MODULE 1:

WHY CLIMATE-SMART AGRICULTURE, FORESTRY AND FISHERIES

Overview

Agriculture has to address simultaneously three intertwined challenges: ensuring food security through increased productivity and income, adapting to climate change and contributing to climate change mitigation (FAO, 2010a; Foresight, 2011a; Beddington *et al.*., 2012a; Beddington *et al.*, 2012b; HLPE, 2012a). Addressing these challenges, exacerbating global pressure on natural resources, especially water, will require radical changes in our food systems. To address these three intertwined challenges, food systems have to become, at the same time, more efficient and resilient, at every scale from the farm to the global level. They have to become more efficient in resource use (use less land, water, and inputs to produce more food sustainably) and become more resilient to changes and shocks.

It is precisely to articulate these changes that FAO has forged the concept of climate-smart agriculture (CSA) as a way forward for food security in a changing climate. CSA aims to improve food security, help communities adapt to climate change and contribute to climate change mitigation by adopting appropriate practices, developing enabling policies and institutions and mobilizing needed finances.

This module gives an overview of climate smart agriculture, as an approach to address in an integrated way the interlinked challenges of food security and climate change. The first section describes the challenges to be addressed. It briefly recalls the current state of food insecurity and prospective of population and food demand growth. The main impacts of climate change on agriculture are summarized as well as the contribution of agriculture to global greenhouse gas emissions. The second section shows how two joint principles guide the necessary changes of systems: more efficiency in the use of resources, to increase production while reducing emissions intensity of the food produced and consumed and more resilience, to get prepared to variability and change. The third section briefly touches upon some of the issues to be addressed to implement climate-smart agriculture and progress towards efficient and resilient food systems. It requires comprehensive policies at every level, adequate institutions and proper governance to make the necessary choices. It also requires new financing to address the needs in terms of investments and research and to enable the farmers to overcome barriers to adoption of new practices including up-front costs and income foregone during the transition period. The last section articulates the concept of CSA closely linked issues of sustainable intensification, green growth and sustainable development.

Key messages

- Agriculture and food systems must undergo significant transformations in order to meet the related challenges of food security and climate change.
- Increasing resource efficiency is essential both to increase and ensure food security on the long term and to contribute to mitigate climate change.
- Building resilience to every type of risk is essential to be prepared for uncertainty and change.
- Efficiency and resilience have to be considered together, at every scale and from both environmental, economic and social perspectives.
- Implementing climate-smart agriculture can be a major driver of a Green Economy and a concrete way to operationalize sustainable development.
- Addressing food security and climate change requires concerted and coordinated involvement and action of all stakeholders on a long term perspective.
- Climate smart agriculture is not a new agricultural system, nor a set of practices. It is a new approach, a way to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change.

Contents

List of Figures

List of Boxes

1.1 Food security and climate change: three intertwined challenges[1]

Agriculture and food systems must improve and ensure food security, and to do so they need to adapt to climate change and natural resource pressures, and contribute to mitigating climate change. These challenges, being interconnected, have to be addressed simultaneously.

Ensuring food security

The world is producing enough food, but in 2010-2012 there were still almost 870 million people estimated to be undernourished, (FAO *et al.*, 2012). In addition, another billion people are malnourished, lacking essential micronutrients. The paradox is that at the same time a large number of people – mainly in richer countries - are over-eating, causing long-term health problems and that 60 percent of the malnourished actually are food producers, smallholders and pastoralists, with 20 percent living in cities and 20 percent landless rural people. For the poor producers, food is not only a basic need, it is the single, and often fragile, support they have for maintaining their livelihood. What is true at the household level is also true at the macroeconomic level. There are 32 countries, 20 of them in Africa, facing food crises and in need of international emergency support. In most of these countries, paradoxically, agriculture is an important, if not the major, part of economy.

The objective is to ensure food and nutrition security, worldwide. Ensuring availability of calories and sufficient global production is not enough; we also need to make sure that enough food is accessible to everyone, everywhere, physically and economically. In addition, we need to ensure that this food is properly utilized in the right quality and diversity. The goal is to ensure the stability of these three components of food and nutrition security: availability, access and utilization.

Between now and 2050, the world's population will increase by one-third. Most of the additional 2 billion people will live in developing countries. At the same time, more people will be living in cities (70 percent against the current 50 percent). Urbanization and rising incomes in developing countries are driving increases in the consumption of animal products (FAO, 2009a). Given these trends, FAO estimates that production will have to increase by 60 percent by 2050 to satisfy the expected demands for food and feed (Conforti, 2011). Demand for biofuels, another important factor for the global market, is very dependent on national policies and global demand is expected to grow. According to the OECD-FAO projections, because of increasing mandates and consumption incentives, biofuel production is expected to double between 2005 and 2019 (OECD and FAO, 2010).

Impacts of climate change on agriculture

Climate change has already significantly impacted agriculture (Lobell et al, 2011) and is expected to further impact directly and indirectly food production. Increase of mean temperature; changes in rain patterns; increased variability both in temperature and rain patterns; changes in water availability; the frequency and intensity of 'extreme events'; sea level rise and salinization; perturbations in ecosystems, all will have profound impacts on agriculture, forestry and fisheries (Gornall, 2010; IPCC, 2007a; Beddington, *et al,*. 2012b; HLPE, 2012a; Thornton *et al.,* 2012). The extent of these impacts will depend not only on the intensity and timing (periodicity) of the changes but also on their combination, which are more uncertain, and on local conditions. Anticipating appropriately the impacts of climate change on agriculture requires data, tools and models at the spatial scale of actual production areas. Since the last Intergovernmental Panel on Climate Change (IPCC) report in 2007, some studies have attempted to anticipate these impacts and provide projections at such a scale, enabling us to have a more concrete vision of projected changes.

[1] This section draws heavily on Meybeck A. Gitz V. Towards Efficiency & Resilience in Agriculture for Food Security in a Changing Climate presented at the OECD-KREI Expert Meeting on Green Growth and Agriculture and Food in Seoul, Korea 6-8 April 2011

A prospective study in Morocco (World Bank, 2009a) points to gradually increasing aridity due to reduced rainfall and higher temperatures, with negative effects on agricultural yields, especially from 2030 onwards. Rainfed crops are expected to be particularly affected. If irrigation water continues to be available in sufficient quantities, crop yields are expected to continue to increase in spite of climate change. However, availability of water for irrigation is uncertain. In this study, agricultural yields are projected to remain more or less stable up to 2030, but they are predicted to drop rather quickly beyond that date (see Module 3 on water management).

A study in Brazil (EMBRAPA, 2008) shows that climate change can have dramatic changes in the potentials for the various crops analysed and their geographic repartition. Globally, the increase of evapotranspiration leads to an increase of the areas at high climatic risk for 7 of the 9 crops studied (cotton, rice, coffee, beans, sunflower, millet, soybean) and a decrease for cassava and sugarcane. It will also cause important displacements in areas suitable for crops, especially for coffee and cassava. In traditional production areas, coffee would be affected by lack of water or high temperatures. In the States of São Paulo and Minas Gerais coffee would no longer be cultivated in areas where it is currently cultivated. On the other hand, with the reduction of the risk of frost, there could be an increase of the production area in Paraná, Santa Catarina and Rio Grande do Sul. As a result, the global area at low climatic risk for coffee would be reduced by 9.5 percent in 2020, 17 percent in 2050, and 33 percent in 2070. On the other hand, more favourable conditions for sugarcane will considerably increase the area of production.

The impacts of climate change will have major effects on agricultural production, with a decrease of production in certain areas and increased variability of production to the extent that important changes may need to be made in the geographic area where crops are cultivated. Local impacts will bring global imbalances. Broadly speaking, with everything else being equal, climate change may lead to an increase in both crop and livestock productivity in mid- to high latitudes (IPCC, 2007a) and a decrease in tropical and subtropical areas. Among the most affected areas are economically vulnerable countries already food insecure and some important food exporting countries. This will induce significant changes in trade, impacting prices and the situation of net food importing countries. Consequently, climate change is expected to increase the gap between developed and developing countries as a result of more severe impacts in already vulnerable developing regions, exacerbated by their relatively lower technical and economical capacity to respond to new threats (Padgham, 2009). Smallholders and pastoralists will suffer complex, localized impacts (IPCC, 2007a). According to the International Food Policy Research Institute (IFPRI) (Nelson *et al.* 2010), it will cause an increase of between 8.5 and 10.3 percent in the number of malnourished children in all developing countries, relative to scenarios without climate change.

The models used for such projections neither take into account the impacts of multiple stress induced by climate change, nor the impacts on the functioning of ecosystems, such as effects on pollinators (FAO, 2011a) and the balance between pests and their predators, nor impacts on animal diseases (FAO-OECD, 2012; HLPE, 2012 a).

It is likely that there will also be important effects on nutrition as a result of climate change. To date, studies mostly focus on cereals. There is a need to better capture all the nutritional consequences of the effects of climate change on livestock and on vegetables and wild foods, all of which have an important role in balanced diets and which are at risk (HLPE, 2012a; Bharucha and Pretty, 2010).

In terms of impacts, it is necessary to distinguish between increased variability and slow onset changes. The potential impacts of increased variability are often less emphasized than slow onset changes for a variety of reasons. This is because these impacts are less well known (HLPE 2012a) even though they will be felt first. The impacts of increased variability are situated between the much emphasized category of 'extreme events', and the much more 'easier to grasp' business as usual category of actual variability. What exactly is an 'extreme event'? What makes an event considered as "extreme"? Is it the intensity, the infrequency of a meteorological event? Or is it the extent and intensity of its consequences? For agriculture, a slight change in temperature at a critical stage of plant growing can compromise a crop. As changes in variability are easier for farmers to apprehend, they could constitute a first target for early adaptation measures (Padgham, 2009). It is therefore important to distinguish between these two categories of impacts to highlight two ways to adapt, each with different time ranges: increasing resilience now to be prepared for more variability, and increasing adaptive capacities and preparedness for slow onset changes. Furthermore, being prepared for increased variability is also a way to prepare for any other change, whatever it may be.

Agriculture's impact on climate change

The agriculture sector has to produce more food and it will be certainly impacted by climate change. As an integral part of the economy, it has also been called upon to contribute to mitigate climate change (UNFCCC 2008). The question is how and to what extent agriculture and food systems can contribute to climate change mitigation without compromising food and nutrition security.

In 2005, agriculture (crop and livestock) directly accounted for 13.5 percent of global GHG emissions (IPCC, 2007b). This figure is based on activities carried out in the fields and with livestock. But agriculture's role in climate change and, importantly, its mitigation potential, should be considered in a wider perspective of 'food systems'. This includes the impact these systems have on forests, the energy sector and transport. Expanding our consideration of agriculture's role in climate change is warranted because some of the on farm emissions are not included in the 13.5 percent figure, but are grouped in other sectors, such as electricity used in farm buildings and fuel used in farm equipment and food transport. Also, agriculture is a major driver of deforestation, which roughly accounts for an additional 17 percent of global GHG emissions (IPCC, 2007b). This is why agriculture is included in the study on the drivers of deforestation, which was requested by the UNFCCC's 17th Conference of the Parties (COP 17) in Cancun to the Subsidiary Body for Scientific and Technological Advice (SBSTA). Finally, within food systems, reductions of emissions in some areas could lead to increases elsewhere. For instance, depending on the efficiency of production systems, shorter food chains could reduce transport but increase agricultural emissions. Currently, there are no studies that quantify emissions from the global food system (Garnett, 2011). A study in 2006 estimated that 31 percent of the European Union's GHG emissions were associated with the food system (European Commission 2006). Therefore, when looking at challenges and opportunities to reduce GHG emissions using agriculture, it is paramount to look beyond the farm, vertically into the whole food chain and horizontally across impacted land-uses such as forests.

The main direct sources of GHG emissions in the agricultural sector are not only carbon dioxide (CO2). Agriculture is a source of nitrous oxide (N2O), accounting for 58 percent of total emissions, mostly by soils and through the application of fertilizers, and of methane (CH4), accounting for 47 percent of total emissions, essentially from livestock and rice cultivation. These emissions are dependent on natural processes and agricultural practices, which makes them more difficult to control and measure. On the other hand, agriculture is a key sector that, along with the forestry sector, if managed effectively. can lead to biological carbon capture and storage in biomass and soil, acting as "sinks". Their management can play an essential role in managing climate change (IPCC, 2007b), especially in the long term (Gitz, 2013).

As agricultural production is projected to increase in developing countries, so are agricultural emissions. IPCC estimates that N_2O emissions will increase by 35 - 60 percent by 2030 and CH_4 by 60 percent (IPCC, 2007b). The IPCC also projects additional land being converted to agriculture.

There are two ways by which agricultural production[2] can contribute to mitigate climate change that are in line with the 'food security first' objective. The first way is to improve efficiency by decoupling production growth from emissions growth. This involves reducing emissions per kilogram of food output (included in this calculation are the effects of emissions from reduced deforestation per kilogram of food). The second way is to

[2] A third way, (last section of the module) would be changes in consumption patterns, a subject that will not be touched upon in within this sourcebook

enhance soil carbon sinks. The IPCC estimates the global technical mitigation potential from agriculture could reach the equivalent of 5 500-6 000 tonnes of CO_2 per year by 2030 (IPCC, 2007b). This is grossly equivalent to three quarters of the sector's emissions in 2030 (around 8 200 tonnes of CO2). About 70 percent of this identified potential lies in developing countries, 20 percent in OECD countries, and 10 percent for EIT countries. IPCC estimates that nine-tenths of the global mitigation potential of agriculture is linked, not to reduction of agricultural GHG (mainly CH_4 and N_2O) emissions, but to managing land carbon stocks. This involves enhanced soil carbon sequestration, reduced tillage, improved grazing management, the restoration of organic soils and restoration of degraded lands.

Reducing emissions per kilogram of a given output[3] might well be, for food security and agriculture, one of the main targets. Direct gains through increased efficiency also imply a series of indirect gains. These indirect gains include reduced emissions from deforestation (not accounted in IPCC's calculations of the 90 percent) as less land is necessary to produce the same amount of food. Indirect gains also include reduced emissions from the production of fertilizer or energy inputs used on the farm. Everything else being equal, a potential reduction equivalent to 770 tonnes of CO_2 per year by 2030 has been identified from reduction of fossil fuel use through improved on-farm energy efficiency (IPCC, 2007b). In addition, there are potential reductions through improved efficiency in food chains, including a reduction of post-harvest losses.

1.2 Towards more efficient and resilient systems

To address these three intertwined challenges, food systems have to become at the same time more efficient and resilient, at every scale from the farm to the global food system. They have to become more efficient in resource use: use less land, water and inputs to produce more food sustainably, and be more resilient to changes and shocks.

More efficient systems

Increase resource efficiency

Most of the GHG emissions of the agricultural sector are directly driven by the use of resources: new land being deforested or turned from grassland to crop land, fertilizers, livestock, energy. Increasing efficiency in the use of resources (i.e. producing more of a given output using less of a given input) is thus key to reducing emissions intensity per kilog of output. It is also key to improve food security, especially in resource scarce areas.

Before looking at how resource efficiency in food systems can be improved (by what means), we need to have a common understanding of what efficiency "means".

Agriculture and food systems not only utilize a very diverse range of resources but also produce a very diverse range of outputs. They provide physical products but also income and employment, for farmers, in agro-industry and as a driver of the non-farm rural economy. From a food security perspective, these three outputs are equally important. It implies a more complex conception of resource efficiency, by which employment, which is formally an input in pure economic terms, can be seen as a key output. This conception implies a shift from the classical economic targets of labour productivity towards resource efficiency with labour intensity being possibly an asset, as a system can be judged superior to another if it uses an equal amount of natural resources but provides more employment (and not less work related costs), everything else being equal. Agriculture is also a producer of environmental services at the landscape level: for example, through improved soil management practices, agriculture can increase carbon stored in soils. Ultimately the output of agriculture can also be defined as human diets.

[3] Comparing different types of food is extremely difficult as they have very different nutritional value (not only energy or protein content but also composition and micronutrients).

The green economy is driven by the idea that, in the long run, given the increasing scarcity of resources, physical resource efficiency and economic efficiency will become closer, due to market fundamentals and through policies, which would factor in environmental and social externalities (positive and negative) of input use and production. Agriculture needs to produce more with resources (land, water, energy and nutrients) that are becoming scarcer and thus more expensive. However, given the relative prices of the various inputs, production factors and outputs, this is not an easy thing to achieve, especially in smallholder farming systems. Evidence shows that farmers economize in their use of inputs in reaction to increased prices (OECD, 2011). A study of how US farmers reacted to higher energy and fertilizer prices in 2006 (Harris et al, 2008) showed that 23 percent of commercial farms reduced their usage of both energy and fertilizers. To reduce energy consumption, they used machines less intensively and serviced engines more frequently. Lower usage of fertilizers was also achieved through greater use of soil testing, precision application and changes of crops.

Increasing efficiency in the use of resources is also one of the driving principles of CSA. GHG emissions from agriculture are linked to its use of resources. Three production factors have an important influence on total agricultural GHG emissions: (i) area, since converting land into cultivations would require either deforestation or grasslands being converted to croplands, which would induce higher CO2 emissions; (ii) fertilizers, whose production is an important source of CO_2 and which at the field level translate into nitrous oxide emissions; and (iii) livestock, which is an important source of methane and nitrous oxide emissions. Physical capital, such as buildings and machines are also a factor, both directly by energy use and indirectly by their production. Everything else being equal, increasing the efficiency in the use of one of these production factors decreases the emissions intensity of output. As irrigation often demands considerable energy, water efficiency is another key factor for increasing production, adapting to climate change and reducing emissions.

Resource efficiency needs to be improved in every type of food system. Studies using the results of detailed on farm energy audits realized in France have shown that energy consumption per kilogram of output can be extremely variable between farms. It has, for instance, been shown (Bochu et al, 2010) that the most efficient dairy farms consume per unit of output half of the energy consumed by the less efficient farms. Results of more than 400 farms have been analysed and categorized according to the importance of corn silage in the system (1-10 percent, 10-20 percent, 20-30 percent, more than 30 percent of the feed). It appears that variability within each of these categories is more important than between categories, and that in every category the more efficient farms use less than half of the energy used by the less efficient ones. This is also true in organic farms. This means that, no matter what the system, there can be important improvements in management practices.

Increase resource efficiency in plant production

As agriculture is an important driver of deforestation, reducing agricultural expansion through sustainable intensification on already cultivated land could have a major mitigation effect. The HLPE considers that ending most conversion of forest to cultivation should be a mitigation priority.

Studies show that, at the global level, from 1961 to 2005, crop production increased by over 160 percent, mostly as a result of 135 percent yield increases, with only 27 percent increases in crop area (Burney *et al.*, 2010). This intensification allowed farmers to increase food production while emitting the equivalent of 590 gigatons of CO_2 less than what would have been emitted by expanding the area under cultivation on the basis of assuming 1961 yields. They conclude that land use change emissions (even avoided ones) are much more important than direct emissions from agricultural systems. Therefore, improvement of crop yields should be prominent in any mitigation strategy. Moreover, these improvements will also contribute to preserving forest sinks and maintaining their capacity to store carbon over the long-term (Gitz and Ciais, 2004).

Other studies show that across the tropics, between 1980 and 2000, more than 55 percent of new agricultural land came at the expense of intact forests and another 28 percent came from disturbed forests (Gibbs *et al.*, 2010). Considering the role of agriculture as a driver of deforestation, sustainable intensification should also play a part in Reducing Emissions from Deforestation and Forest Degradation (REDD) programmes.

Sustainable intensification would be particularly efficient in areas where very low productivity systems, such as shifting cultivation in the Congo Basin, are replacing forests (Bellassen and Gitz, 2008). West *et al.* (2010), comparing worldwide crop yields and carbon stocks, consider that concentrating reforestation and avoided deforestation in the tropics would have the greatest worldwide carbon sink effect with minimum opportunity costs in terms of reduced crop yields.

Studies (Fischer *et al.*, 2009) have shown the importance in many developing countries of the yield gap. The yield gap is the difference between actual farm yields, as represented by the average yield achieved by farmers in a defined region over several seasons, and the potential yields which are the maximum achievable yield with latest varieties and by removing as much as possible all the constraints as achieved in highly controlled experimental stations. Reducing this gap is essential to improve food security and reduce deforestation.

Nutrients are essential to increase yields. But production of synthetic fertilizers is energy intensive, with high CO_2 emissions and economic costs. In addition, when applied in the field, these fertilizers contribute to N_2O emissions. Therefore, there is a need to improve fertilization and to limit the economic costs and the emissions at the same time. Improving fertilizer efficiency is thus essential. This can be done through a variety of techniques. One way is to match more precisely the nutrients with plant needs during the growing season, such as by fractioning the total amount in multiple doses. Other techniques include precision farming and placing nutrients closer to plant roots, such as deep placement of urea for rice (see box 1.1).

Box 1.1
Urea Deep Placement

Urea Deep Placement (UDP) technique, developed by the International Fertilizer Development Center (IFDC), is a good example of a climate-smart solution for rice systems. The usual technique for applying urea, the main nitrogen fertilizer for rice, is through a broadcast application. This is a very inefficient practice, with 60 to 70 percent nitrogen losses contributing to GHG emissions and water pollution.

In the UDP technique, urea is made into “briquettes” of 1 to 3 grams that are placed at 7 to 10 cm soil depth after the paddy is transplanted. This technique decreases nitrogen losses by 40 percent and increases urea efficiency to 50 percent. It increases yields by 25 percent with an average 25 percent decrease in urea use.

UDP has been actively promoted by the Bangladesh Department of Agricultural Extension with IFDC assistance. In 2009, UDP was used on half a million hectares by a million farmers and there are plans to expand its use to 2.9 million more families on 1.5 million hectares.

The widespread adoption of the UDP technique in Bangladesh has had several important impacts:

- Farmers’ incomes have increased because of both increased yields and reduced fertilizers use.
- Jobs have been created locally in small enterprises, often owned by women, to make the briquettes. There are now 2 500 briquette-making machines in Bangladesh.
- On-farm jobs have also been created as the briquettes are placed by hand, which requires 6 to 8 days labour per hectare. Higher yields and savings on fertilizer expenditures compensate for the additional field labour expenses.
- At the national level, imports of urea have been reduced, with savings in import costs estimated by IFDC at USD 22 million and in government subsidies of USD 14 million (2008), for an increase of production of 268 000 metric tons.
- At a global level UDP has reduced GHG emissions caused by the production and management of fertilizers.

It also increases the agricultural system’s resilience. As fertilizer prices are linked to energy prices, and consequently very volatile, reducing fertilizer use also increases farm and country’s resilience to economic shocks.

With the effectiveness of the technique now well proven, UDP is being scaled up, partly through South/South cooperation. For instance, the National Programme for Food Security of Nigeria (NPFS) is supported by South/South cooperation with China. This support includes the promotion and development of the UDP technique in several Nigerian states.

Source: Roy & Misra, 2003; Singh *et al.*, 2010; Ladha *et al.*, 2000; IFDC, 2011

The inclusion of legumes in crop rotations exploits symbiotic microbes to fix nitrogen, which is harvested in the crop and partly transferred to subsequent crops increasing their yields. In forage legume/grass mixtures, nitrogen is also transferred from legume to grass, increasing pasture production. The protein content of legumes makes them important from a nutritional point of view. When included in livestock feed, legumes increase the food conversion ratio and decrease methane emissions from ruminants, thus increasing efficiency and at the same time reducing GHG emissions. By providing proteins and the amino acid lysine, in which cereals are deficient, legumes complement cereals in human diets and can compensate for the lack of animal proteins. Unfortunately, the global area under pulses dropped from approximately 5 million hectares in 1968 to 3.9 million in 2007. Globally, consumption of pulses in terms of kilocalories per capita per day also dropped from 73 in 1968 to 57 in 2007.

Sustainable intensification of crop production (see box 2) aims to increase yields through the better use of natural resources and ecosystem functions.

Plant breeding has a crucial role to play to enhance genetic potential both to increase productivity and thus yields and to improve nutrient and water use as well as resistance to climate variability, diseases and pests.

Box 1.2
Save and Grow – More Sustainable Intensification

Sustainable crop production intensification (SCPI) can be summed up in the words "Save and Grow". Sustainable intensification means a productive agriculture that conserves and enhances natural resources. It uses an ecosystem approach that draws on nature's contribution to crop growth – soil organic matter, water flow regulation, pollination and natural predation of pests. It applies appropriate external inputs at the right time, in the right amount to improved crop varieties that are resilient to climate change. It also uses nutrients, water and external inputs more efficiently.

Increasing the sustainable intensification of crop production is achievable. This can be done through increasing resource use efficiency and cutting the use of fossil fuels. This saves money for farmers and prevents the negative effect of over-use of particular inputs. Inefficient fertilizer use is common in many regions. In some cases, this is a consequence of government subsidies. Yet over-use does not have the intended impact on plant growth and can result in the contamination of ground and surface water. Inappropriate insecticide use may actually induce pest outbreaks by disrupting the natural population of predators. Overuse of herbicides can lead to the emergence of herbicide-tolerant varieties of weeds. Problems of salinization or reduced soil health may also come from inappropriate management practices, such as irrigating without proper drainage. Better maintenance of ecosystem services can be accomplished through: adopting agricultural practices that are based on crop rotations, applying minimum tillage and maintaining soil cover; relying on natural processes of predation or biocontrol of pest or weed problems; managing pollination services; selecting diverse and appropriate varieties; and carefully targeting the use of external inputs. These practices are knowledge-intensive and they are often also interdependent. In the initial stages, encouraging these practices may require public support through targeted incentives and investment. Ideally, the price of agricultural commodities would increasingly reflect the full cost of production, including the potential damage done to natural ecosystems, thereby encouraging more sustainable consumption (FAO, 2011b).

Increase resource efficiency in livestock production

The livestock sector has expanded rapidly in recent decades and will continue to do so as demand for meat, eggs and dairy products is expected to continue to grow, especially in developing countries. Livestock grazing already occupies 26 percent of the earth's ice-free land surface, and the production of livestock feed uses 33 percent of agricultural cropland (Steinfeld *et al.*, 2006). There is an urgent need to improve the resource use and production efficiency of livestock production systems, both to improve food security and reduce the intensity of GHG emissions (FAO, 2009a; HLPE, 2012a). These efforts need to take into account the growing dichotomy between livestock kept by large numbers of small holders and pastoralists and those kept in intensive systems[4]. A study on cow milk (Gerber *et al.*, 2010) shows that the emissions per litre of milk are dependent on the efficiency of the cows: the more efficient the cows, the fewer emissions per litre of milk. This increased efficiency should be pursued in all possible ways, from livestock selection and nutrition to manure management.

The selection to improve efficiency and thus reduce GHG emission of livestock systems involves numerous parameters, including productivity per animal, early maturity, fertility, feed conversion ratio and longevity. In controlled environments, breeding for high performance has already resulted in significant reductions in the amount of feed per unit of product, especially for monogastrics and dairy cattle. The challenge now is to also improve productivity in more diverse environments (Hoffmann, 2010).

Improving animal health, including disease prevention and management, has a strong impact on the efficiency of livestock systems, food security and climate change. Establishing strong veterinary institutions and policies are essential both to improve livestock efficiency and increase the preparedness against new risks, including those that result from climate change.

Nutrition plays a critical role in making livestock production systems more efficient. Proper nutrition is imperative for achieving high reproductive efficiency in animals, protecting them from diseases and making animal health interventions more effective. Imbalanced feeding leads to productivity losses and increase in emission of green house gases, either as CH_4 from enteric fermentation in ruminants (between 2 - 12 percent of feed energy is lost in the form of methane) or as CH_4 and N_2O produced from manure. A balanced diet enhances animal performance and reduces GHG emissions per unit of animal product. Efficient nutritional strategies for monogastrics (pigs and chickens) include matching nutrient contents in feeds (taking into consideration both their level and availability to the animal) to the physiological requirements of animals; selecting feeds with high nitrogen availability in the animal body; and optimizing proteins and amino acids in diets to improve the feed conversion to animal products. For ruminants, techniques such as a) feeding of: diets balanced for nitrogen, energy and minerals - preferably as total mixed rations; chaffed forages, preferably of high quality; chaffed and water-soaked straws or urea-ammoniated straws; and grains- and b) use of feed additives, - e.g. ionophores, probiotics, enzymes, oils including essential oils, some tannins and saponins- can be used either to improve the feed conversion ratio and/or to specifically reduce methane emission and nitrogen release into manure.

Improving pasture productivity and quality, either by improving the composition of forage, especially in artificial pastures, and by better pasture management is an important means to improve food security, adapt to climate change and reduce both direct and indirect GHG emissions. Supplementing poor quality forages with fodder trees, as in silvo-pastoral systems, or with legumes, increases their digestibility, thereby improving the production efficiency of livestock and decreasing methane emissions. The introduction of legumes in pastures also increases forage production and reduces pressure on forests without a corresponding increased use of fertilizers. Improved grazing management could lead to greater forage production, more efficient use of land resources, enhanced profitability and rehabilitation of degraded lands and the restoration of ecosystem services. Grazing practices, such as setting aside, postponing grazing while forage species are growing, or ensuring equal grazing of various species can be used to stimulate diverse grasses; improve nutrient cycling and plant productivity and the development of healthy root systems; feed both livestock and soil biota; maintain plant cover at all times; and promote natural soil forming processes.

[4] Types of systems and size are not necessarily associated.

Box 1.3
Partnership on benchmarking and monitoring the environmental performance of livestock supply chains

Quantitative information on key environmental impacts along livestock supply chains is required to (a) analyse food systems and inform decisions at the production and processing levels to improve environmental performance; (b) develop and evaluate corresponding policy decisions (governmental and non-governmental); and (c) inform relevant stakeholders.

Valuable work aimed at improving the measurement of environmental performance is being carried out by the livestock industry, governments, academia and non-governmental organizations (NGOs). However, inconsistencies in the methods used and the one-off nature of many of the studies do not provide consistent guidance on the required changes in practices and the potential efficiency gains that can be achieved.

Consultations with stakeholders during 2010 and 2011 confirmed that there was demand for a partnership on benchmarking and monitoring the environmental performance of the livestock sector. A participative formulation process led to the identification of key functions and deliverables of the Partnership. It was agreed that representatives of private sector, NGOs, governments, science and international standard organizations should be involved.

The Partnership's objective is to improve environmental performance of the livestock sector, while considering its economic and social viability. This will be achieved through support to decision-making and by providing guidance on performance assessments (metrics and methods) and their use. The partnership was officially launched in July 2012. An important aspect of the work is to assess both negative and positive contributions (e.g. improved carbon sequestration in soils, soil organic matter, water retention and quality, and biodiversity) Activities are structured along four components:

- Component 1 - Sector-specific guidelines and methods for the life cycle assessment of GHG emissions from livestock food chains;
- Component 2 - Global database of GHG emissions related to feed crops;
- Component 3 - Measures of non-GHG environmental performance of livestock food chains; and
- Component 4 - Communication strategy.

Source: FAO, 2012e

Manure management is important both to increase food security and to mitigate climate change as it can be used as organic fertilizer and is also a source of CH_4 and N_2O emissions. When manure is used as organic fertilizer it contributes to the productivity and fertility of the soil by adding organic matter and nutrients, such as nitrogen, which are trapped by bacteria in the soil. It improves productivity and allows for reductions in use of synthetic fertilizers and the associated direct and indirect GHG emissions. The increasing geographic concentration of livestock production means that the manure produced by animals often exceeds the (nitrogen) absorptive capacity of the local area. Manure becomes a waste product rather than being the valuable resource in less concentrated, mixed production systems. Proper use of technologies can reduce direct emissions and also transform manure into a valuable resource and lead to a corresponding reduction in GHG emissions resulting from the use of synthetic fertilizers.

Integrated systems

Crop systems and livestock systems can also be improved by their better integration. Integrated crop and livestock systems, at various scales (on-farm and area-wide) increase the efficiency and environmental sustainability of both production methods. When livestock and crops are produced together, the waste of one is a resource for the other. Manure increases crop production and crop residues and by-products feed animals, improving their productivity. In these systems, livestock is a strategic element for adaptation. The animals provide an alternative to cropping in areas becoming marginal for cropping, offer a way to escape poverty and represent a coping mechanism in vulnerable and variable (in particular weather-related) natural environments. They also constitute a capital that can be converted to cash when needed.

Rice-Fish integrated systems have been traditionally practiced in many Asian countries, either as concurrent or alternate cultivation (FAO *et al*, 2001) and constitute another example of very productive systems that also provide more balanced diets. They hold great potential to improve food security and nutrition and can be both improved and up-scaled as shown by recent research in Bangladesh (Ahmed N. and Garnett S., 2011; Dey M *et al.*, 2012).

Agroforestry is the use of trees and shrubs as part of agricultural systems. It contributes to prevent soil erosion, facilitates water infiltration and diminishes the impacts of extreme weather. Agroforestry also helps diversify income sources and provides energy and often fodder for livestock. Nitrogen-fixing leguminous trees, such as Faidherbia albida, increase soil fertility and yields (Bames and Fagg, 2003; Garrity, 2010). Community-led projects and relaxed forestry measures that enable farmers to manage their trees have led to considerable development of Faidherbia in Niger through farmer-managed natural regeneration (Garrity 2010). Since 2000, FAO has initiated special programmes for food security with the governments of Guatemala, Honduras, Nicaragua and El Salvador among others (see box 6). These programmes work together, sharing practices, experiences and results to improve and develop agroforestry systems. Agroforestry systems are promoted in the subregion as a substitute to traditional slash-and-burn systems, particularly on slopes. Under these systems, productivity of land and labour are increased. Yields are less variable, partly due to better retention of moisture in the soils. The soil is also protected from hydric erosion. Farm production, including wood products, is more diversified, which stabilizes incomes. As they are more efficient in the use of land, agroforestry reduces the pressure on forests, avoiding deforestation which contributes to climate change mitigation. As wood is produced in the fields, these systems also contribute to preventing forest degradation. Agroforestry systems use less fertilizer, reducing the direct emissions of N_2O and indirect GHG emissions created through fertilizer production. By increasing biomass above ground and in soils, they help create carbon sinks.

There is now interest for using carbon projects to facilitate the development of agroforestry. Examples include the Nhambita community carbon project in Mozambique, initiated in 2003. A small-scale agroforestry-based carbon sequestration project, registered with the Plan Vivo system aims to sequester carbon through agroforestry practices, sell carbon credits in international voluntary carbon markets and improve livelihoods in the local community. The Community Association, the body established in 2002 by the Rural Association for Mutual Support (ORAM) as a part of a national government programme to regularize traditional communities' tenure rights, helps to identify the households that wish to become part of the agroforestry scheme and is responsible for the management of the carbon payments, which are transferred into a community fund (Spirik, 2009).

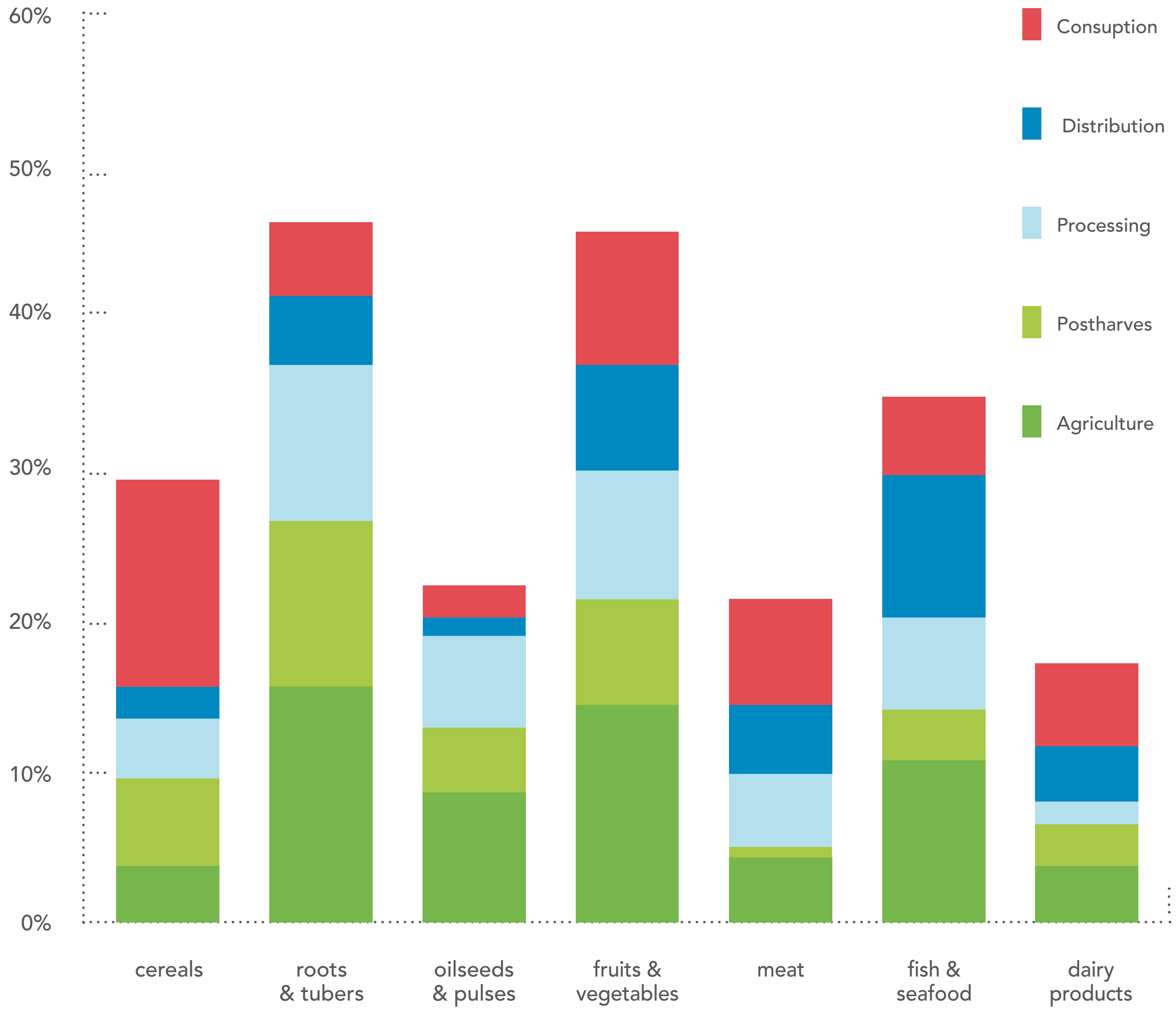
Reduce food losses and waste

Global food losses and waste amount to a third of all food produced (Gustavsson *et al.,* 2011). These losses and waste also mean that the GHG emitted during their production have served no useful purpose. This is especially true when the food has reached the end of the food chain, when the embedded emissions for transport and conservation are very high.

Global differences among regions in food loss and waste for the same type of products indicate potential areas for improvement (Gustavsson *et al.,* 2011). In Europe, cereal losses and waste are twice as high as in sub-Saharan Africa. On the other hand, in sub-Saharan Africa, milk losses and waste are twice as high as in Europe.

Depending on the products, regions, and levels of economic development, the distribution of the losses along the food chain is very different. For instance, in Africa cereals are lost in the first stages of the food chain. In Europe, they are lost mostly at the consumer stage: 25 percent against 1 percent in Africa. For fruits and vegetables, the differences between regions are also striking. In Africa, processing and distribution are the weak links. This highlights the need for investments in these stages of the food chain. In Europe, it is at the production and consumption stages where most losses occur.

Figure 1.1
Global food losses



Source adapted from Gustavsson *et al.*, 2011

However, there are techniques available to reduce food losses. One example is household metal silos for conservation of cereals or tubers (Mejia, 2008; Tadele *et al.*, 2001), which have been actively promoted by various organisations, including FAO and NGOs. The use of metal silos in Afghanistan has reduced storage loss from 15-20 percent to less than 1-2 percent. They are manufactured locally, creating jobs, small enterprises and possibilities for diversification of the local economy. The silos enable farmers to preserve food, making producers less vulnerable (either as sellers or buyers) to price fluctuations on local markets.

In developed countries, given that waste at the retail and consumption stages is extremely significant, reducing waste requires behavioral changes and the involvement of all concerned stakeholders, governments, private sector and civil society.

Box 1.4
The Save Food Global Initiative

In May 2011, FAO's Agriculture & Consumer Protection Department organized the international congress 'Save Food!' in partnership with Interpack/Messe Düsseldorf - a global player on trade fair organization, including the food and packaging industry. Speakers, stakeholders and high-level policy makers in the agriculture, food and packaging sectors from across the globe, signed a joint declaration to show their commitment to the goals of Save Food. The partnership launched the SAVE FOOD Initiative, which is a joint campaign to fight global food losses and waste. The Initiative aims at networking among stakeholders in industry, politics and research, encouraging dialogue and helping to develop solutions to food losses and waste along the food value chain. One of its objectives is to enlist the support of industry in initiating and sponsoring its own SAVE FOOD projects.

Source: Save Food Initiative, 2013

All along food chains, from agricultural production, transport, conservation, processing, cooking and consumption, there are potential areas for improving energy efficiency (FAO, 2011c). In Africa, 90 percent of the extracted wood is used for domestic purposes, mostly cooking. Improved energy-saving cooking stoves can contribute to reduce deforestation. However, trade-offs may need to be made between reducing losses and reducing energy consumption, especially for fresh perishable products, such as meat, dairy products, fish, fruits and vegetables. Consumption of perishable products, which often require cold chains and rapid transport, is increasing. Analyses of food losses and waste should therefore encompass the whole food chain to be able to consider all impacts and all potential solutions. For instance, processing fresh products transported over long distances into less perishable products can reduce foods losses and GHG emissions resulting from conservation and transport, as slower methods of transport can be used.

System efficiency

A change of practice in one component of a given system generally impacts the whole system. So it is not only a single technique or practice that has to be considered but the system as a whole, at the farm and household level and beyond the farm gate. Box 1.1 provides an example of the various consequences of the introduction of the UDP technique in Bangladesh.

Most of the changes in resource use of one factor of production impact on the use of other factors. Therefore, from a 'GHG efficiency' perspective, we need to assess the trade-offs between increasing resource efficiency regarding one or other input, for example, increasing yield per hectare through increased use of fertilizers. Thus, for improvements involving variations of several 'emitting' factors, a comprehensive assessment is needed, using life cycle analysis methodologies or GHG accounting tools.

As seen in the example of UDP in Bangladesh (Box 1.1), changes towards more resource efficiency, even through the introduction of a single new technique, can have major economic and social impacts which, in turn have impacts on food security, especially in terms of access to food. Whatever the 'efficiency' considered, there is a need to look at the allocation of factors and at the issue of scale. Indeed, production efficiency, GHG-efficiency, economic efficiency and food security do not always go hand in hand. For instance, to increase the workforce in the mix of factors of production might go against economic efficiency at the farm level, but may have a positive effect on food security. In that respect, efficiency should be assessed inside a system, at various scales and from various perspectives.

More resilient systems[5]

Climate change will profoundly affect, in any given place, the conditions under which agricultural activities are undertaken. It will affect existing risks and add new risks and uncertainties. As pointed out by the High Level Panel of Experts on Food Security and Nutrition (HLPE, 2012a), models cannot project climate change

[5] This section draws heavily on Gitz V. & Meybeck A. 2012. Risks, vulnerabilities and resilience in a context of climate change. FAO/OECD Workshop: Building Resilience for Adaptation to Climate Change in the Agriculture Sector, Rome, Italy, 23-24 April 2012.

effects precisely, neither in time nor at the local scale needed for decision makers. Moreover, climate models do not deal with the consequences of increased variability, the impacts of stress combinations, the effects of climate change on whole agro-ecosystems, including crops, their pests and predators of these pests. As it is impossible to predict exactly these changes, it is often difficult to devise and promote precise adaptation measures. One of the most effective approaches to be prepared for uncertainty and new risks – a 'no regret' approach that is valid whatever changes happen – is to reduce vulnerability and increase resilience of a given system (FAO and OECD, 2012; HLPE, 2012a).

Risks

Agricultural production is subject to risks of various types: economic and price-related risks, climatic, environmental, pests and diseases, at different scales and, often, political instability. Yield risk in main staple crops is particularly important for smallholders who tend to consume a large part of their own production. Farmers are also exposed to economic risks, including land tenure insecurity, variations in access to inputs (fertilizers, seeds, pesticides, feed) in quantity and quality and variations in access to markets.

'Risk' is used here to designate the potential of shocks and stresses that affect, in different ways, the state of systems, communities, households or individuals. Probability, uncertainty (when probabilities of occurrence or even nature of impacts are unknown), severity, economic scale, time scales and direct and indirect costs are all factors that should be taken into account.

Risks affecting agricultural activities are generally categorized according to the nature of the associated shocks (e.g. biophysical, economic) (Eldin et Milleville , 1989; Holden *et al.*, 1991; Cordier, 2008; OECD, 2009). They are also often classified according to the intensity, frequency and predictability (degree of uncertainty) of the associated shocks. They can be also categorized according to their impacts and their nature, as well as their importance and scope both in space and time (INEA, 2011). Weather is in itself a major cause of risk and also has a major influence on other types of risks. Climate change is expected to affect the nature, extent and intensity of these risks, plant pests, animal diseases, and disruption of ecosystem functions (HLPE, 2012a; FAO and OECD, 2012).

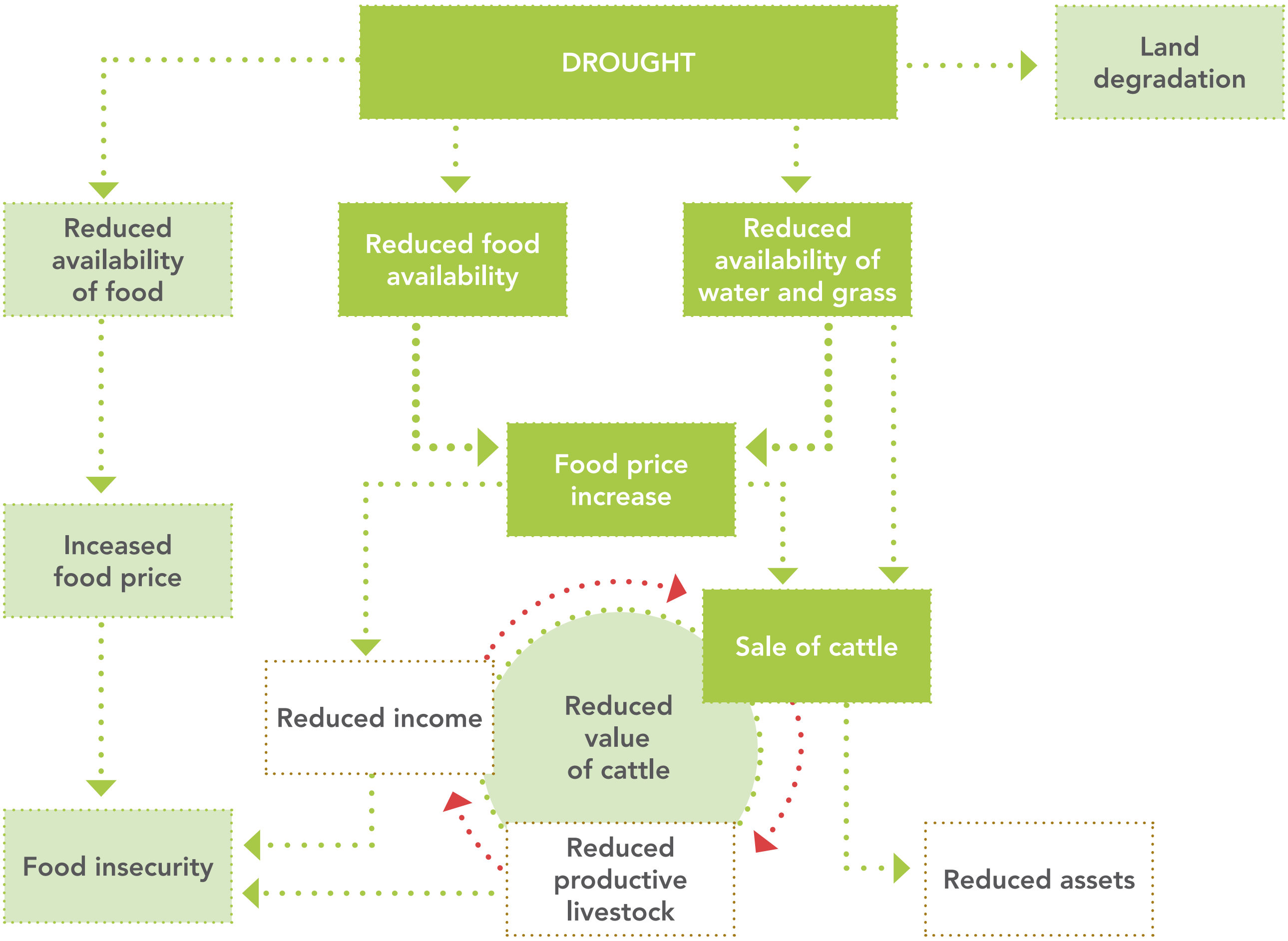
The impact of a risk depends on the shock itself and on the resilience of the system that receives the shock. Depending on their vulnerability, different systems will be more or less affected by the same shock. Depending on their resilience, different systems will recover more or less easily.

Food systems are by nature ecological, economic and social (Ericksen, 2008; Fussel and Klein, 2006). Each dimension has its own organization and interacts with the others. Food systems can be described and analyzed in each of their dimensions. There are also theories attempting to understand and describe 'complex systems' (Holling, 2001; Gunderson and Holling, 2001) to obtain a better grasp of the concept of sustainability.

Even when considering a single simple farming system, a single stress or shock can have various impacts of diverse nature and time scale. The global impact of a shock often also depends on the transmission of its effects from one dimension (biophysical) to the others (economic and social) and from one level (household) to another (community).

For instance, a drought in livestock grazing systems (see Figure 1.2) reduces the availability of water and grass – both directly and indirectly because as the watering points are reduced some pastures are no more accessible- and so increases the demand for feed at the very moment when there is less feed available. Increased demand drives a feed price increase, which forces livestock owners to sell their cattle. Massive sales while there is a reduced demand push down cattle prices, forcing livestock owners to sell even more to buy feed. These effects on prices reduce farm and household income and assets. Moreover, they reduce the value of assets (livestock) and productive capital for the future. Prolonged or repeated drought also has long-lasting degrading effects on land. The combination of drought and overgrazing, particularly near watering points, destroys the vegetal cover and increases soil erosion.

Figure 1.2
Impacts of drought



Gitz and Meybeck, 2012

Vulnerabilities

The net impact of a shock depends not only on the intensity of the shock itself but also on the vulnerability of the system to this particular type of shock.

Vulnerability can be defined as the propensity or predisposition to be adversely affected (IPCC, 2012). It is a complex concept (Fellmann, 2012) that needs to be considered across scales and across various dimensions (Gitz and Meybeck, 2012). It can be defined as vulnerability of 'what' to 'what' (Carpenter *et al.*, 2001).

The degree of 'specific' vulnerability of a system to a particular type of risk can be analysed as exposure and sensitivity to the potential shock that relates to this risk, and also depends on the 'adaptive capacity' of the system to cope with the impact of the shock. The adaptive capacity itself can also be affected by an external shock. In a given system, shocks in one dimension can spread to another dimension. For example, production shocks can be transmitted to the economic and social domains. This transmission can be linear, amplified or reduced, depending on the policies and institutions that are in place.

In many cases, there can be amplifying or positive correlations between the effects of shocks of diverse nature. In such cases, reducing vulnerability to one kind of shock can help also to reduce (specific) vulnerability to another kind of shocks. Vulnerability is also affected by the various shocks (e.g. a drought increases vulnerability to the next drought). By decreasing the strength of cattle, drought also increases their vulnerability to diseases. By reducing assets of households, drought also increases their vulnerability to other kind of shock.

Systems can be defined at various scales. An upper-scale system is generally composed of different systems defined at lower scales. For instance, from a biophysical perspective, landscape systems are composed of farm systems. The vulnerability of an upper-scale system depends on the vulnerability of the subsystems that it includes. It also depends on how other systems to which it is linked, including higher-scale systems, are vulnerable or insensitive to shocks. For example, the vulnerability of a farm to a certain risk is compounded by its own vulnerability and the vulnerability of the landscape in which it is situated, and whose vulnerability is in turn compounded by the vulnerabilities of the various farms situated in it and by the vulnerability of the higher-level system (e.g. the territory) in which it is situated.

Resilience

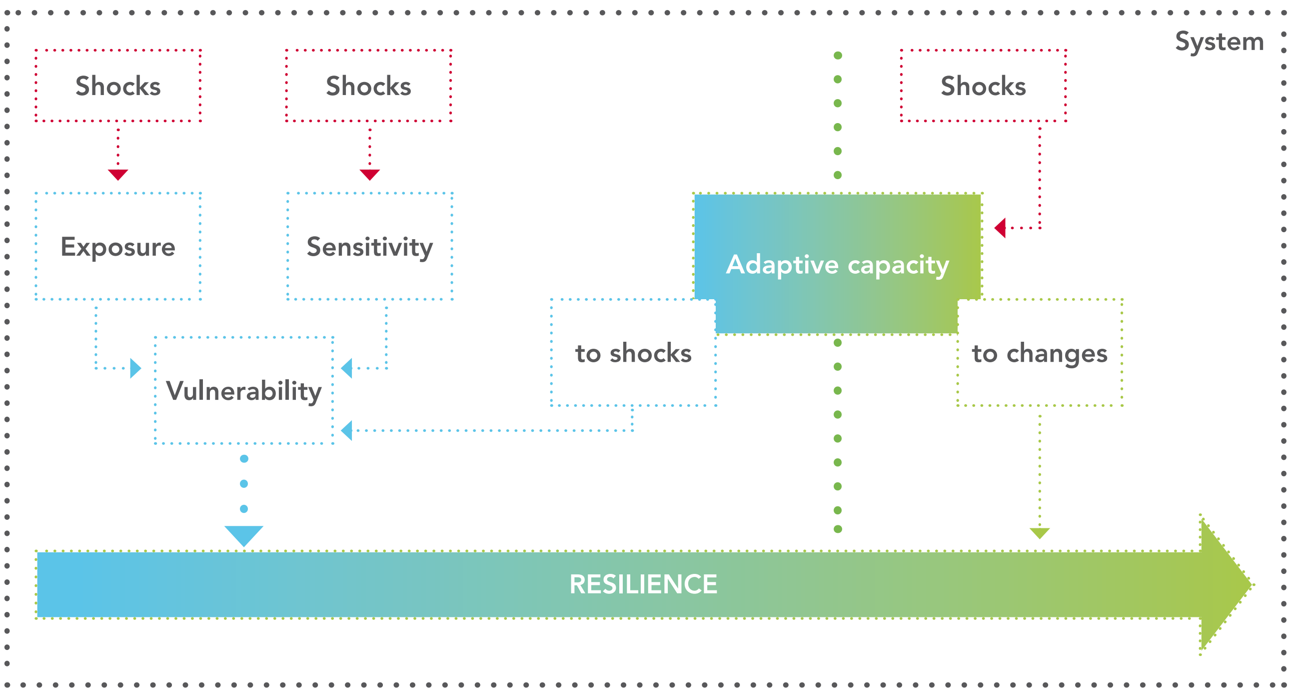
Resilience can be described as the capacity of systems, communities, households or individuals to prevent, mitigate or cope with risk and recover from shocks. At first approximation, resilience is the opposite of vulnerability. However, resilience adds a time dimension. A system is resilient when it is less vulnerable to shocks across time and can recover from them. Essential to resilience is adaptive capacity. Adaptive capacity encompasses two dimensions: recovery from shocks and response to changes in order to ensure the 'plasticity' of the system.

For example, the organization of seed systems enables farmers who have lost a crop to have seeds for the next season. It also enables them to have access to seeds that are adapted to new conditions.

As for vulnerability, resilience can be specified as "resilience of what to what" (Carpenter *et al.*, 2001). However, focusing on specified resilience may cause the system to lose resilience in other ways (Cifdaloz *et al.*, 2010). This is why general resilience can be described as being "about coping with uncertainty in all ways" (Folke *et al.*, 2010).

And as for vulnerability, resilience can be considered in various dimensions (biophysical, economic and social) and at various scales. The way the various dimensions and scales interact is crucial, precisely because of the importance of general resilience for coping with uncertainty. For instance, studies show that increasing the level of education of farmers can be an efficient mean for reducing farmers' household vulnerability to climate change. (Karfakis *et al.*, 2011)

Figure 1.3
Components of resilience



Source: Gitz and Meybeck, 2012

Resilience puts a greater emphasis on the capacity of a system to recover and transform itself over the long term, and adapt to its changing environment in a dynamic perspective. It implies that it is not only shocks, as a change relative to an average, that have to be considered, but also the change of the average itself. Ultimately, the question is until what point can a system adapt before changing to another type of system?

Building resilience

To a great extent increasing resilience can be achieved by reducing vulnerabilities and increasing adaptive capacity. This can be done by reducing exposure to risk, reducing sensitivity and increasing adaptive capacity for every type of risk. It can act in each domain, either biophysical or economic and social. One way to achieve better resilience is to reduce transmission of shocks between types of risks, between scales and between domains and to organize compensation between scales (for instance transport of feed) or between domains (for instance safety nets) to avoid cumulative and long-term effects.

In a first approximation we can identify the following three ways to build resilience:

1. Reduce exposure. There is a fundamental difference between climatic and non-climatic shocks in this regard because most of the shocks on farm can be reduced at the source, or limited in their extension, contrary to climatic shocks. The best example of a non-climatic shock is probably the eradication of Rinderpest, which has totally suppressed a major risk for livestock and those depending on it.
2. Reduce the sensitivity of systems to shocks. Using drought-resistant varieties or keeping adequate stocks of hay can for instance, reduce sensitivity to drought.
3. Increase adaptive capacity. This includes considering the modifications of a system and taking into account all the potential shocks and changes together (to take into account compensating, cumulative or exacerbating effects).

Box 1.5
Prevention of major Desert Locust upsurges in West and Northwest Africa

Emergency Prevention System for Transboundary Animal and Plant Pests and Diseases (EMPRES Programme)
The Desert Locust is a highly destructive transboundary plant pest that threatens people's livelihoods, food security, the environment and economic development in more than 30 countries. In terms of bio-ecology, West and Northwest Africa (Western Region) is an indivisible distribution area of this pest. In that area more than 8 million people faced severe food shortage as a result of the 2003-2005 Desert Locust upsurge. It cost the international community and affected countries over USD 570 million to overcome it and 13 million litres of chemical pesticides were applied. The Sahelian countries also suffered from high crop losses ranging from 30 to 100 percent. To address the Desert Locust issue more effectively, the Western Region countries (Algeria, Burkina Faso, Chad, Libya, Mali, Morocco, Mauritania, Niger, Senegal and Tunisia) set up in 2002 the Commission for Controlling the Desert Locust in the Western Region (CLCPRO) under the aegis of FAO. To implement a sustainable preventive control strategy, they also joined the FAO EMPRES Programme, launched in 2006 in the Western Region. The Evaluation Missions of Phase 1 (2006-2010) of this Programme underlined that substantial progress had been made in achieving the objectives, in particular, in the frontline countries (Chad, Mali, Mauritania and Niger) in terms of: institutional building with the creation of autonomous National Locust Control Units (NLCUs); strengthening of locust control capacities and infrastructure; implementation of early warning systems and rapid interventions, developing health and environmental standards, and better preparedness to Desert Locust crises (ongoing contingency planning).

The improvement of more effective preventive control strategy became obvious during the control operations against locust outbreaks in 2006, 2008, 2009 and 2010-2011 in Mauritania and in 2009 in Niger. Also, a gradual funding of the recurrent costs for preventive control implemented by the NLCUs from the national budgets was observed: from 10 percent in 2006, it reached an average of 60 percent in the frontline countries at the end of 2010. The annual cost of preventive control in the Western Region is USD 3.3 million, less then 0.6 percent of the expenses incurred during the 2003-2005 major outbreak.

Source: Brader *et al.*, 2006; Cossée *et al.*, 2009

Finally, we have to consider that the occurrence of shocks is not certain. The nature of the shock may be uncertain as well as the nature or size of its impacts. In addition, their occurrence in time is generally unknown.

Therefore, building resilience goes hand in hand with the need to anticipate within uncertainty, within the system, or across scales. In that sense, specific risk monitoring not only reduces vulnerability but also increases resilience as it allows for the anticipation of risks and their changes.

A good example of actions to build resilience in the face of uncertainties due to climate change can be found in the domain of genetic resources (HLPE, 2012), which is being considered by the Commission on Genetic Resources for Food and Agriculture (CGRFA)[6] . If climate changes, farmers might need to rely on different genetic resources, some that are already used elsewhere, or other species or varieties that are now considered minor but that may be better adapted to new conditions. To do so, access to the largest possible pool of genetic resources is needed. Genetic resources, which are also threatened by climate change, are crucial for adaptation (see Module 6 on genetic resources). We need to preserve diverse genetic material, including traditional and improved crop varieties and their wild relatives. They are adapted to specific conditions, have been selected for different uses, and constitute the reservoir from which varieties can be developed to cope with effects of climate change, such as drought, the shortening of the growing season, increased incidence of pests and diseases. Preserving genetic resources increases the resilience potential of the whole system. To achieve this, the potential effective genetic resources have to be accessible to farmers where they are needed. It is not enough to have the appropriate genetic resources in a gene bank or a research centre. They have to be multiplied and distributed, which requires plant breeders, seed enterprises and the proper legal system to certify the quality of the seeds and the accuracy of the genetic information. All these actors and elements constitute 'seed systems', which enable farmers to have the seeds they need. Regional harmonization of seed rules and regulations is also essential, particularly as crops will move to adapt to climate change (Burke *et al.*, 2009).
In agroforestry systems the various dimensions and scales interconnect to increase the resilience of farming systems.

Box 1.6
A change of system: from slash and burn to agroforestry in Central America

Since 2000, FAO has initiated special programmes for food security with the governments of Guatemala, Honduras, Nicaragua and El Salvador, among others. To improve and develop agroforestry systems in the sub-region, these programmes worked together, sharing practices, experiences and results. Agroforestry systems are promoted as a substitute to traditional slash-and-burn systems, particularly on slopes. They are at the same time more efficient and resilient.

In traditional slash-and-burn systems, a family needs close to 6 hectares to maintain itself on a diet of corn and beans. The family exploits a plot for two years and then sets it aside for 14 years. In agroforestry systems a plot is exploited for 10 years, producing, along with corn and beans a variety of other products, often including livestock. The plot is then set aside for only 5 years. A family thus needs 1.4 hectares to sustain itself and enjoy a more diverse and balanced diet. Land is therefore almost 4 times more efficient. Efficiency also increases because in agroforestry systems, yields (which are comparable the first year) do not decline over time as they do very rapidly in slash-and-burn systems. In fact, yields can even increase slightly over time in agroforestry systems. Productivity of labour and of capital is also higher in agroforestry systems. Costs are reduced, especially for fertilizers, because of more organic matter in the soil and better use of nutrients by the plants. At the community level, diversification of production triggers the development of local markets. Consequently, in terms of resource use, agroforestry systems are efficient at safeguarding food security and the environment.

Agroforestry systems are also much more resilient:

- Yields are less variable, because of better humidity retention.
- They provide for more diverse production, which ensures in turn a buffer against both the variability of crop yields and price volatility.
- They offer diversified sources of income, including through selling wood for various uses (and at various time scales), which can also provide a buffer against some economic shocks.
- They protect the soil from erosion, which is a major concern in these areas. Studies have shown that in agroforestry systems erosion is reduced by a factor of more than 10.

Source: FAO, 2010d

[6] The Secretariat of the Commission on Genetic Resources for Food and Agriculture has commissioned and prepared several background papers (No 48, 53, 54, 55, 56, 57, 60) on climate change and genetic resources available at http://www.fao.org/nr/cgrfa/cgrfa-back/en/?no_cache=1.

Sustainable management of forests (Braatz, 2012) and sustainable management of fisheries (De Young, 2012) are good examples of where the actions towards increasing resilience in one domain of vulnerability, starting with the biophysical domain, also have positive effects on the resilience and vulnerability in other domains (social and economic). Landscape approaches can play an important role in building resilience (HLPE, 2012a).

Social protection can play an important role in increasing resilience at household and community level. This is especially true if national systems are designed as comprehensive programmes that exploit the synergies between various instruments in such a way as to cover the specific needs of various groups, especially the more vulnerable, and to be easily scaled up to address any kind of shock (HLPE, 2012b).

The notion of resilience is particularly powerful for bringing together interventions that cover different dimensions. Improving the sustainability of forest management not only increases the forest's resilience, but also contributes to improving water management, protecting the soil from erosion and to conserving agrobiodiversity (e.g. by providing habitat to pollinators). In this way, improvements in the sustainability of forest management contribute to improving the resilience of farming systems. As mentioned earlier, landscape approaches can play an important role in that respect (HLPE, 2012a). Forestry and fisheries provide complementary food and income and in so doing contribute to improving the resilience of households and food systems. This notion also helps clarify the relations between 'specific' vulnerabilities and resilience and how addressing known risks can allow for the creation of strategies to build general resilience to cope with uncertainty. As such, resilience provides an efficient way for implementing 'no regret' adaptation. A crucial element would be to better manage known risks, whether climatic or not, to increase preparedness to future, uncertain risks and changes.

Efficiency and resilience

Efficiency and resilience should be pursued together and at various scales in different agricultural systems and food chains. Being efficient without being resilient will not be helpful over the long term, given that shocks will occur more often due to climate change. Being resilient without being efficient or without allowing for an increase in production, will pose problems for ensuring food security over the long term and for supporting livelihoods. In the pursuit of these two goals, there might be trade-offs, but there will also be synergies. Increasing efficiency could lead to greater sensitivity to certain shocks. For example, more productive livestock is more sensitive to heat waves (Hoffmann, 2010). On the other hand, increased efficiency can be a factor in increasing resilience. For example, increasing production in food importing countries will improve their resilience to price volatility. Increasing soil carbon stocks, enhancing diversity in the field and improving trade are of particular interest with regard to improving efficiency and resilience of food systems.

Increasing soil carbon stocks

Increasing soil organic carbon improves both efficiency and resilience. It improves nutrient and water intake by plants, which increases yields and resource efficiency of land, nutrients and water. It also reduces soil erosion and increases water retention, especially as it is often combined with added soil cover, as in conservation agriculture. This combination makes the system more resilient to variability of precipitation and to extreme events. Increasing carbon sinks in the soils also captures carbon, which contributes to climate change mitigation. For all these reasons, restoring degraded lands and increasing the level of organic carbon in soils is a priority action (IPCC, 2007b; FAO, 2009b; FAO, 2010a; HLPE, 2012a).

Box 1.7
Participatory rangeland management in the Syrian Arab Republic

In the Syrian steppe (or Badia), IFAD is working on participatory rangeland management with local communities to reduce herders' vulnerability to climate change and restore the long-term productivity of rangelands. After years of severe drought and intensive grazing, rangelands in the Badia were severely degraded.

By reintroducing native plants that help meet fodder requirements, fix the soil and stop sand encroachment, ecosystems were restored and the local population's vulnerability to the effects of climatic instability was reduced. After two years of resting, reseeding and planting, birds, insects and animals returned to the area. The rehabilitated ecosystems offered further potential for income generation, as truffles grow in some areas of the Badia, and women could gather them to boost their family incomes. In 2010, a community with a 100 000-ha grazing area could earn up to USD1 million through the sale of truffles.

Higher household incomes provided a basis for the project to diversify income-earning opportunities for women through literacy classes and training courses in new skills such as first aid, food processing and sewing. With households being better off, there is less pressure on young girls to marry early, and as women gain more economic autonomy, they are finding that gender relations are shifting.

Source: IFAD, 2012a

Increasing diversity in the field

Increasing diversity of production at farm and landscape level is an important way to improve the resilience of agricultural systems (FAO, 2010a; FAO and OECD, 2012; HLPE, 2012a).

Specialized systems are often presented as being more efficient from an economic point of view, as they generate more income. These systems can benefit from the improved technologies and from economies of scale in the production and distribution of inputs, machines, and especially processing and trade.

Diversifying production can also improve efficiency in the use of land, as is the case in agroforestry systems for instance and of nutrients with the introduction of legumes in the rotation or in integrated crop/livestock or rice/aquaculture systems. Studies show that they can also be more efficient in terms of income (see for instance Box 1.6), especially if this is measured as an average over a period of several years. The Finnish project ADACAPA aims to identify means for assessing and enhancing the adaptive capacity of the Finnish agricultural sector to global environmental and socio-economic changes at various decision-making levels (farm, regional, national). The main hypothesis tested is that increasing diversity enhances resilience and thus adaptive capacity of agrifood systems. Some of the results of studies conducted in the ADACAPA project have shown that diversity can increase income (Kahiluoto, 2012). Farms that both grow crops and exploit forest generate a higher and more stable income. Regions growing more diverse varieties of barley have a higher average yield than areas growing a single variety. More diversified systems can also spur the development of local markets. An example of this is agroforestry in Central America (Box 1.6). Finally, systems providing more diverse types of food are also more efficient from a nutritional point of view as they facilitate more balanced and diverse diets.

Trade

Agriculture is a classical example that illustrates the role of trade to increase global economic efficiency by exploiting local comparative advantages (Huang *et al.*, 2011). This is, however, being questioned from a GHG emissions perspective, initially triggered by the promoters of the 'food miles' concept who advocate the consumption of local products to reduce GHG emissions. In reality, transport represents only a small part of global food systems' emissions. Emissions from transport are estimated to be 11 percent, of which 6 percent results from consumers' transport to buy food (Weber and Matthews, 2008). Obviously, these percentages will vary by distance and the agriculture/food product considered. Life cycle analysis of various products confirms that, apart from fresh fragile products, such as fish, fruits and vegetables, transport is not the determining factor of their carbon footprint (FAO, 2012c). In fact, a more efficient production system can more than compensate for the emissions resulting from transport. The emissions due to transport to retailers should not be isolated but considered on a case by case basis in conjunction with the emissions from the production stage as part of a life cycle analysis. Restricting trade and producing locally may both increase GHG emissions (and other environmental costs) per unit of output as well as reducing economic efficiency.

International trade is – and has been – an essential factor for the resilience of food systems (Meridian Institute, 2011; Nelson *et al.*, 2010; HLPE, 2012a). As shown above, climate change is expected to have different effects in various regions of the world. Available research indicates that climate change is expected to lead to important changes in the geographical distribution of agricultural production potential, with increases in mid to high latitudes and a decrease in low latitudes. International trade plays an important role in compensating, albeit partially, for regional changes in productivity that are induced by climate change. Together with productivity changes, changes in endowments of arable land and usable water, developments in energy markets, population growth and government policies, both existing agricultural policies and climate-related policies, all drive the patterns of regional specialisation and of international trade.

Trade can compensate for local production deficits caused by increased variability and extreme events. However, recent commodity price volatility has shown that trade does not always buffer local production variations (HLPE, 2011; MacMahon, 2011; FAO, 2012d). On the contrary, it can exacerbate and transmit the effects of a local shock, and consequently it can become a factor of systemic risk. In addition, price volatility has hit poor importing countries especially hard (HLPE, 2011). Trade could then appear as a factor of risk, rather than a way to cope with shocks. The ability to realize the compensating potential of international trade depends on a well-functioning international trade architecture. Imposing import restrictions, perhaps motivated by the desire to increase domestic production in the face of declining yields, and hence confounding food security with food self-sufficiency, is clearly not a sustainable solution. Likewise, imposing export restrictions in surplus regions, as witnessed during food price spikes in 2007/2008 and motivated by the objective to keep domestic prices low relative to world prices, creates problems for food importing countries and undermines the trust in the functioning of the global trade system.

Overdependence on imports to satisfy national needs can lead to severe food crises for the poor during price upsurges, which are often aggravated by measures to restrict exports. Trade's role in improving the resilience of food systems would be enhanced paying greater attention to food security concerns (HLPE, 2011and 2012a).

1.3 Increase systemic efficiency and resilience: policies, institutions finances

Appropriate policies, institutions and finances are essential to increase systemic resilience and efficiency at local, national and international level and to achieve needed changes in agricultural and food systems. These are detailed below (see also Module 12 on institutions, 13 on policies and 14 on financing CSA).

Invest in agriculture in developing countries

There is already a gap today in funding for investment in developing countries. The needs will increase. FAO estimated that cumulative gross investment requirements for agriculture in developing countries add up to nearly US$ 9.2 trillion until 2050 or nearly US$ 210 billion annually (FAO, 2009c). Therefore, the decreasing trend in funding has to be reversed. It includes increasing the share of Official Development Assistance directed to agriculture. Domestic efforts have to be pursued at the appropriate level.

The needs are even greater when the need to address the challenges of climate change is included (FAO 2010a, Nelson *et al.*, 2009, Nelson *et al.* 2010, HLPE 2012). It must be emphasized that the major part of these investments will be made by the private sector, and most of them by the farmers themselves. Public actors can play a key role in building an enabling environment, including policies, institutions and key investments. Reducing risk and improving resilience is key to enabling private actors, especially the more financially vulnerable, to invest. Often these private actors will also need support, particularly during the transition phase towards new systems. Payments for environmental services can play an important role to facilitate this transition (Lipper and Neves, 2011).

Among the needed investments are important land management schemes and infrastructure, such as local roads and irrigation systems, which are an important source of job creation in rural areas. These public works can be supported by social protection schemes in order to provide work, food and income to food-insecure people. A recent report of the HLPE (2012b) reviews some of these schemes and concludes that public works programmes have proved to be efficient in dealing with covariate shocks and, if they are well designed, can contribute to improving food security.

They also include major investments in research (HLPE 2012a, Beddington *et al.*, 2012c). To be able to embrace the whole range of issues to be addressed, these investments need to be coordinated at a global scale. Increased investment in public research is particularly needed in areas where return on investment cannot immediately benefit the private sector. To address systemic issues to be adapted to local specificities and needs, research will have to be closely linked to extension services and be open to local knowledge and to the demands addressed by all stakeholders, including small-scale food producers (HLPE 2012a). The transfer of technology will also play an important role. It should include the development of the human capacity to accommodate the technology and structured partnerships to ensure that it is adapted and established locally.

Manage risks at local, national, international levels

Climate change will add more risks to production and aggravate existing risks, especially for the more vulnerable. Increased variability and uncertainty make ever more necessary the establishment of risk management strategies to address every type of risk, whether climate, animal or plant diseases or even economic. Such strategies should aim to limit losses ex ante by monitoring risks, assessing vulnerability, identifying (ex-ante) damage reduction measures and acting at the earliest stage of the event. They would include quick reparation of losses to productive assets in order to avoid long-term consequences.

In doing so, such strategies should combine specific policies targeted to address specific agents and categories of risks.

Policies targeted at farmers can include measures aiming at building economic resilience at farm level either by increasing income, enabling saving, by promoting diversification (especially if the risks affecting each activity are not correlated) or by insurance (in certain cases). They also include measures to reduce or eliminate specific risks, such as plant pests and animal diseases, including advanced observation networks for quick response. Other measures either prevent the loss of productive assets, such as feed banks for livestock during droughts, or enable quick recovery, such as availability of seeds.

Policies should also address risks along the food chain (including for small scale food producers), including storage, post harvest losses and food safety risks. Prevention of food safety risks or effectiveness to handle large-scale food safety emergencies will depend on the services available (inspection and analytical capacities, information sharing, health services) (see Module 11 on sustainable food value chains).

Policies targeted at consumers would use measures specifically designed to address access to food that is nutritionally adequate, safe and culturally appropriate.

The efficiency of any specific risk management policy is largely dependent on the existence of enabling policies, institutions, coordination mechanisms, and basic infrastructures. For example, opening markets and adequate transport systems have an important role in diluting the impact of a shock over greater areas.

Enable farmers to overcome barriers to change

Land use and management play a crucial role in improving agricultural practices to address food security and climate change. Improving land management, soil fertility, or practices like implementing agro-forestry have long-term benefits but often imply up front costs either in inputs or labour. Securing land tenure is paramount to enable farmers to benefit from the value added on the land and to encourage them in adopting a long-term perspective. The Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security[7] recently adopted by the Committee on World Food Security promote secure tenure rights and equitable access to land, fisheries and forests as a means of eradicating hunger and poverty, supporting sustainable development and enhancing the environment. They can play an important role.

Whatever the change in farming systems envisaged or implemented, it involves costs. Even if a new practice will provide the same or an increased income in the long run, there are barriers to adoption: upfront costs, income foregone during the transition period or additional risks during the transition period which all have to be covered. Take for instance mitigation measures. Mitigation measures in the agricultural sector are considered among the cheapest, with a quarter of the technical mitigation potential being estimated as costing less than 20$/t$CO_2$ (IPCC, 2007b). But these estimations compare the income with a new practice to the income without the practice. They do not take into account transition costs, or the costs of the enabling environment, such as extension services for instance. These costs have to be assessed and taken into account (FAO, 2009a).

The recent report of the High Level Panel of Experts on food security and nutrition on Social Protection for Food Security (HLPE, 2012b) shows how social protection can be a powerful means to enable farmers, and especially the more vulnerable, to invest and modify their practices to improve their food security. Many measures, such as providing inputs or public works to improve infrastructures and landscapes have both direct short term and longer term impacts. In cash subsidies provided as social protection are often used to invest for improving livelihoods (HLPE, 2012b). Moreover an integrated and up-scalable social protection system is essential to enable investment particularly of the more vulnerable.

It is also essential to facilitate access to the needed knowledge, including for local specific practices, through the development and improvement of extension services and initiatives such as farmer field schools and formal and informal knowledge sharing networks (HLPE, 2012).

Need for a systemic approach

The changes required in agricultural and food systems will require the creation of supporting institutions and enterprises to provide services and inputs to smallholders, fishermen and pastoralists, and transform and commercialize their production more efficiently. These changes will also require major investments from both public and private sector. For this reason, they will drive economic development and create jobs, especially in rural areas and in countries where agriculture is a major economic sector.

Changes in the field require the introduction of new inputs, techniques and services. Making them accessible to smallholders, pastoralists, fishermen and foresters, both physically and financially, is a major challenge. This situation in turn creates opportunities for the development of small local enterprises dedicated to providing inputs and services to farmers.

Changes in farming systems should be accompanied by changes all along food chains.
For instance, as pointed out by the HLPE (2012) increasing diversity in the field often requires changes in consumption patterns. In fact, diversification often requires changes along the entire food chain, from input production and distribution to collection, transformation and commercialization of products. For these reasons, diversification is often more easily carried out as a collective project. Several diversified farms can realize the same economies of scale on each of their production systems as a specialized one. This can lead to the creation of services, for example to share machinery and collect and sell their production.

[7] FAO, 2012f.

The introduction of better processing techniques that are more resource efficient not only reduces expenses but also often gives the opportunity to improve quality, exploit new markets and increase incomes. This in turn creates jobs in the agricultural and food sector, as well as in other rural-based sectors.

Comprehensive governance, from local to international

To improve efficiency and resilience of food systems at every scale requires comprehensive governance, at every level, local, national, regional and international. It shall involve all stakeholders, farmers, agro-industry, retailers, consumers and public authorities.

At a global scale, there is an urgent necessity to better consider the interrelations between agriculture, food security and climate change. The international community needs to establish appropriate links between the international fora discussing food security issues and climate change. Fortunately, this is starting to happen.

Food security and climate change policies have to be better integrated at every level. Implementing CSA, and particularly adaptation to climate change also requires adequate means to promote collective management of natural resources, such as water or landscape.

The 47 National Adaptation Programmes of Action (NAPA) prepared by the least developed countries provide a rich panorama of adaptation priority measures. These projects are of special interest and relevance because they have been designed and prioritized by the countries themselves. A close analysis of all the categories of projects (Meybeck *et al.*, 2012) shows that most of these priority projects are linked to agriculture, including forestry and fisheries.

As pointed out by the High Level Panel of Experts on food security and nutrition (2012a), "addressing food security and climate change requires concerted and coordinated involvement and action of many actors, farmers, private sector, and public actors national and international, civil society and NGOs. It is especially challenging as they are very different, sometimes have conflicting objectives and there is a need to work on a long-term perspective while most of them have to consider first a short term outcome. This requires the involvement of all stakeholders."

Integrating food security and climate change concerns has to be done at every level and pursued at different scales. It also needs to be done on a day-to-day basis at farm level. But it also must be carried out with a long-term perspective at the landscape level and country level to design locally specific, coherent, inclusive and cohesive policy packages.

1.4 What's new with CSA?

Indeed, what is different about CSA? (Grainger-Jones, 2011) Climate smart agriculture is not a new agricultural system, nor is it a set of practices. It is a new approach, a way to guide the needed changes of agricultural systems, given the necessity to jointly address food security and climate change. This section aims at clarifying how CSA relates to some other approaches.

CSA shares with sustainable development and green economy objectives and guiding principles. It aims also for food security and contributes to preserve natural resources. As such, it has close links with the concept of sustainable intensification, which has been fully developed by FAO for crop production (FAO, 2011b) and is now being extended to other sectors and to a food chain approach.

Sustainable development and Green Economy

The concept of sustainable development was given prominence by the Brundtland Commission in Our Common Future - Report of the World Commission on Environment and Development (1987) as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". The report's framing of the concept of sustainable development twinned environmental action with poverty reduction, and helped set the stage for the 1992 Earth Summit and Rio Declaration. The concept recognized the value of the environment, extended the time horizon and emphasized the role of equity. The Brundtland Commission noted that sustainable development embodies two key themes:

- The idea of "needs", in particular the essential needs of the world's poor, to which overriding priority should be given; and
- The idea of "limitations" imposed by the state of technology and social organization on the environment's ability to meet present and future needs.

In 1992, five years after the release of the 1987 Brundtland report, the United Nations Conference on Environment and Development (UNCED), also known as the "Earth Summit" was held in Rio de Janeiro, Brazil. The conference articulated the notion of sustainable development and launched milestone international agreements on environment, the "Rio conventions", including the United Nations Framework Convention on Climate Change (UNFCCC).

Twenty years after, the United Nations Conference on Sustainable Development, known as Rio+20 or the Rio Earth Summit 2012, was also held in Rio de Janeiro. While some progress has been made towards sustainable development between 1992 and 2012, large challenges remain as the human footprint on the planet is increasing and some 'planetary boundaries' are (or are close to be) crossed. We are now at a time when it is urgent to give a new and more concrete expression to the concept of sustainable development, make it more operational, and pave ways on how to integrate its three (economic, environmental and social) dimensions. This is also why the concept of the 'green economy' was developed.

In its Green Economy Report, UNEP has defined the green economy as follows:

> *"An economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities."*
>
> (UNEP, 2010).

Practically speaking, a green economy is one whose growth in income and employment is driven by investments that simultaneously:

- reduce carbon emissions and pollution,
- enhance energy and resource-use efficiency; and
- prevent the loss of biodiversity and ecosystem services.

As per the definition of the concept, green economy objectives should resonate with sustainable development agendas, highlighting a concern with human well-being and social equity – both now and for future generations; as well as balancing risks and scarcities faced by peoples across the globe.

As stated in the outcome document of the Rio + 20 conference the "green economy in the context of sustainable development and poverty eradication will enhance our ability to manage natural resources sustainably and with lower negative environmental impacts, increase resource efficiency, and reduce waste." (United Nations, 2012)

CSA and Green Economy and Sustainable Development

Agriculture, (intended in the FAO sense of 'agriculture, forestry and fisheries') is at the nexus of the challenges that need to be addressed to make sustainable development a reality (FAO, 2012a).

One of the first planetary boundaries, perhaps the most important one, is that the world needs to feed itself. But today, almost one billion people are hungry. Another billion is malnourished, lacking essential micronutrients. While, globally, enough food is being produced to feed the entire word, one-third of it is lost or wasted, and low incomes and problems of distribution mean that accessibility to food is still out of reach for one out of six people on our planet. By 2050, food production has to increase, both in quantity, quality, and diversity, especially in developing countries. Population and income growth will drive an ever- increasing demand, especially in developing countries (Lutz and Samir, 2010; Cirera and Masset, 2010; Foresight, 2011a; Foresight, 2011b). Assuming these trends continue, FAO estimates that production has to increase by 60 percent between now and 2050, especially in developing countries (Bruinsma, 2009; Conforti, 2011). Agriculture is also an essential driver of economic growth, particularly in rural areas and least developed countries. At the national level boosting agricultural production stimulates overall economic growth and development, particularly in those countries with a high economic dependence on agriculture. According to the World Bank (2008), investment in agriculture is particularly efficient in creating new jobs. Agricultural and rural development acts as an engine for sustainable economic development, making an effective contribution to national economic growth. At the community level, agricultural development increases farm productivity, reduces food deficits, increases food surpluses and raises incomes. Improved agriculture production provides opportunities to sustainably reduce poverty, food insecurity and malnutrition and thereby improves livelihoods.

At the same time, food production and consumption already exerts a considerable impact on the environment (UNEP, 2010; FAO, 2012b). Food systems rely on resources, especially land, water, biodiversity, and fossil fuels, which are becoming ever more fragile and scarce.

Agriculture is essential for a green economy. In fact, FAO considers that there can be no green economy without agriculture. This is why FAO proposed "Greening Economy with Agriculture" as the basis key message for Rio+20 (FAO, 2012b).

Climate-smart agriculture contributes to the goals of making sustainable development concrete. It integrates the three dimensions of sustainable development in addressing food security and climate concerns in a forward-looking perspective. It is guided by the need for more resource efficiency and resilience. These principles are also central in the Rio + 20 outcome document[8], which recognizes resource efficiency as key to a green economy and affirms the need to enhance agriculture's resilience.

The green economy and CSA share the common goal of integrating the three dimensions of sustainable development. Both make sustainable development tangible by focusing on issues that can and must be addressed right now in local communities but that have global, long-term consequences.

CSA brings together global and local concerns, climate change to be addressed globally, climate change to get adapted to locally; and first of all, food security, which has to be addressed both locally and globally. To do so it brings together practices, policies and institutions, which are not necessarily new. What is new is the harmonization and synchronization needed of practices and policies in order to address multiple challenges, faced by agriculture and food systems, now and for the future. What is also new is the objective of avoiding contradictory and conflicting policies by internally managing trade-offs and synergies in the pursuit of multiple objectives.

Food security and natural resources: sustainable intensification

CSA takes into account the four dimensions of food security, availability, accessibility, utilization and stability[9]. Still, the entry point and the emphasis is on production, on farmers, on increasing productivity and income, and on ensuring their stability. As such it is centered on the key dimension of food security, - availability, which is associated with stability. It also has much to do with raising and stabilizing incomes of smallholders, and thus with accessibility to food. Diversification of production is a powerful way to increase efficiency and resilience; it is also an essential path towards more balanced and nutritious diets.

[8] Id paragraphs 108-118.

[9] Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". (World Food Summit, 1996)

The emphasis on resource efficiency has obvious environmental co-benefits. It preserves natural resources, water, resources, both agrobiodiversity and wild biodiversity (by preserving land). The project Enhanced Strategies for Climate-Resilient and Environmentally Sound Agricultural Production (C-RESAP) in the Yellow River Basin (Licona Manzur and Rhodri, 2011) aiming to contribute to the adaptation of vulnerable communities to climate change and to reduce the impact of agricultural practices on the environment provides a good example of these potential synergies. When focussing on a single environmental issue (here climate change) potential trade-offs with other issues have to be identified and addressed (IFAD, 2012b).

CSA shares objectives and principles with sustainable intensification of crop production. Sustainable crop production intensification (SCPI) can be summed up in the words "save and grow". Sustainable intensification means a productive agriculture that conserves and enhances natural resources. It uses an ecosystem approach that draws on nature's contribution to crop growth – soil organic matter, water flow regulation, pollination and natural predation of pests – and applies appropriate external inputs at the right time, in the right amount to improved crop varieties that are resilient to climate change and use nutrients, water and external inputs more efficiently. A CSA approach adds a more forward looking dimension, more concern about future potential changes and the need to be prepared for them.

1.5 Conclusions and focus of the sourcebook

Addressing food security and climate change challenges has to be done in an integrated manner. To increase food production and to reduce emissions intensity, thus contributing to mitigate climate change, food systems have to be more efficient in the use of resources. To ensure food security and adapt to climate change they have to become more resilient.

This has to happen globally, worldwide and everywhere. Increased efficiency in one part of the world provides food and income where it takes place but it also provides more food, globally and thus can provide food elsewhere and reduce its cost, globally. With increased risks, increasing resilience of the worldwide food system also means that efficiency and resilience have to be improved everywhere, so as to spread risk. Therefore CSA is a dynamic approach that concerns all farmers, all over the world. But developing countries are more at risk of food insecurity. They are more at risk of climate change. They also have more potential for mitigation (and adaptation?), because they have to increase their production more, and because there is an important efficiency gap. On the other hand developing countries have less means, policies and institutions to address these challenges. Therefore, this book will be primarily aimed at developing countries.

The changes outlined in this book have to be supported by efforts to harness consumption. Consumption patterns play an important role in the increased demand on agriculture, on the impact of food systems on environment and also on food security. More sustainable patterns of consumption would, in particular, play an essential role to mitigate climate change (HLPE 2012a). Sustainable diets are defined by FAO as "those diets with low environmental impacts that contribute to food and nutrition security and to healthy lives for present and future generations. Sustainable diets are protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable, nutritionally adequate, safe and healthy, while optimizing natural and human resources" (FAO, 2010d). But, to a great extent the tools, policies and institutions that could influence consumption and diets, especially in developed countries, are very different from those that would be used to transform agricultural systems. This is why this book does not address, as such, the issue of consumption patterns as a driver of environmental impact.

Notes

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Acronyms

CH_4	methane
CGRFA	Commission on Genetic Resources for Food and Agriculture
CLCPRO	Commission for Controlling the Desert Locust in the Western Region
CSA	climate-smart agriculture
CO_2	carbon dioxide
EIT	Economies in Transition
EMBRAPA	Brazilian Agricultural Research Corporation
EMPRES	Emergency Prevention System
FAO	Food and Agriculture Organization of the United Nations
FSCA	Food Security for Commercialisation for Agriculture
GDP	gross domestic product
GFFBO	Good Father Fishery Based Organization
GHG	greenhouse gas
HLPE	High Level Panel of Experts on Food Security and Nutrition
IDP	internally displaced persons
IFAD	International Fund for Agricultural Development
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
IRRI	International Rice Research Institute
N_2O	nitrous oxide
NAPA	National Adaptation Programmes of Action
NGO	non-governmental organization
NLCUs	National Locust Control Units
NPFS	National Program for Food Security
OECD	Organization for Economic Co-operation and Development
ORAM	Rural Association for Mutual Support
REDD	Reducing Emission from Deforestation and Forest Degradation
SBSTA	Subsidiary Body for Scientific and Technological Advice
SCP	sustainable consumption and production
SCPI	sustainable crop production intensification
SIDS	Small Island States
UDP	urea deep placement
UNCED	United Nations Conference on Environment and Development
UNCTAD	United Nations Conference on Trade and Development
UN DESA	United Nations Department of Economic and Social Affairs
UNEP	United Nations Environment Programme
UNCSD	United Nations Conference on Sustainable Development
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

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Additional Resources

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