecosystem services, agriculture, nonmarket valuation, research needs*

Abstract: Crop and rangelands are over 25% of the Earth's land area, and they are

expanding. Agricultural ecosystems rely on a suite of supporting ecosystem services to provide food, fiber and fuel as well as a range of accompanying but non-marketed ecosystem services (ES). Ecosystem services from agriculture include regulation of water and climate systems, aesthetic and cultural services, as well as enhanced supporting services (such as soil fertility). Many of these ES are appreciated by people, but they lack markets, so they lack the incentives for provision that come with prices. For public policy decisions to take them into account, non-market valuation techniques are needed, such as travel cost, contingent valuation, hedonic valuation, and cost-based or factor-income approaches. This article offers an overview of ES from agriculture and non-market valuation methods as it introduces the articles in this special section on "Ecosystem Services and Agriculture." Understanding how ecological functions generate ES is fundamental to management, but so too is understanding how humans perceive and value those services. Research is required both to design cost-effective incentives to provide ES and to measure which kinds of ES could provide the greatest overall welfare benefits to society. Agricultural ecosystems offer newly recognized potential to deliver more diverse ecosystem services and mitigate the level of past ecosystem disservices. This special section of Ecological Economics conveys both how these are becoming possible and the challenges to science and public policy design of turning that potential into reality.

Tacconi, L. (2012). "Redefining payments for environmental services." Ecological Economics **73**: 29-36.
Category: Ecosystem services
Keywords: *PES, coase, efficiency, equity, cost-effectiveness, livelihoods*

Abstract: The Environmental Economics and the Ecological Economics perspectives on payments for environmental services (PES) propose rather different views on how to define PES, its key elements, and on the role of PES in ecosystem conservation and rural development. This paper compares these two perspectives and addresses the following questions: what is an appropriate definition of PES, grounded in the theory and practice underlying it? What are the key design elements of PES? What should the scope of PES be given the possible trade-offs between efficiency and equity? It is found that PES schemes should focus on cost-effectiveness and best practice for positive livelihood impacts. PES schemes should be transparent, and provide additional services with conditional payments to voluntary providers.

Tacconi, L., S. Mahanty and H. Suich (2010). Payments for environmental services, forest conservation and climate change: Livelihoods in the REDD?, Edward Elgar Publishing.
Category: Climate change
Keywords: *Deforestation, forest degradation, greenhouse gas mitigation, climate change mitigation*

Abstract: This book draws on several case studies in Africa, Asia and Latin America to derive implications for the design of Payment for Environmental Services (PES) schemes that are very relevant to current climate change negotiations and the implementation of Reduced Emissions from Deforestation and forest Degradation

(REDD) schemes at the national level. With its focus on livelihoods, the book also provides important lessons that are relevant to the design of PES schemes focusing on environmental services other than carbon conservation. Drawing practical lessons for the design of activities aimed at reducing deforestation and forest degradation while benefiting rural people, this book will appeal to academics, practitioners and students involved in the fields of environment and natural resource management, forestry and development studies. This insightful study is accessible also to non-experts in presenting the key issues faced in avoiding deforestation and benefiting livelihoods.

Tallis, H., R. Goldman, M. Uhl and B. Brosi (2009). "Integrating conservation and development in the field: implementing ecosystem service projects." Frontiers in Ecology and the Environment **7**(1): 12-20.

Category: Ecosystem services; Policy

Keywords: *Ecosystem services, conservation, biodiversity, projects, financial tools*

Abstract: Ecosystem services can bridge biodiversity conservation and development needs, but there is little information available on how conservation organizations implement such projects. We documented 103 ecosystem service projects – from 37 countries – implemented by The Nature Conservancy (TNC) and the World Wildlife Fund (WWF). These projects commonly involved traditional conservation tactics, such as land purchase and restoration, but also adopted new approaches, such as targeting working landscapes, using new financial tools, and drawing new funding and partners from the corporate sector. We identified nine specific project types, characterized by consistent combinations of tools and activities. TNC and WWF used project types differently; TNC focused more on land purchase, whereas WWF concentrated more on developing markets. Both organizations showed some alignment of project type with socioeconomic conditions. For example, land purchases were used in countries with relatively secure property rights, while access to clean water or food was targeted when these human needs were unmet.

Thiele-Bruhn, S., J. Bloem, F. de Vries, K. Kalbitz and C. Wagg (2012). "Linking soil biodiversity and agricultural soil management." Current Opinion in Environmental Sustainability **4**(5): 523-528.

Category: Ecosystem services

Keywords: *Soil biodiversity, aboveground biodiversity, ecosystem stability, ecosystem services, agricultural soil management, soil biota, plant biodiversity nutrient cycling and storage, soil organic matter (SOM), soil nutrients/cycling*

Abstract: Soil biodiversity vastly exceeds aboveground biodiversity, and is prerequisite for ecosystem stability and services. This review presents recent findings in soil biodiversity research focused on interrelations with agricultural soil management. Richness and community structure of soil biota depend on plant biodiversity and vice versa. Soil biota govern nutrient cycling and storage, soil organic matter (SOM) formation and turnover. Agriculture manipulates plants, soils and SOM. With intensification, regulation of functions through biodiversity is replaced by regulation through agricultural measures. Fertilizers and agrochemicals

exert strong effects on soil biodiversity and functioning. Resulting community shifts feed back on soil functions such as carbon and nutrient cycling and pest control. Therefore, agricultural systems with less inputs may promote self-regulating systems and higher biodiversity.

Thies, C., S. Haenke, C. Scherber, J. Bengtsson, R. Bommarco, L. Clement, P. Ceryngier, C. Dennis, M. Emmerson, V. Gagic, V. Hawro, J. Liira, W. Weisser, C. Winqvist and T. Tscharntke (2011). "Agricultural intensification changes food-web interactions and biological control across Europe." Ecological applications **21**(6): 2187–2196.

Category: Ecosystem services

Keywords: *Wild biodiversity, agricultural intensification, Europe, pest regulation*

Abstract: Agricultural intensification can affect biodiversity and related ecosystem services such as biological control, but large-scale experimental evidence is missing. We examined aphid pest populations in cereal fields under experimentally reduced densities of (1) ground-dwelling predators (−G), (2) vegetation-dwelling predators and parasitoids (−V), (3) a combination of (1) and (2) (−G−V), compared with open-fields (control), in contrasting landscapes with low vs. high levels of agricultural intensification (AI), and in five European regions. Aphid populations were 28%, 97%, and 199% higher in −G, −V, and −G−V treatments, respectively, compared to the open fields, indicating synergistic effects of both natural-enemy groups. Enhanced parasitoid : host and predator : prey ratios were related to reduced aphid population density and population growth. The relative importance of parasitoids and vegetation-dwelling predators greatly differed among European regions, and agricultural intensification affected biological control and aphid density only in some regions. This shows a changing role of species group identity in diverse enemy communities and a need to consider region-specific landscape management.

Thies, C., S. Haenke, C. Scherber, J. Bengtsson, R. Bommarco, L. W. Clement, P. Ceryngier, C. Dennis, M. Emmerson, V. Gagic, V. Hawro, J. Liira, W. Weisser, C. Winqvist and T. Tscharntke (2011). "The relationship between agricultural intensification and biological control: experimental tests across Europe." Ecological applications **21**(6): 2187-2196.

Category: Ecosystem services

Keywords: *Agricultural intensification, cereal aphid, ecosystem service, European agricultural landscapes, functional group identity and diversity, landscape complexity, parasitoid, predator, pest regulation*

Abstract: Agricultural intensification can affect biodiversity and related ecosystem services such as biological control, but large-scale experimental evidence is missing. We examined aphid pest populations in cereal fields under experimentally reduced densities of (1) ground-dwelling predators (−G), (2) vegetation-dwelling predators and parasitoids (−V), (3) a combination of (1) and (2) (−G−V), compared with open-fields (control), in contrasting landscapes with low vs. high levels of agricultural intensification (AI), and in five European regions. Aphid populations were 28%, 97%, and 199% higher in −G, −V, and −G−V treatments, respectively, compared to the open fields, indicating synergistic effects of both natural-enemy groups. Enhanced parasitoid : host and predator : prey ratios were related to reduced aphid population

density and population growth. The relative importance of parasitoids and vegetation-dwelling predators greatly differed among European regions, and agricultural intensification affected biological control and aphid density only in some regions. This shows a changing role of species group identity in diverse enemy communities and a need to consider region-specific landscape management.

Thrupp, L. (2000). "Linking agricultural biodiversity and food security: the valuable role of agrobiodiversity for sustainable agriculture." International Affairs **76**(2): 283-297.
Category: Agroecology and agroecological practices; Policy
Keywords: *Agricultural biodiversity, food security, ecosystems services and functions, agricultural production, local experiences and knowledge, traditional farming practices, agroecology, ecosystem health*

Abstract: Agricultural biodiversity is critical for food security throughout the world. At the genetic, species, and farming systems levels, biodiversity provides valuable ecosytems services and functions for agricultural production. How can the erosion of agrobiodiversity be halted? How can it effectively be conserved and enhanced?
This article highlights key principles, policies, and practices for the sustain-able use, conservation and enhancement of agrobiodiversity for sustaining food security. After clarifying the serious threats from the global loss of agrobiodiversity, the article summarizes practical guidelines and lessons for biodiversity management in farming systems and landscapes. Such strategies build upon valuable local experiences and knowledge in traditional farming practices, and they also take advantage of recent scientific findings in agroecology and ecosystem health. There is an urgent need to adopt an agroecosytems approach, beyond a focus on genetic resource conservation alone, to implement other biodiversity-enhancing methods in farms, such as integrated ecological pest and soil management. Conflicting agricultural politics that promote monocultural industrial farming models and uniform technology packages need to be eliminated. In addition, the protection of intellectual property rights is vital for those who have knowledge of the values and uses of such biodiversity, particularly for indigenous peoples and small farmers. The approaches reviewed in this analysis show effective ways to conserve, use and enhance biodiversity that will encourage sustainable food security.

Tilman, D., C. Balzer, J. Hill and B. Befort (2011). "Global food demand and the sustainable intensification of agriculture." Proceedings of the National Academy of Sciences **108**(50): 20260-20264.
Category: Ecosystem services; Policy
Keywords: *Food security, land-use change, biodiversity, climate change, soil fertility*

Abstract: Global food demand is increasing rapidly, as are the environmental impacts of agricultural expansion. Here, we project global demand for crop production in 2050 and evaluate the environmental impacts of alternative ways that this demand might be met. We find that per capita demand for crops, when measured as caloric or protein content of all crops combined, has been a similarly increasing function of per capita real income since 1960. This relationship forecasts a 100–110% increase in global crop demand from 2005 to 2050. Quantitative

assessments show that the environmental impacts of meeting this demand depend on how global agriculture expands. If current trends of greater agricultural intensification in richer nations and greater land clearing (extensification) in poorer nations were to continue, ~1 billion ha of land would be cleared globally by 2050, with CO2-C equivalent greenhouse gas emissions reaching ~3 Gt y−1 and N use ~250 Mt y−1 by then. In contrast, if 2050 crop demand was met by moderate intensification focused on existing croplands of underyielding nations, adaptation and transfer of high-yielding technologies to these croplands, and global technological improvements, our analyses forecast land clearing of only ~0.2 billion ha, greenhouse gas emissions of ~1 Gt y−1, and global N use of ~225 Mt y−1. Efficient management practices could substantially lower nitrogen use. Attainment of high yields on existing croplands of underyielding nations is of great importance if global crop demand is to be met with minimal environmental impacts.

Tilman, D., K. G. Cassman, P. A. Matson, R. Naylor and S. Polasky (2002). "Agricultural sustainability and intensive production practices." Nature **418**(6898): 671-677.
Category: Policy; Ecosystem services
Keywords: *Agro-ecosystems, sustainability, ecosystem services, intensive production systems*
Abstract: A doubling in global food demand projected for the next 50 years poses huge challenges for the sustainability both of food production and of terrestrial and aquatic ecosystems and the services they provide to society. Agriculturalists are the principal managers of global useable lands and will shape, perhaps irreversibly, the surface of the Earth in the coming decades. New incentives and policies for ensuring the sustainability of agriculture and ecosystem services will be crucial if we are to meet the demands of improving yields without compromising environmental integrity or public health.

Tilman, D., J. Fargione, B. Wolff, C. D'Antonio, A. Dobson, R. Howarth, D. Schindler, W. Schlesinger, D. Simberloff and D. Swackhamer (2001). "Forecasting agriculturally driven global environmental change." Science **292**(5515): 281-284.
Category: Policy; Agriculture-induced impacts
Keywords: *Agriculture, environment impact, planetary scale, ecological damage, agricultural development, biodiversity, eutrophication, demographic evolution, irrigation, land use, agricultural policy, environmental policy, agricultural production, ecosystem, habitat, freshwater environment, marine environment, terrestrial environment, Nitrogen, fertilizers, Nitrogen fertilizer, Phosphate fertilizer, pesticides, phosphorus, pasture, arable land, forecasting, prospective, economic statistic, food production, soil nutrients/cycling*
Abstract: During the next 50 years, which is likely to be the final period of rapid agricultural expansion, demand for food by a wealthier and 50% larger global population will be a major driver of global environmental change. Should past dependences of the global environmental impacts of agriculture on human population and consumption continue, 10(to the power of 9) hectares of natural ecosystems would be converted to agriculture by 2050. This would be accompanied

by 2.4- to 2.7-fold increases in nitrogen- and phosphorus-driven eutrophication of terrestrial, freshwater, and near-shore marine ecosystems, and comparable increases in pesticide use. This eutrophication and habitat destruction would cause unprecedented ecosystem simplification, loss of ecosystem services, and species extinctions. Significant scientific advances and regulatory, technological, and policy changes are needed to control the environmental impacts of agricultural expansion.

Tilman, D., P. Reich and J. Knops (2006). "Biodiversity and ecosystem stability in a decade-long grassland experiment." Nature **441**(7093): 629-632.

Category: Ecosystem services

Keywords: *Biodiversity, biological productivity, grassland, ecosystem, long term, stability, vegetation, species diversity*

Abstract: Human-driven ecosystem simplification has highlighted questions about how the number of species in an ecosystem influences its functioning. Although biodiversity is now known to affect ecosystem productivity1–6, its effects on stability are debated6–13. Here we present a long-term experimental field test of the diversity–stability hypothesis. During a decade of data collection in an experiment that directly controlled the number of perennial prairie species4, growing-season climate varied considerably, causing year-to-year variation in abundances of plant species and in ecosystem productivity. We found that greater numbers of plant species led to greater temporal stability of ecosystem annual aboveground plant production. In particular, the decadal temporal stability of the ecosystem, whether measured with intervals of two, five or ten years, was significantly greater at higher plant diversity and tended to increase as plots matured. Ecosystem stability was also positively dependent on root mass, which is a measure of perenniating biomass. Temporal stability of the eco- system increased with diversity, despite a lower temporal stability of individual species, because of both portfolio (statistical aver-aging) and overyielding effects. However, we found no evidence of a covariance effect. Our results indicate that the reliable, efficient and sustainable supply of some foods (for example, livestock fodder), biofuels and ecosystem services can be enhanced by the use of biodiversity.

Tittonell, P. and K. Giller (2013). "When yield gaps are poverty traps: The paradigm of ecological intensification in African smallholder agriculture." Field Crops Research **143**: 76-90.

Category: Policy; Ecosystem services; Farmer and societal benefits; Agriculture-induced impacts

Keywords: *Yield gaps, poverty traps, ecological intensification, smallholder agriculture, Africa, framework for yield gap assessment, soil quality, precision agriculture, soil nutrients/cycling*

Abstract: Yield gaps are pervasive in African smallholder agriculture, and are large for almost all crops in all regions. There is consensus that poor soil fertility and nutrient availability are the major biophysical limitations to agricultural production in the continent. We identify two major yield gaps: (1) the gap between actual yields (YA) and the water-limited yield potential (Yw), which is the maximum yield

achievable under rain- fed conditions without irrigation if soil water capture and storage is optimal and nutrient constraints are released, and (2) The gap between YA, and a locally attainable yield (YL) which corresponds to the water and nutrient-limited yields that can be measured in the most productive fields of resource endowed farmers in a community. Estimates of these two yield gaps are given for major crops, together with a framework for how yield gaps can be estimated in a pragmatic way for different farming systems. The paradigm of ecological intensification which focuses on yield potential, soil quality and precision agriculture is explored for the African context. Our analysis suggests that smallholder farmers are unable to benefit from the current yield gains offered by plant genetic improvement. In particular, continued cropping without sufficient inputs of nutrients and organic matter leads to localised but extensive soil degradation and renders many soils in a non-responsive state. The lack of immediate response to increased inputs of fertiliser and labour in such soils constitutes a chronic poverty trap for many smallholder farmers in Africa. This necessitates a rethink for development policy aimed to improve productivity and address problems of food insecurity.

Tittonell, P., M. T. van Wijk, M. Herrero, M. C. Rufino, N. de Ridder and K. E. Giller (2009). "Beyond resource constraints. Exploring the biophysical feasibility of options for the intensification of smallholder crop-livestock systems in Vihiga district, Kenya." Agricultural Systems **101**(1-2): 1-19.

Category: Policy; Farmer and societal benefits; Ecosystem services

Keywords: *Sub-Saharan Africa, farming systems design, smallholder farms, farm-scale modelling, food security, resource use efficiency, intensification*

Abstract: Yield gaps are pervasive in African smallholder agriculture, and are large for almost all crops in all regions. There is consensus that poor soil fertility and nutrient availability are the major biophysical limitations to agricultural production in the continent. We identify two major yield gaps: (1) the gap between actual yields (YA) and the water-limited yield potential (Yw), which is the maximum yield achievable under rain- fed conditions without irrigation if soil water capture and storage is optimal and nutrient constraints are released, and (2) The gap between YA, and a locally attainable yield (YL) which corresponds to the water and nutrient-limited yields that can be measured in the most productive fields of resource endowed farm- ers in a community. Estimates of these two yield gaps are given for major crops, together with a framework for how yield gaps can be estimated in a pragmatic way for different farming systems. The paradigm of ecological intensification which focuses on yield potential, soil quality and precision agriculture is explored for the African context. Our analysis suggests that smallholder farmers are unable to benefit from the current yield gains offered by plant genetic improvement. In particular, continued cropping without sufficient inputs of nutrients and organic matter leads to localised but extensive soil degrada- tion and renders many soils in a non-responsive state. The lack of immediate response to increased inputs of fertiliser and labour in such soils constitutes a chronic poverty trap for many smallholder farmers in Africa. This necessitates a rethink for development policy aimed to improve productivity and address problems of food insecurity.

Tryjanowski, P. (2000). "Changes in breeding bird populations of some farmland birds in W. Poland in relation to changes in crop structure, weather conditions and number of predators." Folia Zoologica **49**: 305-315.
Category: Agriculture-induced impacts
Keywords: *Farmland birds, predators, crop structure, weather*

Abstract: The studies were carried out in eastern Poland, near Siedlce (52°12'N, 22°17'E). The study area covered 788 ha of extensive agricultural landscape. The fieldwork was conducted in 1999-2003 and it comprised 7 counts per season in each year. Tendencies in changes of numbers were followed for 19 bird species. Directional increasing trends in numbers of the Serin (Serinus serinus) and Ortolan Bunting (Emberiza hortulana) were revealed. A statistically significant decreases in numbers considered the Lapwing (Vanellus vanellus), Corn Bunting (Miliaria calandra) and Whinchat (Saxicola rubetra). For the remaining 14 species — e.g. the Red-backed Shrike (Lanius collurio), Linnet (Carduelis cannabina), Goldfinch (C. chloris), Whitethroat (Sylvia communis), Yellowhammer (Emberiza citrinella) — no directional tendencies in numbers of breeding pairs were found. A comparison of tendencies in numbers of analysed species with tendencies observed in western Europe and in western Poland showed that the status of birds in the agricultural landscape of eastern Poland was much better. This has probably been caused by lower intensity of farming practice and more diverse mosaic of habitats.

Tryjanowski, P., B. Gołdyn and A. Surmacki (2002). "Influence of the red fox (Vulpes vulpes, Linnaeus 1758) on the distribution and number of breeding birds in an intensively used farmland." Ecological Research **17**(3): 395-399.
Category: Agriculture-induced impacts
Keywords: *Breeding bird community, fox, point counts, predation, Vulpes vulpes*

Abstract: This study tested the hypothesis that small birds at their nest sites avoid areas around dens of the red fox (Vulpes vulpes, Linneaus 1758) in an intensively used farmland. Birds were counted at 18 points (radius 100 m) located near dens, as well as at 18 control points that were located at least 600 m away from the nearest den. These two types of points did not differ with respect to the number of recorded bird species. However, a negative effect of the proximity of fox dens on the total density of the bird community was observed. This effect was also recorded for the most abundant bird species, the skylark (Alauda arvensis, Linneaus 1758). In agreement with our expectations, these results indicate a negative impact of fox presence on a breeding bird community in an open farmland.

Tryjanowski, P., T. Hartel, A. Baldi, P. Szymaaki, M. Tobolka, I. Herzon, A. Golawski, M. Konvika, M. Hromada, L. Jerzak, K. Kujawa, M. Lenda, G. Orlowski, M. Panek, P. Skorka, T. H. Sparks, S. Tworek, A. Wuczynski and M. Zmihorski (**2011**). "Conservation of Farmland Birds Faces Different Challenges in Western and Central-Eastern Europe." Acta Ornithologica **46**(1): 1-12.
Category: Agriculture-induced impacts
Keywords: *Landscape ecology, habitat, matrix, Central and Eastern Europe, Grey Partridge,*

Perdix perdix, Red-backed Shrike, Lanius collurio, land use, wild biodiversity

Abstract: Birds are commonly used as an example of the strongly declining farmland biodiversity in Europe. The populations of many species have been shown to suffer from intensification of management, reduction of landscape heterogeneity, and habitat loss and fragmentation. These conditions particularly dominate farmland in the economically well developed countries of Western Europe. Currently, the farmland environment in Central-Eastern Europe is generally more extensive than in Western Europe and a larger proportion of people still live in rural areas; thus generating different conditions for birds living in agricultural areas. Furthermore, the quasi-subsistence farming in much of Central-Eastern Europe has resulted in agricultural landscapes that are generally more complex than those in Western Europe. To protect declining bird populations living in farmland, detailed knowledge on both species and communities is necessary. However, due to scientific tradition and availability of funding, the majority of studies have been carried out in Western Europe. In consequence this provokes a question: are findings obtained in western conditions useful to identify the fate of farmland bird biodiversity in Central-Eastern Europe? Therefore, the major goal of this paper is to highlight some local and regional differences in biodiversity patterns within EU farmland by comparing intensive agricultural landscapes with more extensive ones. More specifically, we aim to outline differences in agricultural landscapes and land use history in the two regions, use farmland birds to provide examples of the differences in species dynamics and species-habitat interactions between the two regions, and discuss possible social and ecological drivers of the differences in the context of biodiversity conservation. Factors governing spatio-temporal dynamics of farmland bird populations may differ in intensive and extensive landscapes as illustrated here using the Grey Partridge Perdix perdix and the Red-backed Shrike Lanius collurio as examples. The unevenness of farmland bird studies distribution across Europe was also presented. We call for more emphasis on pluralism in furthering both pan-European research on farmland bird ecology and conservation strategies. We also highlight some features specific to Central-Eastern Europe that merit consideration for the more efficient conservation of farmland birds and farmland biodiversity across Europe.

Tryjanowski, P., T. Pawlikowski, K. Pawlikowski, W. Banaszak-Cibicka and T. H. Sparks (2010). "Does climate influence phenological trends in social wasps (Hymenoptera: Vespinae) in Poland?" Eur. J. Entomol **107**(2): 203-208.

Category: Climate change

Keywords: *Hymenoptera, Vespinae, Vespa crabro, Vespula germanica, German wasp, hornet, appearance date, climate change, long-term study, temperature, social insects, Poland, pest regulation*

Abstract: Responses of insects to recent climate change have been well documented in a number of taxa, but not in wasps. This study examined shifts in phenology of the two most important wasp species (Vespa crabro and Vespula germanica) in Poland over the last three decades. Both species showed similar temporal trends, advancing their phenology after the early 1980s, but this pattern was detected only for workers not for the appearance of queens. The appearance times for V. germanica were

negatively related to mean April temperature, appearing earlier in years with warmer springs, and positively related to precipitation in April. The studied species advanced aspects of their phenology, but linking this to temperature was not achieved for V. crabro suggesting that we have to pay more attention to the life history traits of the study organisms.

Tryjanowski, P., T. Sparks and P. Profus (2005). "Uphill shifts in the distribution of the white stork Ciconia ciconia in southern Poland: the importance of nest quality." Diversity and Distributions **11**(3): 219-223.

Category: Climate Change

Keywords: *Altitudinal gradient, Central Europe, climate change, foraging areas, historical records, uplands, white stork*

Abstract: The aim of this paper is to explain the altitudinal changes that have occurred during the 20th century to the white stork distribution in the Podhale region of the uplands of the Tatra mountains, southern Poland. We analysed both historical data from the white stork censuses and detailed yearly records from 1974 to 2003 on population size, distribution and breeding success.

A white stork nest was first recorded at Podhale in 1931 and numbers increased to seven nests in 1933, all located below 650 m altitude. During the 30-years, 1974–2003, both the maximum and upper-quartile altitudes of nests increased significantly. In 1974 the highest nest was at an altitude of 770 m, and the maximum reached 890 m in 1999. In the same period, the breeding population increased significantly. The minimum and lower-quartile altitudes of nests decreased significantly following initial occupation of suitable lower altitude sites before uphill expansion. We noted the positive association between nest occupancy over the study period and breeding performance. As a result, long-occupied nests contributed most of the young produced in the population and chicks from these nests probably colonized new areas. We believe this is the first well-documented evidence of, and mechanism for, a particular bird species to ascend to higher elevations and that the altitudinal shifts reported for butterflies, plants and whole biomes can be detected in birds as well.

Tryjanowski, P., T. H. Sparks, L. Kuczynski and S. Kuzniak (2004). "Should avian egg size increase as a result of global warming? A case study using the red-backed shrike (Lanius collurio)." Journal of Ornithology **145**(3): 264-268.

Category: Climate change

Keywords: *Breeding biology, climate change, egg size, long-term study*

Abstract: From some life-history traits, avian egg size can be postulated as potentially affected by climate change. In this paper, we present and discuss the potential effect of mean temperature in the breeding season on egg size of the red-backed shrike (Lanius collurio). During the 1971–2002 study period, egg volume of the red-backed shrike decreased significantly, birds arrived at the breeding site significantly earlier, and arrival date was correlated with the earliest first egg date. To our knowledge, we present the first evidence that avian egg size decreased significantly in a long-term study. However, we do not have experimental

manipulations in support of our data and we can only conclude that the decrease in egg volume in the studied population might result as a consequence of a number of factors, including changes in temperature, as well as in food supply. Therefore climate change effects on a bird's life-history traits can be more complex than just the simple direct effect of temperature.

Tscharntke, T., P. Batary, Y. Clough, D. Kleijn, C. Scherber, C. Thies, T. C. Wanger and C. Westphal (2012). Combining biodiversity conservation with agricultural intensification. Land Use Intensification: Effects on Agriculture, Biodiversity and Ecological Processes. S. Cunningham, A. Young and D. Lindenmayer, CSIRO**:** 7.

Category: Ecosystem services; Farmer and societal benefits

Keywords: *Agricultural intensification, biodiversity conservation*

Abstract:

Lesson #1: Pesticides are a largely underestimated determinant of biodiversity loss.

Lesson #2: Farmiland biodiversity reduces household vulnerability and provides natural insurance to risk-averse farmers

Lesson #3: Biodiversity conservation needs a landscape perspective.

Lesson #4: Farmland biodiversity is good for ecosystem services but rarely include endangered species

Lesson #5: High yield and high farmland biodiversity can be combined.

Lesson #6: The concept of land sparing, instead of wildlife-friendly farming, does not contribute to connecting hunger reduction with biodiversity.

Tscharntke, T., R. Bommarco, Y. Clough, T. O. Crist, D. Kleijn, T. Rand, J. Tylianakis, S. Nouhuys and S. Vidal (2007). "Conservation biological control and enemy diversity on a landscape scale." Biological Control **43**(3): 294-309.

Category: Ecosystem services

Keywords: *Agroecosystems, Beta diversity, dispersal, habitat fragmentation, insurance hypothesis, multitrophic interactions, parasitoid and predator spillover, SLOSS spatial ecology, specialists vs. generalists, sustainability, pest regulation*

Abstract: Conservation biological control in agroecosystems requires a landscape management perspective, because most arthropod species experience their habitat at spatial scales beyond the plot level, and there is spillover of natural enemies across the crop–noncrop interface. The species pool in the surrounding landscape and the distance of crop from natural habitat are important for the conservation of enemy diversity and, in particular, the conservation of poorly-dispersing and specialized enemies. Hence, structurally complex landscapes with high habitat connectivity may enhance the probability of pest regulation. In contrast, generalist and highly vagile enemies may even profit from the high primary productivity of crops at a landscape scale and their abundance may partly compensate for losses in enemy diversity. Conservation biological control also needs a multitrophic perspective. For example, entomopathogenic fungi, plant pathogens and endophytes as well as below- and above-ground microorganisms are known to influence pest-enemy interactions in ways that vary across spatiotemporal scales. Enemy distribution in agricultural landscapes is determined by beta diversity among

patches. The diversity needed for conservation biological control may occur where patch heterogeneity at larger spatial scales is high. However, enemy communities in managed systems are more similar across space and time than those in natural systems, emphasizing the importance of natural habitat for a spillover of diverse enemies. According to the insurance hypothesis, species richness can buffer against spatiotemporal disturbances, thereby insuring functioning in changing environments. Seemingly redundant enemy species may become important under global change. Complex landscapes characterized by highly connected crop–noncrop mosaics may be best for long-term conservation biological control and sustainable crop production, but experimental evidence for detailed recommendations to design the composition and configuration of agricultural landscapes that maintain a diversity of generalist and specialist natural enemies is still needed.

Tscharntke, T., Y. Clough, T. C. Wanger, L. Jackson, I. Motzke, I. Perfecto, J. Vandermeer and A. Whitbread (2012). "Global food security, biodiversity conservation and the future of agricultural intensification." Biological Conservation **151**(1): 53-59.

Category: Policy; Ecosystem services

Keywords: *Land sparing vs sharing, wildlife-friendly farming, land grabbing, biofuel directive, food wastage, yield-biodiversity trade offs, pest regulation*

Abstract: Under the current scenario of rapid human population increase, achieving efficient and productive agricultural land use while conserving biodiversity is a global challenge. There is an ongoing debate whether land for nature and for production should be segregated (land sparing) or integrated on the same land (land sharing, wildlife-friendly farming). While recent studies argue for agricultural intensification in a land sparing approach, we suggest here that it fails to account for real-world complexity. We argue that agriculture practiced under smallholder farmer-dominated landscapes and not large-scale farming, is currently the backbone of global food security in the developing world. Furthermore, contemporary food usage is inefficient with one third wasted and a further third used inefficiently to feed livestock and that conventional intensification causes often overlooked environmental costs. A major argument for wildlife friendly farming and agroecological intensification is that crucial ecosystem services are provided by “planned” and “associated” biodiversity, whereas the land sparing concept implies that biodiversity in agroecosystems is functionally negligible. However, loss of biological control can result in dramatic increases of pest densities, pollinator services affect a third of global human food supply, and inappropriate agricultural management can lead to environmental degradation. Hence, the true value of functional biodiversity on the farm is often inadequately acknowledged or understood, while conventional intensification tends to disrupt beneficial functions of biodiversity. In conclusion, linking agricultural intensification with biodiversity conservation and hunger reduction requires well-informed regional and targeted solutions, something which the land sparing vs sharing debate has failed to achieve so far.

Tscharntke, T., A. M. Klein, A. Kruess, I. Steffan-Dewenter and C. Thies (2005). "Landscape

perspectives on agricultural intensification and biodiversity – ecosystem service management." Ecology Letters **8**(8): 857-874.

Category: Policy; Ecosystem services

Keywords: *Agri-environment schemes, biological control, dispersal, ecosystem functioning, land-use systems, pollination, resilience, spatial scale, sustainability, trophic, interactions*

Abstract: Understanding the negative and positive effects of agricultural land use for the conservation of biodiversity, and its relation to ecosystem services, needs a landscape perspective. Agriculture can contribute to the conservation of high-diversity systems, which may provide important ecosystem services such as pollination and biological control via complementarity and sampling effects. Land-use management is often focused on few species and local processes, but in dynamic, agricultural landscapes, only a diversity of insurance species may guarantee resilience (the capacity to reorganize after disturbance). Interacting species experience their surrounding landscape at different spatial scales, which influences trophic interactions. Structurally complex landscapes enhance local diversity in agroecosystems, which may compensate for local high- intensity management. Organisms with high-dispersal abilities appear to drive these biodiversity patterns and ecosystem services, because of their recolonization ability and larger resources experienced. Agri-environment schemes (incentives for farmers to benefit the environment) need to broaden their perspective and to take the different responses to schemes in simple (high impact) and complex (low impact) agricultural landscapes into account. In simple landscapes, local allocation of habitat is more important than in complex landscapes, which are in total at risk. However, little knowledge of the relative importance of local and landscape management for biodiversity and its relation to ecosystem services make reliable recommendations difficult.

Turbe, A., A. De Toni, P. Benito, P. Lavelle, P. Lavelle, N. Camacho, W. Van Der Putten, E. Labouze and S. Mudgal (2010). Soil biodiversity: functions, threats and tools for policy makers. Brussels, Bio Intelligence Service, IRD, and KNAW, Report for European Commission (DG Environment).

Category: Ecosystem services

Keywords: *Soil biodiversity, soil functions*

Abstract: Human societies rely on the vast diversity of benefits provided by nature, such as food, fibres, construction materials, clean water, clean air and climate regulation. All the elements required for these ecosystem services depend on soil, and soil biodiversity is the driving force behind their regulation. With 2010 being the international year of biodiversity and with the growing attention in Europe on the importance of soils to remain healthy and capable of supporting human activities sustainably, now is the perfect time to raise awareness on preserving soil biodiversity. The objective of this report is to review the state of knowledge of soil biodiversity, its functions, its contribution to ecosystem services and its relevance for the sustainability of human society. In line with the definition of biodiversity given in the 1992 Rio de Janeiro Convention1, soil biodiversity can be defined as the variation in soil life, from genes to communities, and the variation in soil habitats, from micro-aggregates to entire landscapes.

Tylianakis, J., R. K. Didham, J. Bascompte and D. Wardle (2008). "Global change and species interactions in terrestrial ecosystems." Ecology Letters **11**(12): 1351-1363.

Category: Climate change

Keywords: *Climate change, CO2, competition, disease, food web, global warming, interaction effect, land-use change, mycorrhiza, nitrogen deposition, parasite, pollination, seed dispersal*

Abstract: The main drivers of global environmental change (CO2 enrichment, nitrogen deposition, climate, biotic invasions and land use) cause extinctions and alter species distributions, and recent evidence shows that they exert pervasive impacts on various antagonistic and mutualistic interactions among species. In this review, we synthesize data from 688 published studies to show that these drivers often alter competitive interactions among plants and animals, exert multitrophic effects on the decomposer food web, increase intensity of pathogen infection, weaken mutualisms involving plants, and enhance herbivory while having variable effects on predation. A recurrent finding is that there is substantial variability among studies in both the magnitude and direction of effects of any given GEC driver on any given type of biotic interaction. Further, we show that higher order effects among multiple drivers acting simultaneously create challenges in predicting future responses to global environmental change, and that extrapolating these complex impacts across entire networks of species interactions yields unanticipated effects on ecosystems. Finally, we conclude that in order to reliably predict the effects of GEC on community and ecosystem processes, the greatest single challenge will be to determine how biotic and abiotic context alters the direction and magnitude of GEC effects on biotic interactions.

Tylianakis, J. and C. Romo (2010). "Natural enemy diversity and biological control: Making sense of the context-dependency." Basic and Applied Ecology **11**(8): 657-668.

Category: Ecosystem services

Keywords: *Biodiversity, ecosystem functioning, niche partitioning, pest, agriculture, insect, parasitoid, management, IPM, intraguild predation, habitat complexity, heterogeneity, pest regulation*

Abstract: Numerous studies have demonstrated that diverse predator assemblages can be more effective at controlling prey populations. Yet, other studies have shown no effect of predator diversity on prey mortality, or even negative effects (for example due to intraguild predation or interference). Much research emphasis has been placed on the traits of predators that maximise functional complementarity. However, comparatively less attention has been paid to the traits of the prey or habitat that may maximise predator diversity effects, even though there must be a variety of prey niches available to be partitioned in order for niche complementarity to occur. Following this logic, we review six hypotheses for when diverse enemy assemblages should be most effective: when 1) prey communities are diverse; 2) prey have complex life cycles; 3) prey are patchily distributed in space or time; 4) studies are conducted at larger spatial and temporal scales; 5) plant structures are complex; 6) prey are abundant. Many of these hypotheses lack direct tests,

particularly in agricultural systems, but we find little or no direct or indirect support for hypotheses 1, 4, 5 and 6. However, previous work does provide some support for hypotheses 2 and 3. We discuss methods to test these hypotheses directly, and suggest that natural enemy diversity may only benefit the biological control of arthropods in heterogeneous systems.

UK National Ecosystem Assessment (2011). The UK National Ecosystem Assessment Technical Report. Cambridge, UNEP-WCMC.
Category: Ecosystem services; Policy
Keywords: *UK National Ecosystem Assessment, change, biodiversity, ecosystem services, England, Northern Ireland, Scotland, Wales, well-being*
Abstract: The UK National Ecosystem Assessment (UK NEA) is the first analysis of the UK's natural environment in terms of the benefits it provides to society and the nation's continuing prosperity. Carried out between mid-2009 and mid-2011, the UK NEA has been a wide-ranging, multi-stakeholder, cross- disciplinary process, designed to provide a comprehensive picture of past, present and possible future trends in ecosystem services and their values; it is underpinned by the best available evidence and the most up-to-date conceptual thinking and analytical tools. The UK NEA is innovative in scale, scope and methodology, and has involved more than 500 natural scientists, economists, social scientists and other stakeholders from government, academic and private sector institutions, and non-governmental organisations (NGOs).

Ulgiati, S., A. Zucaro and P. Franzese (2011). "Shared wealth or nobody's land? The worth of natural capital and ecosystem services." Ecological Economics **70**(4): 778-787.
Category: Farmer and societal benefits; Ecosystem services
Keywords: *Emergy, commons, natural capital, ecosystem services, environmental policy*
Abstract: The prerequisite for a sustainable and equitable use of common resources (the so-called Commons) must be the proper evaluation of their role within the complex network of relationships that ensure ecosystems functioning, resilience, and evolutionary dynamics. It is crucial to ascertain to what extent the common wealth is used for the common benefit. Money-based schemes for valuing the Commons, such as the so-called "willingness-to-pay", provide a user-side evaluation perspective based on the idea that value only stems from utilization by humans. As a complement to such a point of view, we present and discuss in this paper a donor-side evaluation method (Emergy Synthesis) based on the idea that a proper measure of value can be achieved by also accounting for the work done by the biosphere in generating services and resources. It should not be disregarded that such resources and services also provide support to other species in the web of life. Emergy, a scientific measure of such environmental support, is suggested as a tool capable to assess quantity and quality of shared resources, thus providing a basis for their environmentally sound management.

United Nations Economic Commission for Europe (2007). Recommendations on payments

for ecosystem services in integrated water resources management. Geneva, United Nations Publications.
Category: Policy
Keywords: *Water management, planning, ecosystem services, public-benefit compensations*
Abstract: Payments for ecosystem services (PES) have the potential to be an environmentally effective, economically efficient and socially equitable tool for implementing integrated water resources management (IWRM). PES schemes complement other approaches, such as command-and-control and structural measures.The Recommendations brought forward in this document reflect good practices in order to support Governments at all levels of decision-making (global, regional, transboundary, national and local) in the implementation of PES. They also address joint bodies, such as international river and lake commissions, and other appropriate institutional arrangements for cooperation between riparian countries.These recommendations should also guide other actors, such as suppliers and users of ecosystem services, in the protection, restoration and sustainable use of water-related ecosystems and the establishment of PES.

Vaissiere, B., B. Freitas and B. Gemmill-Herren (2011). Protocol to detect and assess pollination deficits in crops: a handbook for its use. Rome, FAO**:** 70.
Category: Ecosystem services
Keywords: *Pollinators, pollination, apidae, crops, data collection, treaties, plant production, agricultural development, sustainability, ecosystems, human well bieng, ecosystem services, biodiversity*
Abstract: As a contribution to the International Pollinators Initiative, FAO and its partners have collaborated with INRA (Institut National de la Recherche Agronomique, a public research body of the French government) to develop a protocol for assessing and detecting if a crop production system is suffering a pollination deficit. This document thus presents a handbook for the application of the protocol, outlining the underlying concepts, the hypothesis to be tested, and the modification and application of the protocol to a variety of circumstances in developing countries, such as small fields, home gardens, and high environmental variability.

Van Buskirk, J. and Y. Willi (2004). "Enhancement of farmland biodiversity within set-aside Land." Conservation Biology **18**(4): 987-994.
Category: Policy
Keywords: *Agriculture, biodiversity, conservation, set-aside land, wild biodiversity*
Abstract: The efficacy of agricultural set-aside policies for protecting farmland biodiversity is widely debated. Based on a meta-analysis of 127 published studies, we found that land withdrawn from conventional production unequivocally enhances biodiversity in North America and Europe. The number of species of birds, insects, spiders, and plants is 1–1.5 standard deviation units higher on set-aside land, and population densities increase by 0.5–1 standard deviation units. Set-aside land may be especially beneficial for desirable taxa because North American bird species that have exhibited population declines react most positively to set-aside agricultural

land. Larger and older plots protect more species and higher densities, and set-aside land is more effective in countries with less-intensive agricultural practices and higher fractions of land removed from production. Although policies specifically designed to protect biodiversity might work even better, current incentives clearly improve the standing of plants and animals in farmland.

van der Putten, W., R. Bardgett, P. De Ruiter, W. Hol, K. Meyer, T. Bezemer, M. Bradford, S. Christensen, M. Eppinga, T. Fukami, L. Hemerik, J. Molofsky, M. Schadler, C. Scherber, S. Y. Strauss, M. Vos and D. A. Wardle (2009). "Empirical and theoretical challenges in aboveground-belowground ecology." Oecologia **161**(1): 1-14.

Category: Ecosystem services

Keywords: *Succession, sustainable crop protection, invasion, global change, temporal and spatial models, soil/nutrient cycling, pest regulation, pollination*

Abstract: A growing body of evidence shows that aboveground and belowground communities and processes are intrinsically linked, and that feedbacks between these subsystems have important implications for community structure and ecosystem functioning. Almost all studies on this topic have been carried out from an empirical perspective and in specific ecological settings or contexts. Belowground interactions operate at different spatial and temporal scales. Due to the relatively low mobility and high survival of organisms in the soil, plants have longer lasting legacy effects belowground than aboveground. Our current challenge is to understand how aboveground-belowground biotic interactions operate across spatial and temporal scales, and how they depend on, as well as influence, the abiotic environment. Because empirical capacities are too limited to explore all possible combinations of interactions and environmental settings, we explore where and how they can be supported by theoretical approaches to develop testable predictions and to generalise empirical results. We review four key areas where a combined aboveground-belowground approach offers perspectives for enhancing ecological understanding, namely succession, agro-ecosystems, biological invasions and global change impacts on ecosystems. In plant succession, differences in scales between aboveground and belowground biota, as well as between species interactions and ecosystem processes, have important implications for the rate and direction of community change. Aboveground as well as belowground interactions either enhance or reduce rates of plant species replacement. Moreover, the outcomes of the interactions depend on abiotic conditions and plant life history characteristics, which may vary with successional position. We exemplify where translation of the current conceptual succession models into more predictive models can help targeting empirical studies and generalising their results. Then, we discuss how understanding succession may help to enhance managing arable crops, grasslands and invasive plants, as well as provide insights into the effects of global change on community re-organisation and ecosystem processes.

Van der Putten, W., L. Vet, J. Harvey and F. Wackers (2001). "Linking above- and belowground multitrophic interactions of plants, herbivores, pathogens, and their antagonists." Trends in ecology & evolution **16**(10): 547-554.

Category: Ecosystem services

Keywords: *Tropic link, spatio-temporal dynamics, interaction strength, plant defense, nutrition, ecology, rhizosphere, soil ecology, multitropic interactions, pathogens, soil nutrients/cycling, pest regulation*

Abstract: Plants function in a complex multitrophic environment. Most multitrophic studies, however, have almost exclusively focused on aboveground interactions, generally neglecting the fact that above- and belowground organisms interact. The spatial and temporal dynamics of above- and belowground herbivores, plant pathogens, and their antagonists, can differ in space and time. This affects the temporal interaction strengths and impacts of above- and belowground higher trophic level organisms on plants. Combining both above- and belowground compartments in studies of multitrophic interactions throughout the life cycle of plants will improve our understanding of ecology and evolution in the real world.

Vanbergen, A. J. (2013). "Threats to an ecosystem service: pressures on pollinators." Frontiers in Ecology and the Environment **11**(5): 251-259.

Category: Ecosystem services

Keywords: *Ecosystem services, pollinators, pollination*

Abstract: Insect pollinators of crops and wild plants are under threat globally and their decline or loss could have profound economic and environmental consequences. Here, we argue that multiple anthropogenic pressures – including land-use intensification, climate change, and the spread of alien species and diseases – are primarily responsible for insect-pollinator declines. We show that a complex interplay between pressures (eg lack of food sources, diseases, and pesticides) and biological processes (eg species dispersal and interactions) at a range of scales (from genes to ecosystems) underpins the general decline in insect-pollinator populations. Interdisciplinary research on the nature and impacts of these interactions will be needed if human food security and ecosystem function are to be preserved. We highlight key areas that require research focus and outline some practical steps to alleviate the pressures on pollinators and the pollination services they deliver to wild and crop plants.

Vandermeer, J., I. Perfecto, R. E. Green, S. J. Cornell, J. Scharlemann and A. Balmford (2005). "The future of farming and conservation." Letters. Science **308**: 4.

Category: Ecosystem services

Keywords: *High and low yield farming, natural habitats, wildlife-friendly schemes, wildlife conservation*

Summary: THE RESEARCH ARTICLE BY R. E. GREEN ET AL. “Farming and the fate of wild nature” (28 Jan., p. 550) adds to the already burgeoning literature on agroecosystems and conservation. The authors are to be commended for their attempt to develop a model that could be of use in decision-making about agricultural development and wildlife conservation. Unfortunately, this work contains some critical errors, conceptual flaws, and missing literature that invalidate its conclusions. We list here a few such problems.

Vandermeer, J., M. van Noordwijk, J. Anderson, C. Ong and I. Perfecto (1998). "Global change and multi-species agroecosystems: Concepts and issues." Agriculture, Ecosystems & Environment **67**(1): 1-22.

Category: Ecosystem services

Keywords: *Multi-species agroecosystems, biodiversity, concepts, issues, soil nutrients/cycling*

Abstract: Complex (multi-species) agroecosystems change rapidly as a result of farmers' decisions based on their perception of opportunities and constraints. Overall, the major trend is still one of reducing complexity. This review addresses the driving forces as well as consequences of this change and discusses the hypothesis that complex agricultural systems are more dependable in production and more sustainable in terms of resource conservation than simple ones. Farmer decisions regarding planned diversity on the farm have consequences not only for the harvested produce, but also for associated diversity and non-harvested components which may contribute to ecological sustainability. Functional attributes of plants which can lead to complementarity in resource capture include root architecture and phenology. Three hypotheses on biodiversity and ecosystem function are formulated (ranging from weak negative to strong positive interactions) and discussed. Evidence is not yet conclusive.

Vanloqueren, G. and P. Baret (2009). "How agricultural research systems shape a technological regime that develops genetic engineering but locks out agroecological innovations." Research Policy **38**(6): 971-983.

Category: Policy

Keywords: *Technological trajectories, evolutionary economics, transgenic plants, lock-in, path dependence*

Abstract: Agricultural science and technology (S&T) is under great scrutiny. Reorientation towards more holistic approaches, including agroecology, has recently been backed by a global international assessment of agriculture S&T for development (IAASTD). Understanding the past and current trends of agricultural S&T is crucial if such recommendations are to be implemented. This paper shows how the concepts of technological paradigms and trajectories can help analyse the agricultural S&T landscape and dynamics. Genetic engineering and agroecology can be usefully analysed as two different technological paradigms, even though they have not been equally successful in influencing agricultural research. We used a Systems of Innovation (SI) approach to identify the determinants of innovation (the factors that influence research choices) within agricultural research systems. The influence of each determinant is systematically described (e.g. funding priorities, scientists' cognitive and cultural routines etc.). As a result of their interactions, these determinants construct a technological regime and a lock-in situation that hinders the development of agroecological engineering. Issues linked to breaking out of this lock-in situation are finally discussed.

Vaughn, C., D. Spooner and H. Galbraith (2007). "Context-dependet species identity effects within a functional group of filter-feeding bivalves." Ecology **88**(7): 1654-1662.

Category: Ecosystem services

Keywords: *Biodiversity, Bivalvia, ecosystem function, functional group, species identity, species richness, stream, Unionidae*

Abstract: We asked whether species richness or species identity contributed more to ecosystem function in a trait-based functional group, burrowing, filter-feeding bivalves (freshwater mussels: Unionidae), and whether their importance changed with environmental context and species composition. We conducted a manipulative experiment in a small river examining the effects of mussel assemblages varying from one to eight species on benthic algal standing crop across two sets of environmental conditions: extremely low discharge and high water temperature (summer); and moderate discharge and water temperature (fall). We found strong species identity effects within this guild, with one species (Actinonaias ligamentina) influencing accrual of benthic algae more than other species, but only under summer conditions. We suspect that this effect is due to a combination of the greater biomass of this species and its higher metabolic and excretion rates at warm summer temperatures, resulting in increased nitrogen subsidies to benthic algae. We also found that Actinonaias influenced the condition of other mussel species, likely through higher consumption, interference, or both. This study demonstrates that species within trait-based functional groups do not necessarily have the same effects on ecosystem properties, particularly under different environmental conditions.

Verbruggen, E., W. Röling, H. Gamper, G. Kowalchuk, H. Verhoef and M. van der Heijden (2010). "Positive effects of organic farming on below-ground mutualists: large-scale comparison of mycorrhizal fungal communities in agricultural soils." New Phytologist **186**(4): 968-979.

Category: Agriculture-induced impacts

Keywords: *Arbuscular mycorrhizal fungi (AMF), below-ground mutualism, crop rotation, organic agriculture, soil biodiversity, symbiosis, terminal restriction fragment length, polymorphism (T-RFLP), β-diversity, soil nutrients/cycling*

Abstract: The impact of various agricultural practices on soil biodiversity and, in particular, on arbuscular mycorrhizal fungi (AMF), is still poorly understood, although AMF can provide benefit to plants and ecosystems. Here, we tested whether organic farming enhances AMF diversity and whether AMF communities from organically managed fields are more similar to those of species-rich grasslands or conventionally managed fields.

•To address this issue, the AMF community composition was assessed in 26 arable fields (13 pairs of organically and conventionally managed fields) and five semi-natural grasslands, all on sandy soil. Terminal restriction fragment length polymorphism community fingerprinting was used to characterize AMF community composition.

•The average number of AMF taxa was highest in grasslands (8.8), intermediate in organically managed fields (6.4) and significantly lower in conventionally managed fields (3.9). Moreover, AMF richness increased significantly with the time since conversion to organic agriculture. AMF communities of organically managed fields were also more similar to those of natural grasslands when compared with those under conventional management, and were less uniform than their conventional

counterparts, as expressed by higher β-diversity (between-site diversity).

•We suggest that organic management in agro-ecosystems contributes to the restoration and maintenance of these important below-ground mutualists.

Veteläinen, M., V. Negri and N. Maxted (2009). Section 1 - Introduction. 1. European landrace conservation: an introduction European landraces: on farm conservation, management and use. M. Veteläinen, V. Negri and N. Maxted. Rome, Bioversity International: 359.

Category: Ecosystem services

Keywords: *On farm conservation, landraces, Europe, Bulgaria, Denmark, Finland, Germany, Greece, Hungary, Lazio, Romania, Russia, Sweden, UK, Switzerland, Umbria, Lefkada, Scotland, Georgia, genetic diversity*

Abstract: The need to develop work on on-farm conservation of crop genetic diversity in the form of traditional crop varieties, or landraces (in the sense of Harlan) is emphasized in the Convention of Biological Diversity (CBD), Agenda 21, and the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), all of which confirm on-farm conservation as an essential component of sustainable agriculture. The adoption of the CBD Programme of Work on Agricultural Biodiversity in 2000 (Decision V/5, annex 5) has substantially expanded the work on on-farm conservation throughout the world, including in Europe.

Efforts to measure landrace diversity within European production systems have shown that crop landraces are not only complex and highly varied in their genetic structure, but dynamic and evolving entities, characteristics that are now being recognized in designing policies to support their maintenance. Increasingly, attention is now being paid to how increasing the levels of genetic diversity within production systems can be a means of reducing risk to changes in pest and disease and precipitation regimes, particularly in light of the predicted effects of climate change.

Actions are being taken in Europe to make landraces more competitive with modern varieties. Interventions to increase competitiveness have included better characterization of local materials, improvement through breeding and processing, greater access to materials and information, increasing consumer demand, and more supportive policies and incentives.

One area of importance in the on-farm conservation of landraces has been the recognition of the central importance of maintaining local seed systems. Significant work has been undertaken to understand the value of local seed systems, including investigating ways that allow continual migration and selection of landrace populations to generate the qualities needed in local planting materials.

A second important element in European landrace conservation efforts has been the collaboration between partners from the formal and informal sectors, with the best results driven by a clear appreciation of the central role of the farmer in managing crop genetic diversity. These programmes have given importance to adopting working practices that are fully participatory and start from a desire to reflect farmers' needs and concerns in diversity management.

This Technical Bulletin provides a wealth of information on landrace inventories in Europe, on landrace management within a European context, and the promotion of landrace use, together with the development of European national policies to

support the conservation and use of landraces in production systems for sustainable agriculture.

Vignola, R., T. Koellner, R. Scholz and T. McDaniels (2010). "Decision-making by farmers regarding ecosystem services: Factors affecting soil conservation efforts in Costa Rica." Land Use Policy **27**(4): 1132-1142.

Category: Ecosystem services

Keywords: *Soil regulation services, cognitive variables, farmers, decision-making, Costa Rica, soil nutrients/cycling*

Abstract: The impact of climate change on farm soils in the tropics is the combined result of short-term soil management decisions and expanding precipitation extremes. This is particularly true for cultivated lands located in steeply sloping areas where bare soil is exposed to extreme rainfall such as the Birris watershed in Costa Rica. Farmers in this watershed are affected by increasing degradation of soil regulation services and respond with different level of efforts to conserve their soils. This paper examines influences on farmers' decisions through a survey involving interviews with a sample of farmers (n = 56) to test hypotheses on how a combination of cognitive variables (beliefs, risk perception, values) and socioeconomic variables shape decisions on soil conservation. Results show that farmers' awareness of their exposure level to soil erosion combines with other variables to determine their level of soil conservation. Using discriminant analysis, three groups of farmers were identified based on their soil conservation efforts. ANOVA pairwise-comparison among these groups showed significant differences in respect to levels of awareness, perception of risk, and personal beliefs along with territorial exposure and participation in soil conservation programs. Our results help to understand farmers' complex decision-making on soil conservation and help designing policies to support the provision of soil regulation services especially in areas highly exposed to increasing frequency of extreme precipitation events such as Central America.

Viketoft, M., J. Bengtsson, B. Sohlenius, M. P. Berg, O. Petchey, C. Palmborg and K. Huss-Danell (2009). "Long-term effects of plant diversity and composition on soil nematode communities in model grasslands." Ecology **90**(1): 90-99.

Category: Ecosystem services

Keywords: *BIODEPTH, functional diversity, plant–soil feedback, plant–soil relations, soil fauna, species diversity, soil nutrients/cycling*

Abstract: An important component of plant-soil feedbacks is how plant species identity anddiversity influence soil organism communities. We examine the effects of grassland plant species growing alone and together up to a richness of 12 species on nematode diversity and feeding group composition, eight years after the establishment of experimental grassland plots at the BIODEPTH site in northern Sweden. This is a substantially longer time than most other experimental studies of plant effects on soil fauna. We address the hypotheses that (la) higher species or functional diversity of plants increases nematode diversity, as well as influences nematode community composition. Alternatively, (1b) individual plant species traits

are most important for nematode diversity and community composition. (2) Plant effects on soil organisms will decrease with increasing number of trophic links between plants and soil fauna. Plant species identity was often more important than plant diversity for nematode community composition, supporting hypothesis 1b. There was a weak positive relation between plant and nematode richness;which could be attributed to the presence of the legume Trifolium pratense, but also to some other plant species, suggesting a selection or sampling effect. Several plant species in different functional groups affected nematode community composition. For example, we found that legumes increased bacterial-feeding nematodes, most notably r-selected Rhabditida, while fungal-feeding nematodes were enhanced by forbs. Other bacterial feeders and obligate root feeders were positively related to grasses. Plant effects were usually stronger on plant-, bacterial- and fungal-feeding nematodes than on omnivores/predators, which supports hypothesis 2. Our study suggests that plant identity has stronger effects than plant diversity on nematode community composition, but when comparing our results with similar previous studies the effects of particular plant species appear to vary. We also found that more productive plant species affected bacterial-feeding nematodes more than fungal feeders. Moreover, we observed stronger effects the fewer the number of trophic links there were between a nematode feeding group and plants. Although we found clear effects of plants on soil nematodes, these were probably not large enough to result in strong and persistent plant-soil-organism-plant feedback loops.

Walker, B., C. Holling, S. Carpenter and A. Kinzig (2004). "Resilience, adaptability and transformability in social--ecological systems." Ecology and Society **9**(2): 5.

Category: Ecosystem services

Keywords: *Resilience, adaptative cycles, cross-scale effects, adaptability, transformability*

Abstract: The concept of resilience has evolved considerably since Holling's (1973) seminal paper. Different interpretations of what is meant by resilience, however, cause confusion. Resilience of a system needs to be considered in terms of the attributes that govern the system's dynamics. Three related attributes of social–ecological systems (SESs) determine their future trajectories: resilience, adaptability, and transformability. Resilience (the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks) has four components—latitude, resistance, precariousness, and panarchy—most readily portrayed using the metaphor of a stability landscape. Adaptability is the capacity of actors in the system to influence resilience (in a SES, essentially to manage it). There are four general ways in which this can be done, corresponding to the four aspects of resilience. Transformability is the capacity to create a fundamentally new system when ecological, economic, or social structures make the existing system untenable.

The implications of this interpretation of SES dynamics for sustainability science include changing the focus from seeking optimal states and the determinants of maximum sustainable yield (the MSY paradigm), to resilience analysis, adaptive resource management, and adaptive governance.

Walker, B., A. Kinzig and J. Langridge (1999). "Plant attribute diversity, resilience, and ecosystem function: The nature and significance of dominant and minor species." Ecosystems **2**(2): 95-113.

Category: Ecosystem services

Keywords: *Ecosystem, function, diversity, redundancy, resilience*

Abstract: This study tested an hypothesis concerning patterns in species abundance in ecological communities. Why do the majority of species occur in low abundance, with just a few making up the bulk of the biomass? We propose that many of the minor species are analogues of the dominants in terms of the ecosystem functions they perform, but differ in terms of their capabilities to respond to environmental stresses and disturbance. They thereby confer resilience on the community with respect to ecosystem function. Under changing conditions, ecosystem function is maintained when dominants decline or are lost because functionally equivalent minor species are able to substitute for them. We have tested this hypothesis with respect to ecosystem functions relating to global change. In particular, we identified five plant functional attributes—height, biomass, specific leaf area, longevity, and leaf litter quality—that determine carbon and water fluxes. We assigned values for these functional attributes to each of the graminoid species in a lightly grazed site and in a heavily grazed site in an Australian rangeland. Our resilience proposition was cast in the form of three specific hypotheses in relation to expected similarities and dissimilarities between dominant and minor species, within and between sites. Functional similarity—or ecological distance—was determined as the euclidean distance between species in functional attribute space. The analyses provide evidence in support of the resilience hypothesis. Specifically, within the lightly grazed community, dominant species were functionally more dissimilar to one another, and functionally similar species more widely separated in abundance rank, than would be expected on the basis of average ecological distances in the community. Between communities, depending on the test used, two of three, or three of four minor species in the lightly grazed community that were predicted to increase in the heavily grazed community did in fact do so. Although there has been emphasis on the importance of functional diversity in supporting the flow of ecosystem goods and services, the evidence from this study indicates that functional similarity (between dominant and minor species, and among minor species) may be equally important in ensuring persistence (resilience) of ecosystem function under changing environmental conditions.

Wall, D. and R. Bardgett (2012). Soil ecology and ecosystem services, Oxford University Press.

Category: Ecosystem services

Keywords: *Soil biodiversity, soil functions, ecosystem services, bioindicators, microorganisms, fauna, environmental economy, long term observatories, soil nutrients/cycling*

Abstract: This multi-contributor, international volume synthesizes contributions from the world's leading soil scientists and ecologists, describing cutting-edge research that provides a basis for the maintenance of soil health and sustainability. The book covers these advances from a unique perspective of examining the

ecosystem services produced by soil biota across different scales - from biotic interactions at microscales to communities functioning at regional and global scales. The book leads the user towards an understanding of how the sustainability of soils, biodiversity, and ecosystem services can be maintained and how humans, other animals, and ecosystems are dependent on living soils and ecosystem services.

Wallimann, I. (2013). Environmental policy is social policy--social policy is environmental policy: Toward sustainability policy. New York, Springer.
Category: Policy
Keywords: *Sustainable development, physical planning, regional planning, environmental legislation, environmental policy, environment*

Abstract: If sustainability is our goal, social and environmental policy must be treated as one and the same field. Examples from Agriculture, Nutrition, Forestry, Urban Planning, Care Work, Tourism, and University Management show that such a paradigm shift is indicated, important, and timely. They also show that Environmental or Social Impact Assessments are no longer adequate. The new paradigm synthetically combines environmental and social policy. Not to do so leads to policy inefficiency and perverse effects. One policy domain may counteract or outright "sabotage" the other. To synthetically combine environmental and social policy calls for a trans-disciplinary perspective to include both policy fields and academic disciplines. This is well illustrated by the contributors in this book who represent numerous academic disciplines. They help professionals and students appreciate the centrality of trans-disciplinary thought and practice in working toward sustainability.

Wardle, D. (2006). "The influence of biotic interactions on soil biodiversity." Ecology Letters **9**(7): 870-886.
Category: Ecosystem services
Keywords: *Aboveground, belowground, biodiversity, competition, ecosystem functioning, herbivory, plant litter, predation, soil, soil nutrients/cycling, pest regulation*

Abstract: Belowground communities usually support a much greater diversity of organisms than do corresponding aboveground ones, and while the factors that regulate their diversity are far less well understood, a growing number of recent studies have presented data relevant to understanding how these factors operate. This review considers how biotic factors influence community diversity within major groups of soil organisms across a broad spectrum of spatial scales, and addresses the mechanisms involved. At the most local scale, soil biodiversity may potentially be affected by interactions within trophic levels or by direct trophic interactions. Within the soil, larger bodied invertebrates can also influence diversity of smaller sized organisms by promoting dispersal and through modification of the soil habitat. At larger scales, individual plant species effects, vegetation composition, plant species diversity, mixing of plant litter types, and aboveground trophic interactions, all impact on soil biodiversity. Further, at the landscape scale, soil diversity also responds to vegetation change and succession. This review also considers how a conceptual understanding of the biotic drivers of soil biodiversity may assist our

knowledge of key topics in community and ecosystem ecology, such as aboveground-belowground interactions, and the relationship between biodiversity and ecosystem functioning. It is concluded that an improved understanding of what drives the diversity of life in the soil, incorporated within appropriate conceptual frameworks, should significantly aid our understanding of the structure and functioning of terrestrial communities.

Wardle, D., R. Bardgett, R. Callaway and W. Van der Putten (2011). "Terrestrial ecosystem responses to species gains and losses." Science **332**(6035): 1273-1277.
Category: Ecosystem services
Keywords: *Introduced species, anthropogenic factor, species, loss, gain, terrestrial environment, ecosystem functioning, soil nutrients/cycling*

Abstract: Ecosystems worldwide are losing some species and gaining others, resulting in an interchange of species that is having profound impacts on how these ecosystems function. However, research on the effects of species gains and losses has developed largely independently of one another. Recent conceptual advances regarding effects of species gain have arisen from studies that have unraveled the mechanistic basis of how invading species with novel traits alter biotic interactions and ecosystem processes. In contrast, studies on traits associated with species loss are fewer, and much remains unknown about how traits that predispose species to extinction affect ecological processes. Species gains and losses are both consequences and drivers of global change; thus, explicit integration of research on how both processes simultaneously affect ecosystem functioning is key to determining the response of the Earth system to current and future human activities.

Wardle, D., R. Bardgett, J. Klironomos, H. Setala, W. van der Putten and D. Wall (2004). "Ecological linkages between aboveground and belowground biota." Science **304**(5677): 1629-1633.
Category: Ecosystem services
Keywords: *Belowground, aboveground, biota, community, ecological, linkage, linkage between, ecosystem, soil, driver, biodiversity, soil organism, human-induced, influence community, terrestrial ecosystem, soil nutrients/cycling, pest regulation*

Abstract: All terrestrial ecosystems consist of aboveground and belowground components that interact to influence community- and ecosystem-level processes and properties. Here we show how these components are closely interlinked at the community level, reinforced by a greater degree of specificity between plants and soil organisms than has been previously supposed. As such, aboveground and belowground communities can be powerful mutual drivers, with both positive and negative feedbacks. A combined aboveground-belowground approach to community and ecosystem ecology is enhancing our understanding of the regulation and functional significance of biodiversity and of the environmental impacts of human-induced global change phenomena.

Welbaum, G. E., A. V. Sturz, Z. Dong and J. Nowak (2004). "Managing soil microorganisms to improve productivity of agro-ecosystems." Critical Reviews in Plant Sciences **23**(2): 175-193.
Category: Agroecology and agroecological practices
Keywords: *Soil microbial communities, diversity, management, plant-microbial interaction, feeding microbes, soil nutrients/cycling*

Abstract: Historically, agricultural production has relied on practices designed to manage nutrients, water, weeds, and crop diseases. Precision agriculture and integrated pest management programs have gone one step further by recognizing the need to target inputs where they are required in the field. The major objective of these programs has been to minimize adverse environmental impacts of intensive agriculture practices and reduce per unit production costs. This review surveys the literature, examining the manipulation of microbial (primarily bacterial) populations as linked to agricultural production, and discusses new approaches that involve the precision management of microorganisms in the agro-ecosystem. It is proposed that our understanding of plant–soil interactions can be greatly refined through the development of "smart" field technology, where real-time, computer-controlled electronic diagnostic devices can be used to monitor rhizosphere and plant health. We submit that "smart field" generated information could be used to develop a prescription for timely and low-level production interventions that will avoid the traditional inundative approaches to crop maintenance and soil husbandry. Consequently, a lesser impact on the agricultural soil environment is envisioned. The maximization of production efficiencies will also involve the development of crop cultivars that are bred specifically to capitalize on beneficial plant–microbial associations.

Westphal, C., I. Steffan-Dewenter and T. Tscharntke (2003). "Mass flowering crops enhance pollinator densities at a landscape scale." Ecology Letters **6**(11): 961-965.
Category: Ecosystem services
Keywords: *Agri-environment schemes, Bombus spp, bumblebees, conservation measures, foraging habitats, landscape structure, landscape-scale study, mass flowering crops, nesting sites, pollination*

Abstract: To counteract the decline of pollinators in Europe, conservation strategies traditionally focus on enhancing the local availability of semi-natural habitats, as supported by the European Union's Common Agriculture Policy. In contrast, we show that densities of bumblebees, an important pollinator group in agroecosystems, were not determined by the proportion of semi-natural habitats in agricultural landscapes. Instead, bumblebee densities were positively related to the availability of highly rewarding mass flowering crops (i.e. oilseed rape) in the landscape. In addition, mass flowering crops were only effective determinants of bumblebee densities when grown extensively at the landscape scale, but not at smaller local scales. Therefore, future conservation measures should consider the importance of mass flowering crops and the need for management schemes at landscape level to sustain vital pollination services in agroecosystems.

Westra, L., P. Taylor and A. Michelot (2013). Confronting ecological and economic collapse:

Ecological integrity for law, policy and human rights, Routledge.
Category: Policy
Keywords: *Environmental law, ecological integrity, climatic changes, financial crises, economic forecasting, international economic relations, human beings*

Abstract: From the first appearance of the term in law in the Clean Water Act of 1972 (US), ecological integrity has been debated by a wide range of researchers, including biologists, ecologists, philosophers, legal scholars, doctors and epidemiologists, whose joint interest was the study and understanding of ecological/biological integrity from various standpoints and disciplines. This volume discusses the need for ecological integrity as a major guiding principle in a variety of policy areas, to counter the present ecological and economic crises with their multiple effects on human rights.

The book celebrates the 20th anniversary of the Global Ecological Integrity Group and reassesses the basic concept of ecological integrity in order to show how a future beyond catastrophe and disaster is in fact possible, but only if civil society and ultimately legal regimes acknowledge the necessity to consider ecointegrity as a primary factor in decision-making. This is key to the support of basic rights to clean air and water, for halting climate change, and also the basic rights of women and indigenous people. As the authors clearly show, all these rights ultimately depend upon accepting policies that acknowledge the pivotal role of ecological integrity.

Wezel, A., S. Bellon, T. Doré, C. Francis, D. Vallod and C. David (2011). Agroecology as a science, a movement and a practice. Sustainable Agriculture, Springer Netherlands. **2:** 27-43.
Category: Agroecology and agroecological practices
Keywords: *Agroecosystem, Agronomy, Ecology, Food system, Rural development, Scientific discipline, Sustainable agriculture, Systems approach*

Abstract: Agroecology involves various approaches to solve actual challenges of agricultural production. Though agroecology initially dealt primarily with crop production and protection aspects, in recent decades new dimensions such as environmental, social, economic, ethical and development issues are becoming relevant. Today, the term 'agroecology' means either a scientific discipline, agricultural practice, or political or social movement. Here we study the different meanings of agroecology. For that we analyse the historical development of agroecology. We present examples from USA, Brazil, Germany, and France. We study and discuss the evolution of different meanings agroecology. The use of the term agroecology can be traced back to the 1930s. Until the 1960s agroecology referred only as a purely scientific discipline. Then, different branches of agroecology developed. Following environmental movements in the 1960s that went against industrial agriculture, agroecology evolved and fostered agroecological movements in the 1990s. Agroecology as an agricultural practice emerged in the 1980s, and was often intertwined with movements. Further, the scales and dimensions of agroecological investigations changed over the past 80 years from the plot and field scales to the farm and agroecosystem scales. Actually three approaches persist: (1) investigations at plot and field scales, (2) investigations at the agroecosystem and farm scales, and (3) investigations covering the whole food system. These different

approaches of agroecological science can be explained by the history of nations. In France, agroecology was mainly understood as a farming practice and to certain extent as a movement, whereas the corresponding scientific discipline was agronomy. In Germany, agroecology has a long tradition as a scientific discipline. In the USA and in Brazil all three interpretations of agroecology occur, albeit with a predominance of agroecology as a science in the USA and a stronger emphasis on movement and agricultural practice in Brazil. These varied meanings of the term agroecology cause confusion among scientists and the public, and we recommend that those who publish using this term be explicit in their interpretation.

Wezel, A., M. Casagrande, F. Celette, J. F. Vian, A. Ferrer and J. Peigné (2013). "Agroecological practices for sustainable agriculture. A review." Agronomy for Sustainable Development **2013**: 1-16.

Category: Ecosystem services

Keywords: *agroecology, diversification of cropping system, efficiency increase, substitution, systems redesign*

Abstract: The forecasted 9.1 billion population in 2050 will require an increase in food production for an additional two billion people. There is thus an active debate on new farming practices that could produce more food in a sustainable way. Here, we list agroecological cropping practices in temperate areas. We classify practices according to efficiency, substitution, and redesign. We analyse their advantages and drawbacks with emphasis on diversification. We evaluate the potential use of the practices for future agriculture. Our major findings are: (1) we distinguish 15 categories of agroecological practices (7 practices involve increasing efficiency or substitution, and 8 practices need a redesign often based on diversification). (2) The following agroecological practices are so far poorly integrated in actual agriculture: biofertilisers; natural pesticides; crop choice and rotations; intercropping and relay intercropping; agroforestry with timber, fruit, or nut trees; allelopathic plants; direct seeding into living cover crops or mulch; and integration of semi-natural landscape elements at field and farm or their management at landscape scale. These agroecological practices have only a moderate potential to be broadly implemented in the next decade. (3) By contrast, the following practices are already well integrated: organic fertilisation, split fertilisation, reduced tillage, drip irrigation, biological pest control, and cultivar choice.

Wiens, J., J. Fargione and J. Hill (2011). "Biofuels and biodiversity." Ecological applications **21**(4): 1085-1095.

Category: Agriculture-induced impacts

Keywords: *Biodiversity, biofuels, Conservation Reserve Program, corn ethanol, Henslow's Sparrow, land use*

Abstract: The recent increase in liquid biofuel production has stemmed from a desire to reduce dependence on foreign oil, mitigate rising energy prices, promote rural economic development, and reduce greenhouse gas emissions. The growth of this industry has important implications for biodiversity, the effects of which depend largely on which biofuel feedstocks are being grown and the spatial extent and

landscape pattern of land requirements for growing these feedstocks.

Current biofuel production occurs largely on croplands that have long been in agricultural production. The additional land area required for future biofuels production can be met in part by reclaiming reserve or abandoned croplands and by extending cropping into lands formerly deemed marginal for agriculture. In the United States, many such marginal lands have been enrolled in the Conservation Reserve Program (CRP), providing important habitat for grassland species. The demand for corn ethanol has changed agricultural commodity economics dramatically, already contributing to loss of CRP lands as contracts expire and lands are returned to agricultural production.

Nevertheless, there are ways in which biofuels can be developed to enhance their coexistence with biodiversity. Landscape heterogeneity can be improved by interspersion of land uses, which is easier around facilities with smaller or more varied feedstock demands. The development of biofuel feedstocks that yield high net energy returns with minimal carbon debts or that do not require additional land for production, such as residues and wastes, should be encouraged. Competing land uses, including both biofuel production and biodiversity protection, should be subjected to comprehensive cost–benefit analysis, so that incentives can be directed where they will do the most good.

Willemen, L., E. Drakou, M. Dunbar, P. Mayaux and B. Egoh (2013). "Safeguarding ecosystem services and livelihoods: Understanding the impact of conservation strategies on benefit flows to society." Ecosystem Services **4**(0): 95-103.

Category: Farmer and societal benefits

Keywords: *Protected area, Democratic Republic of Congo, GIS, Ecosystem Service Partnership*

Abstract: Society has always benefited from ecosystems through the provision of ecosystem services. To ensure a continuous flow of these benefits, different strategies aimed at safeguarding ecosystem services are proposed. In this paper we explore how biodiversity conservation measures, particularly protected areas, influence the flow of ecosystem services to different members of society. We highlight the impact of these measures on the poorer members of society because of their strong dependence on ecosystem services to sustain their livelihood. For the Democratic Republic of Congo we mapped five ecosystem services (food production, tourism, carbon, timber and fuel wood production) using spatial landscape indicators, within and outside protected areas, and identified their direct beneficiaries. This illustration was used to feed a round-table discussion on the impact of different conservation strategies on society, held with ecosystem services professionals during the 4th Ecosystem Service Partnership Conference in the Netherlands. The discussion highlighted the need for spatial methods to assess ecosystem service trade-offs, as well as the main challenges for conservation measures to contribute to both livelihood improvement and conservation gains. We argue that, ecosystem services maps can play a crucial role in understanding and managing the trade-offs in ecosystem service flows resulting from conservation strategies.

Williams, N., E. Crone, T. Roulston, R. Minckley, L. Packer and S. Potts (2010). "Ecological and life-history traits predict bee species responses to environmental disturbances." Biological Conservation **143**(10): 2280-2291.

Category: Agriculture-induced impacts

Keywords: *Anthropogenic disturbance, bees, functional traits, landscape change, life-history response guilds, pollination*

Abstract: The ability to predict the responses of ecological communities and individual species to human-induced environmental change remains a key issue for ecologists and conservation managers alike. Responses are often variable among species within groups making general predictions difficult. One option is to include ecological trait information that might help to disentangle patterns of response and also provide greater understanding of how particular traits link whole clades to their environment. Although this ''trait-guild" approach has been used for single disturbances, the importance of particular traits on general responses to multiple disturbances has not been explored. We used a mixed model analysis of 19 data sets from throughout the world to test the effect of ecological and life-history traits on the responses of bee species to different types of anthropogenic environmental change. These changes included habitat loss, fragmentation, agricultural intensification, pesticides and fire. Individual traits significantly affected bee species responses to different disturbances and several traits were broadly predictive among multiple disturbances. The location of nests – above vs. below ground – significantly affected response to habitat loss agricultural intensification, tillage regime (within agriculture) and fire. Species that nested above ground were on average more negatively affected by isolation from natural habitat and intensive agricultural land use than were species nesting below ground. In contrast below-ground-nesting species were more negatively affected by tilling than were above-ground nesters. The response of different nesting guilds to fire depended on the time since the burn. Social bee species were more strongly affected by isolation from natural habitat and pesticides than were solitary bee species. Surprisingly, body size did not consistently affect species responses, despite its importance in determining many aspects of individuals' interaction with their environment. Although synergistic interactions among traits remain to be explored, individual traits can be useful in predicting and understanding responses of related species to global change.

Winqvist, C., J. Bengtsson, T. Aavik, F. Berendse, L. W. Clement, S. Eggers, C. Fischer, A. Flohre, F. Geiger, J. Liira, T. Pärt, C. Thies, T. Tscharntke, W. W. Weisser and R. Bommarco (2011). "Mixed effects of organic farming and landscape complexity on farmland biodiversity and biological control potential across Europe." Journal of applied ecology **48**(3): 570-579.

Category: Ecosystem services; Policy

Keywords: *Agricultural intensification, agri-environment schemes, biological control, ecosystem services, landscape homogenization, species richness, pest regulation*

Abstract:

1. Organic farming in Europe has been shown to enhance biodiversity locally, but potential interactions with the surrounding landscape and the potential effects on

ecosystem services are less well known.

2. In cereal fields on 153 farms in five European regions, we examined how the species richness and abundance of wild plants, ground beetles and breeding birds, and the biological control potential of the area, were affected by organic and conventional farming, and how these effects were modified by landscape complexity (percentage of arable crops within 1000 m of the study plots). Information on biodiversity was gathered from vegetation plots, pitfall traps and by bird territory mapping. The biological control potential was measured as the percentage of glued, live aphids removed from plastic labels exposed in cereal fields for 24 h.

3. Predation on aphids was highest in organic fields in complex landscapes, and declined with increasing landscape homogeneity. The biological control potential in conventional fields was not affected by landscape complexity, and in homogenous landscapes it was higher in conventional fields than in organic fields, as indicated by an interaction between farming practice and landscape complexity.

4. A simplification of the landscape, from 20% to 100% arable land, reduced plant species richness by about 16% and cover by 14% in organic fields, and 33% and 5·5% in conventional fields. For birds, landscape simplification reduced species richness and abundance by 34% and 32% in organic fields and by 45·5% and 39% in conventional fields. Ground beetles were more abundant in simple landscapes, but were unaffected by farming practice.

5. Synthesis and applications. This Europe-wide study shows that organic farming enhanced the biodiversity of plants and birds in all landscapes, but only improved the potential for biological control in heterogeneous landscapes. These mixed results stress the importance of taking both local management and regional landscape complexity into consideration when developing future agri-environment schemes, and suggest that local-regional interactions may affect other ecosystem services and functions. This study also shows that it is not enough to design and monitor agri-environment schemes on the basis of biodiversity, but that ecosystem services should be considered too.

Wood, S., K. Sebastian and S. Scherr (2001). Pilot analysis of global ecosystems: agroecosystems. Washington, DC, International Food Policy Research Institute and World Resources Institute.

Category: Ecosystem services

Keywords: *Millennium Ecosystem Assessment, agricultural Intensification, agricultural land use changes, food, feed, fiber, soil, water services, biodiversity, carbon services*

Abstract: This study analyzes quantitative and qualitative information and develops selected indicators of the condition of the world's agroecosystems. We assess condition in terms of the delivery of a number of key goods and services valued by society: food, feed and fiber; water services; biodiversity; and carbon storage. We also attempt to assess pressures on, and current state of the underlying natural resource base. To this end we include an additional section dealing with soil resource condition, both as a determinant of agroecosystem capacity to produce goods and services and as a consequence of agroecosystem management practices.

Wratten, S., M. Gillespie, A. Decourtye, E. Mader and N. Desneux (2012). "Pollinator habitat enhancement: Benefits to other ecosystem services." Agriculture, Ecosystems & Environment **159**(0): 112-122.

Category: Ecosystem services; Farmer and societal benefits

Keywords: *Ecosystem service enhancement, economics, aesthetic services, weeds, soil and water quality, conservation, biological control, pollinator decline, agricultural landscapes, bee habitat, environmental policy, pollination*

Abstract: A range of policy initiatives have been promoted in recent years to address the decline of bee populations in Europe and North America. Among these has been the establishment of flower-rich habitat within or around intensively farmed landscapes to increase the availability of pollen and nectar resources. The composition of these habitats depends on location and compatibility with adjacent cropping systems, but they often consist of fields planted with temporary flowering cover crops, field borders with peren-nial or annual flowering species, hedgerows comprising prolifically flowering shrubs, and grass buffer strips (used to manage erosion and nutrient runoff) which are supplemented with dicotyledonous flower species. While the primary objective of such measures is to increase the ecological fitness of pollinator populations through enhanced larval and adult nutrition, such strategies also provide secondary bene-fits to the farm and the surrounding landscape. Specifically, the conservation of pollinator habitat can enhance overall biodiversity and the ecosystem services it provides (including pest population reduc-tion), protect soil and water quality by mitigating runoff and protecting against soil erosion, and enhance rural aesthetics. Incorporating these secondary benefits into decision making processes is likely to help stakeholders to assess the trade-offs implicit in supplying ecosystem services.

Wurtenberger, L., T. Koellner and C. Binder (2006). "Virtual land use and agricultural trade: Estimating environmental and socio-economic impacts." Ecological Economics **57**(4): 679-697.

Category: Policy, Agriculture-induced impacts

Keywords: *Virtual land use, agricultural trade, sustainability, developing countries, impact assessment*

Abstract: Liberalization has caused an increase in the global trade of goods and services. In particular, the value and physical volume of agricultural goods traded have largely increased. As the environmental and social consequences of trade are complex, they are rarely included in the national and international agricultural policies. One reason is that there is a lack of concepts and methods for assessing the environmental and social impacts of trade policies. In this paper we develop a method for quantifying and assessing the land use hidden in the export and import of agricultural goods for the case of Switzerland. For our analysis we focus on arable crops. The first methodological step of our research illustrates the spatial relationship of Switzerland with countries all over the world through the import and export of land use for arable crops. The second step links this spatial dimension with a qualitative assessment of the environmental and socio-economic impacts of agricultural land use. We applied the method to the case of wheat cultivation within Switzerland and import to Switzerland. The major problem we were confronted with

was the availability of data, which had both to be reliable and available for the countries wheat is imported from. The results show that the calculation of land use is credible. In spite of the problems related with data availability, the assessment results for each indicator are in agreement with the current situation in the respective countries. In addition, the aggregation seems to accurately reflect the countries' agricultural polices. The developed method is used to estimate the overall environmental and socio-economic impacts of an increase in wheat imports to Switzerland. We argue that this method could be applied for anticipating potential impacts of trade agreements. Still, further research is required for fine-tuning of the utility functions, including a weighting procedure in the aggregation procedure. For practical applications important aspects like water shortage should enlarge our limited set of indicators. In addition the average impact on a country level was assessed. To refine that, different agricultural systems ranging from intensive to extensive to organic should be considered. Beyond our scope was to analyze impacts due to other life cycle stages than the agricultural production. For informed decision, however, information on the whole life cycle of agricultural products is required.

Xu, W. and J. A. Mage (2001). "A review of concepts and criteria for assessing agroecosystem health including a preliminary case study of southern Ontario." Agriculture, Ecosystems & Environment **83**(3): 215-233.

Category: Agriculture-induced impacts

Keywords: *Agroecosystem, agroecosystem health, agroecosystem health assessment, agroecosystem health criteria, agricultural land use*

Abstract: The model of agroecosystem health has been advocated as an appealing guideline for agricultural research. Yet, some ambiguity remains in how the concept can be defined and how the general criteria for assessing the health of an agroecosystem at a particular scale can be selected. This paper reviews the literature from various disciplines pertinent to the concept of agroecosystem health. It focuses on assessing the applicability of assorted concepts, norms, and criteria to agroecosystem health assessment, and develops a general definition of agroecosystem health. A classification scheme is proposed which scattered while potentially useful concepts in the literature are discussed, using southern Ontario as a case study to further illustrate the usefulness of the conceptual framework in studying agroecosystem health. Agroecosystem health can be characterized from four different perspectives that are related to agroecosystem structure, function, organization, and dynamics. Given the complexity of agroecosystems. the health of the systems at different scales cannot be fully captured from one perspective only. Criteria, such as resource availability, diversity, and accessibility, are some of the existing concepts capable of depicting the structural state of agroecosystem health. Concepts including productivity, efficiency. and effectiveness appear very useful for assessing the functional performance of agroecosystems. As any agroecosystem interacts actively with its external environments and changes over timer such characteristics are not necessarily captured by structural or functional criteria. Organizational criteria, such as autonomy and self-dependence, are useful to characterize the organizational nature inherent to agroecosystem health. Stability

and resilience on the other hand are two appealing concepts capable of revealing the temporal dimension of agroecosystem health. Numerous empirical studies that are used to illustrate how these concepts developed in different disciplines of agricultural research can be potentially employed to facilitate the assessment of agroecosystem health. It is argued that any holistic investigation of the health of an agroecosystem needs to examine biophysical. economic, and human conditions of the system and to evaluate these conditions from perspectives pertinent to system structure. function, organization. and dynamics.

Yachi, S. and M. Loreau (1999). "Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis." Proceedings of the National Academy of Sciences **96**(4): 1463-1468.

Category: Ecosystem services

Keywords: *Stochastic dynamic model, species richness, ecosystem processes, temporal variability, ecosystem stability*

Abstract: Although the effect of biodiversity on ecosystem functioning has become a major focus in ecology, its significance in a fluctuating environment is still poorly understood. According to the insurance hypothesis, biodiversity insures ecosystems against declines in their functioning because many species provide greater guarantees that some will maintain functioning even if others fail. Here we examine this hypothesis theoretically. We develop a general stochastic dynamic model to assess the effects of species richness on the expected temporal mean and variance of ecosystem processes such as productivity, based on individual species' productivity responses to environmental fluctuations. Our model shows two major insurance effects of species richness on ecosystem productivity: (i) a buffering effect, i.e., a reduction in the temporal variance of productivity, and (ii) a performance-enhancing effect, i.e., an increase in the temporal mean of productivity. The strength of these insurance effects is determined by three factors: (i) the way ecosystem productivity is determined by individual species responses to environmental fluctuations, (ii) the degree of asynchronicity of these responses, and (iii) the detailed form of these responses. In particular, the greater the variance of the species responses, the lower the species richness at which the temporal mean of the ecosystem process saturates and the ecosystem becomes redundant. These results provide a strong theoretical foundation for the insurance hypothesis, which proves to be a fundamental principle for understanding the long-term effects of biodiversity on ecosystem processes.

Yergeau, E., T. Bezemer, K. Hedlund, S. Mortimer, G. Kowalchuk and W. Van Der Putten (2010). "Influences of space, soil, nematodes and plants on microbial community composition of chalk grassland soils." Environmental Microbiology **12**(8): 2096-2106.

Category: Ecosystem services

Keywords: *Soil, grassland, nematodes, plants, soil nutrients/cycling*

Abstract: Microbial communities respond to a variety of environmental factors related to resources (e.g. plant and soil organic matter), habitat (e.g. soil characteristics) and predation (e.g. nematodes, protozoa and viruses). However, the

relative contribution of these factors on microbial community composition is poorly understood. Here, we sampled soils from 30 chalk grassland fields located in three different chalk hill ridges of Southern England, using a spatially explicit sampling scheme. We assessed microbial communities via phospholipid fatty acid (PLFA) analyses and PCR-denaturing gradient gel electrophoresis (DGGE) and measured soil characteristics, as well as nematode and plant community composition. The relative influences of space, soil, vegetation and nematodes on soil microorganisms were contrasted using variation partitioning and path analysis. Results indicate that soil characteristics and plant community composition, representing habitat and resources, shape soil microbial community composition, whereas the influence of nematodes, a potential predation factor, appears to be relatively small. Spatial variation in microbial community structure was detected at broad (between fields) and fine (within fields) scales, suggesting that microbial communities exhibit biogeographic patterns at different scales. Although our analysis included several relevant explanatory data sets, a large part of the variation in microbial communities remained unexplained (up to 92% in some analyses). However, in several analyses, significant parts of the variation in microbial community structure could be explained. The results of this study contribute to our understanding of the relative importance of different environmental and spatial factors in driving the composition of soil-borne microbial communities.

Zeitoun, M. (2013). The justices and injustices of ecosystem services. London, Routledge.
Category: Policy; Farmer and societal benefits
Keywords: *Ecosystem services, social aspects, moral and ethical aspects, Government policy, justice*

Outline from Amazon.com: Humankind benefits from a multitude of resources and processes that are supplied by ecosystems, and collectively these benefits are known as ecosystem services. Interest in this topic has grown exponentially over the last decade, as biologists and economists have tried to quantify these benefits to justify management interventions. Yet, as this book demonstrates, the implications for justice and injustice have rarely been explored and works on environmental justice are only now addressing the importance of ecosystem services.

The authors establish important new middle ground in arguments between conservationists and critics of market-based interventions such as Payment for Ecosystem Services. Neither can environmental management be separated from justice concerns, as some conservationists like to believe, nor is it in fundamental opposition to justice, as critics like to put it. The book develops this novel interpretation of justice in environmental management through analyses of prominent governance interventions and the conceptual underpinnings of the ecosystem services framework. Key examples described are revenue-sharing around protected areas and REDD+ for forest ecosystems.

The analyses demonstrate that interventions create opportunities for enhancing social justice, yet also reveal critical design features that cause ostensibly technical interventions to generate injustices.

Zhang, W., T. H. Ricketts, C. Kremen, K. Carney and S. M. Swinton (2007). "Ecosystem services and dis-services to agriculture." Ecological Economics **64**(2): 253-260.

Category: Ecosystem services; Policy

Keywords: *Ecosystem services, agriculture, pollination, soil fertility, ecology, hydrology, environmental economics, environmental policy, pest regulation, soil nutrients/cycling*

Abstract: Agricultural ecosystems are actively managed by humans to optimize the provision of food, fiber, and fuel. These ecosystem services from agriculture, classified as provisioning services by the recent Millennium Ecosystem Assessment, depend in turn upon a web of supporting and regulating services as inputs to production (e.g., soil fertility and pollination). Agriculture also receives ecosystem dis-services that reduce productivity or increase production costs (e.g., herbivory and competition for water and nutrients by undesired species). The flows of these services and dis-services directly depend on how agricultural ecosystems are managed and upon the diversity, composition, and functioning of remaining natural ecosystems in the landscape. Managing agricultural landscapes to provide sufficient supporting and regulating ecosystem services and fewer dis-services will require research that is policy-relevant, multidisciplinary and collaborative. This paper focuses on how ecosystem services contribute to agricultural productivity and how ecosystem dis-services detract from it. We first describe the major services and dis-services as well as their key mediators. We then explore the importance of scale and economic externalities for the management of ecosystem service provision to agriculture. Finally, we discuss outstanding issues in regard to improving the management of ecosystem services and dis-services to agriculture.