2. Environmental services and agriculture

The benefits that humans have realized from agriculture have been immense. Today, agriculture feeds over 6 billion people, and recent decades have seen significant increases in the productivity of agriculture with the introduction of new varieties and production methods (Tilman *et al*., 2002). However, these benefits have come at a cost. Of the ecosystem services evaluated in the Millennium Ecosystem Assessment, agriculture is credited with increasing the provisioning services of food and fibre production over the past half century, but at the expense of degradation of many other ecosystem services. The Millennium Ecosystem Assessment, as well as reports arising from other more recent studies such as *Water for food: water for life* (Comprehensive Assessment of Water Management in Agriculture, 2007) and *Livestock's long shadow: environmental issues and options* (FAO, 2006a) recognize that agriculture can and should be managed to enhance ecosystem services beyond the provision of food and other goods.

Increased production of agricultural goods at the expense of other ecosystem services has resulted in global and local environmental changes that have significant impacts on human health and well-being (Foley *et al*., 2005). Agricultural production practices can generate greenhouse gas emissions and lead to water depletion and pollution, land degradation and loss of biodiversity. Agriculture itself is one of the main victims of degraded ecosystems, with agricultural productivity hampered by problems of climate variability, soil depletion, water scarcity and quality, and pest and disease vulnerability. Changing the balance of ecosystem services provided by agriculture constitutes a significant step towards redressing the negative consequences of certain forms of agricultural production. A further motivation for such a change also exists: the potential for offsetting or compensating for environmental degradation generated by other sectors of the economy. Bioenergy is another newly emerging market that may also lead to major shifts in the ecosystem services provided by agriculture (see also UN-Energy, 2007).

The changes in ecosystem management that are necessary depend on location, the existing level of economic development, population density, agro-ecological conditions and primary technologies employed in agriculture. All these factors affect the returns to land and labour in agriculture and the potential costs and benefits of changes in practice aimed at generating additional environmental services.

This chapter, and the remainder of the report, focuses primarily on three categories of environmental problems where agriculture has a significant role to play: climate change, water degradation (pollution and depletion) and biodiversity loss. These three domains have already seen an expansion of payment programmes to agricultural producers to enhance the provision of environmental services. Farmers are being paid to sequester carbon to mitigate climate change, to improve watershed management (and thus water quality and flow) and to conserve biodiversity. These categories also appear to have the most significant potential for future growth in such payment programmes. There are, of course, a number of other ecosystem services for whose management agriculture plays a crucial role, such as soil formation or nutrient cycling, which are crucial for maintaining soil fertility and reversing land degradation.

This chapter provides a brief overview of the technical relationship between agriculture and environmental changes, how this relationship shapes policy options and the specific types of actions farmers and other agricultural producers can undertake to increase the supply of the three categories of environmental services.

How can agricultural producers generate environmental services?

Before discussing the specific issues associated with each of the three categories, some general observations are called for. Generally, for farmers to increase their supply of certain environmental services, some change in the agricultural production system is needed.

To provide enhanced levels of environmental services, farmers can alter their production practices in a variety of ways, including:

- changes in production systems, where lands remain in agriculture but production activities are modified to achieve environmental objectives (e.g. reduced tillage or leaving more crop residues on fields);
- land-diversion programmes, where lands are diverted from crop and livestock production to other uses;
- avoiding a change in land use (e.g. refraining from the conversion from forest to agriculture).

These distinctions are important in assessing the degree to which environmental service provision involves a trade-off with agricultural production, which in turn is fundamental for understanding the motivations of producers regarding whether or not to implement a change. The type of change required could also have macro-level implications, if implemented on a large scale, through its impacts on food, land and labour availability, and on prices (Zilberman, Lipper and McCarthy, forthcoming).

The conditions determining the potential to change the mix of ecosystem services provided by agricultural production systems have several dimensions. First, changes to increase the output of one ecosystem service are likely to have effects on a number of other services. These may be positive or negative. In many cases, changes involve a reduction in some provisioning services – even if only temporary – in order to enhance the supply of other supporting, regulating or cultural services. Trade-offs may also arise among the various types of regulating and supporting ecosystems services supplied. For example, establishing a plantation of fast-growing tree species to generate carbon sequestration may reduce biodiversity. Likewise, increasing habitat for one species could have negative impacts on another.

Second, agro-ecological conditions such as climate, soil quality, topography and water availability are key determinants of the mix of ecosystem services that can be generated from a particular system of management. Specific agro-ecological conditions may be highly productive for one service but not for another; for example, steep topography can result in highly productive watershed protection, but be very unproductive for agriculture.

Third, the potential for changing the mix of services provided by agro-ecosystems depends critically on the management systems currently in place and on the policy and economic factors that drive them. For example, wheat can be produced within a large-scale, highly capital-intensive mechanized system, as in Australia or Canada, or through small-scale, labour-intensive systems with few or no chemical inputs, as in Ethiopia. Both are examples of wheat farming systems, but the productivity of each, in terms of wheat yield and the mix of ecosystem services, is quite different. Changes to increase environmental services for one system may not be relevant to the other.

A fourth and final point to be made is that ecosystem services take different forms, not all of which are equal from the point of view of the beneficiaries. A major reason for the past emphasis on provisioning services over other types of ecosystem service, is the fact that most provisioning services take the form of what, in economists' terms, are considered "private goods". In contrast, regulating, supporting and cultural ecosystem services are often "public goods" (see Box 2).

The sections below look more closely at the types of change that agricultural producers can make to enhance the provision of the specific services of climate change mitigation, improved water management and biodiversity conservation.

BOX 2
Public goods

Public goods are a special case of externalities (see Box 1). They are goods or services for which consumption cannot be confined to a particular consumer or group of consumers and whose use by one consumer does not affect the use by another. For example, mitigating the impacts of climate change is a benefit to everyone in the global community, and it is not possible to exclude some people from enjoying the benefit even if they do not pay for the service. At the same time, one person's enjoyment of the climate change mitigation benefit does not detract from another person's enjoyment of the same benefit. Public goods can range from global (e.g. climate change mitigation, biodiversity conservation) to local (e.g. flood control).

It is important to note that, while services such as climate change mitigation are public goods, the resources that provide them (e.g. forest lands) may well be privately owned. Indeed, it is this distinction that helps motivate payments for environmental services.

Source: FAO, 2002b.

Agriculture and climate change mitigation

The summary for policy-makers of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) states unequivocally that global warming is occurring and that it is very likely caused by greenhouse gas emissions arising from human activities. It warns that:

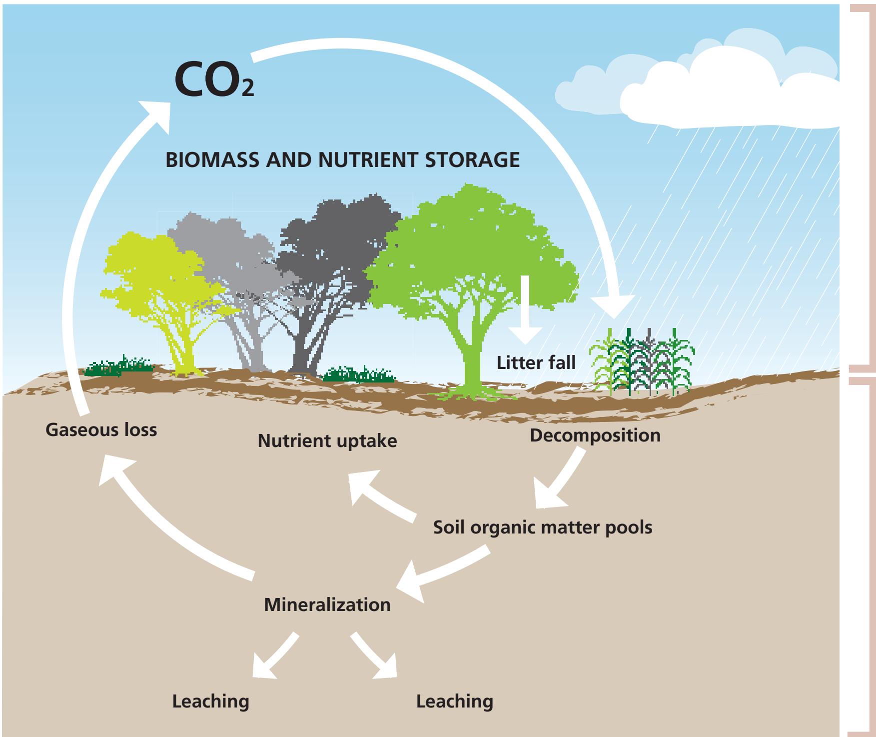
> *Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.*
>
> (IPCC, 2007a, p. 13)

Climate change will generate significant costs to both developing and developed countries. Such costs will include increased frequency and intensity of severe weather events such as floods, tornados and hurricanes; increased drought in some regions; loss of coastal areas and water shortages; and changes in the incidence of disease. Developing countries are likely to bear a heavier burden owing to their greater vulnerability as well as the severity of changes they are likely to experience. Climate change could result in large-scale migration and conflicts, which also carry significant costs (Stern, 2007).

The IPCC Fourth Assessment Report also notes the importance of making immediate and significant reductions in greenhouse gas emissions. The report states that mitigation efforts over the next two to three decades will determine to a large extent the long-term global mean temperature increase and the corresponding climate change impacts that can be avoided (IPCC, 2007b). Essentially, there are two ways of mitigating climate change: reducing the source of the emission or increasing the amount of greenhouse gas storage in terrestrial systems (e.g. through carbon sequestration). Thus, agriculture's role in mitigating climate change is twofold: reducing its own emissions and enhancing the absorption of greenhouse gases.

Agriculture is a notable source of the three major greenhouse gases: carbon dioxide, methane and nitrous oxide. Carbon dioxide is most significant in relation to global warming, but methane and nitrous oxide also make substantial contributions. Agricultural activities and land-use changes contribute about one-third of the total carbon dioxide emissions and are the largest sources of methane (from livestock and flooded rice production) and nitrous oxide (primarily

FIGURE 3
Above- and below-ground carbon sequestration



Source: FAO.

from application of inorganic nitrogenous fertilizer).

Agriculture also plays an important role as a carbon "sink" through its capacity to sequester and store greenhouse gases, especially as carbon in soils and in plants and trees (see Figure 3). Carbon sequestration involves increasing carbon storage in terrestrial systems, either above or below ground. Changes in land- and soil-use practices can trigger a process of soil carbon accumulation over time. Eventually, the system will reach a new carbon stock equilibrium or saturation point, and no new carbon will be absorbed. Carbon sequestration presents both advantages and disadvantages as a means of mitigating climate change. The main advantage is that it is relatively low-cost and can be readily implemented. Moreover, it provides multiple associated benefits as the resultant increase in root biomass and soil organic matter enhance water and nutrient retention, availability and plant uptake and hence land productivity. A major disadvantage is that, unlike other forms of climate change mitigation, carbon sequestration is reversible; indeed, changes in agricultural management practices can accelerate or reverse the degree of sequestration in a relatively short time frame.

The physical potential to sequester carbon varies considerably by land-use type and region. Table 1 shows an estimate of carbon sequestration potential through land-use change for a total of 48 developing countries over a ten-year period. The figures suggest that significant technical potential exists for carbon emissions mitigation from agriculture: almost 2.3 billion tonnes. Realizing this potential would require changes in land management on an additional 50 million hectares of land (Niles *et al.*, 2002). In comparison, 95 million hectares are currently farmed using conservation agriculture systems, which provide significant soil carbon sequestration

TABLE 1
Potential carbon mitigation from land-use change, 2003–12

Region	Avoided deforestation[1]	Sustainable agriculture[2]	Forest restoration[3]	TOTAL
	(Million tonnes of carbon)			
Africa	167.8	69.7	41.7	279.2
Asia	300.5	227.3	96.2	624.0
Latin America	1 097.3	93.1	177.9	1 368.3
TOTAL	**1 565.6**	**390.1**	**315.8**	**2 271.5**

[1] Calculated from the most recent estimates of annual forest loss multiplied by weighted carbon stocks; assumes deforestation rates remain constant.
[2] Includes soil carbon sequestration from reducing tillage and increasing soil cover, conversion of annual crops to agroforests and improved grasslands management.
[3] Includes reforesting degraded lands and agroforestry, not plantations. Excludes carbon sequestration in soils undergoing reforestation.
Source: adapted from Niles *et al*., 2002.

services (Derpsch, 2005). The economic feasibility of the required land-use changes is not yet clear, although there is growing evidence that changes in production systems leading to carbon sequestration could also provide other economic benefits.

Potential for carbon sequestration in above-ground biomass

Above-ground sequestration is achieved by increasing the amount of biomass above ground in the form of trees and shrubs. Carbon sequestration rates vary by tree species, soil type, regional climate, topography and management practice. The adoption of agroforestry, rehabilitation of degraded forests and establishment of forest plantation and silvopastoral systems count among the many land-use changes that can generate above-ground carbon sequestration.

The carbon sequestration potential of a land-use system is determined by the average carbon stored in that system during a rotation period relevant to the type of growth in question. Carbon is sequestered when moving from systems with lower to higher time-averaged stocks. Palm *et al*. (2005) estimated the annual average amount of carbon stored over 20 years under various land-use systems for three sites in the humid tropics. They found that a change from managed and logged forests to undisturbed forest in Indonesia yielded a net gain of 213 tonnes of carbon per hectare over the life of the forest. Similarly, changing from short fallow to improved fallow in Brazil increased carbon sequestered per hectare by 4.6 tonnes over eight years.

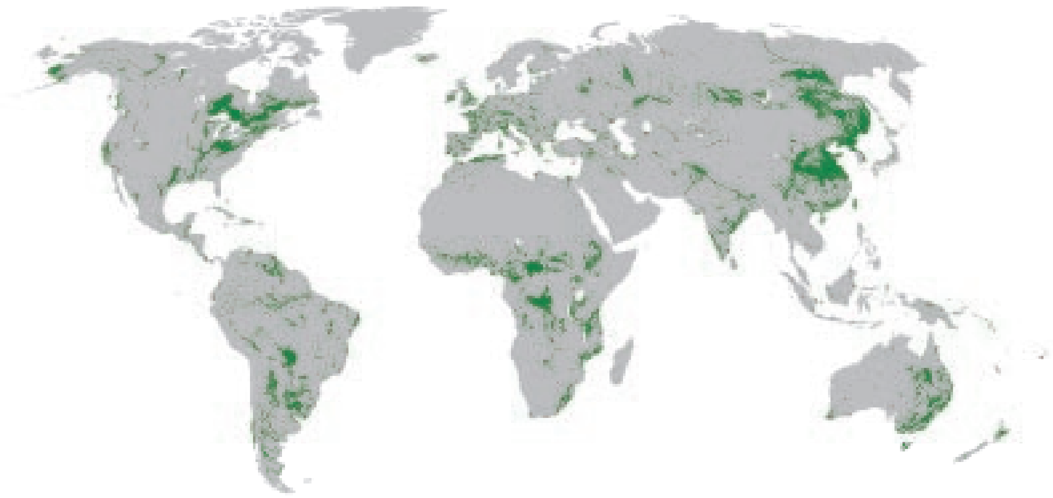
The highest average amount of carbon that can be sequestered per hectare per year is generally obtained by expanding forest area via afforestation or reforestation. Annual crops and pastures store a small fraction of that amount. Amounts achieved by logged forests, agroforests, tree crops, timber plantations and secondary forest fallows fall in between. Secondary forest fallows of 20–30 years, for example, store around 75 tonnes of carbon per hectare, with sequestration occurring at an annual rate of 5 tonnes per hectare during the first ten years of regrowth (Fearnside and Guimarães, 1996).

Any intervention that prevents conversion from a higher to a lower carbon-storing land use, or that encourages conversion from a lower to a higher carbon-storing land use, will contribute to net carbon storage. Thus, a wide range of other forestry and agroforestry systems can make a meaningful contribution. For example, Poffenberger *et al*. (2001) estimated that, with protection and assisted regeneration, dry forests in central India could double per hectare rates of carbon sequestration from 27.3 to 55.2 tonnes within ten years in secondary forests, and increase them from 18.8 to 88.7 tonnes in old growth forest after 50 years, at a very modest cost.

Potential for carbon sequestration below ground

All soils contain some carbon, deposited as dead plant material or in some inorganic

MAP 1
Potential to sequester additional carbon in soils



Note: available at
http://www.fao.org/geonetwork/srv/en/google.kml?id=31151&layers=potential_sequester_carbon
Source: FAO.

form such as calcium carbonate or carbon dioxide dissolved in groundwater. The extent of additional carbon that can be sequestered depends both on local geophysical conditions and the cropping system.

Map 1 presents a global view of areas with significant potential to sequester additional carbon in soils. This potential, referred to as the "soil carbon gap", indicates locations where soil carbon levels are currently low but medium-to-high technical potential for sequestration exists, depending on soil type, climate soil moisture and land cover conditions. It must be stressed that this map, as well as other maps presented in this report, is based on global databases at a coarse scale of resolution and with variable accuracy. Consequently, the results presented can only suggest locations that show potential for the various indicators considered. Country-level studies and more sophisticated models would be required to derive more accurate estimates.

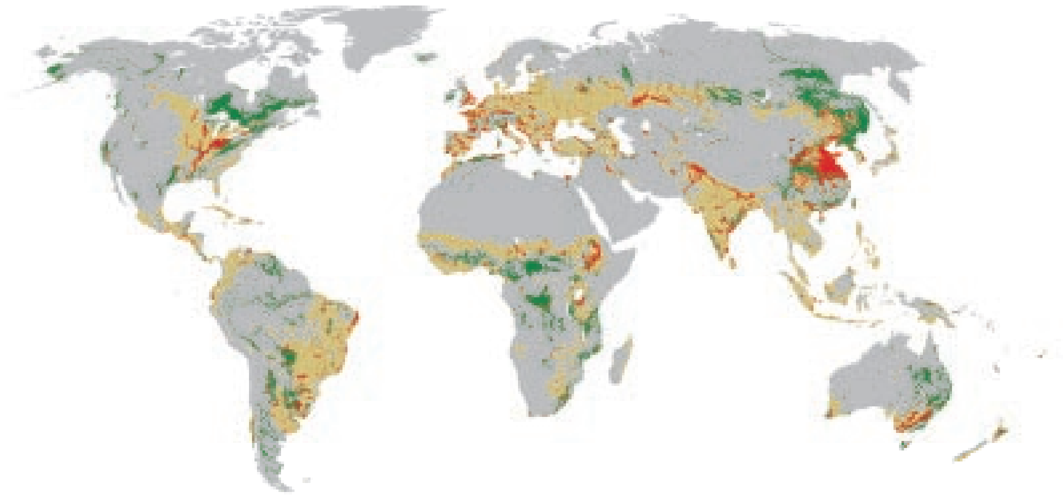
Map 2 indicates the location of croplands with medium-to-high technical potential to sequester carbon. This map provides a preliminary perspective on where cropping systems could be changed to achieve substantial soil carbon sequestration. It highlights the intersection of locations with medium-to-high soil carbon sequestration potential (indicated in Map 1) and croplands, as identified by the Global Land Cover 2000 Project (GLC 2000) database.[3]

Around 30 percent (4.7 million km^2) of the land characterized by medium-to-high potential for carbon sequestration is located in areas where agricultural production is practised, representing 15 percent of total croplands as defined by GLC 2000. One-quarter of this area is located in Asia and one-quarter in Africa.

Which types of changes to agricultural production practices could increase soil

[3] GLC 2000 is a collaboration of partners around the world with the general objective to provide for the year 2000 a harmonized land cover database over the whole globe. Croplands are defined by GLC land classes 16 (cultivated and managed areas), 17 (mosaic: cropland/tree cover/other natural vegetation) and 18 (mosaic: cropland/shrub or grass cover). Further details are available at http://www-gvm.jrc.it/glc2000/.

MAP 2
Potential to sequester additional carbon in soils on croplands



Note: available at
http://www.fao.org/geonetwork/srv/en/google.kml?id=31152&layers=potential_sequester_carbon_cropland
Source: FAO.

carbon sequestration? Lasse (2002) provides a list of management techniques with this potential, including the planting of cover crops, mulch farming combined with zero tillage, and agroforestry. Some of these practices would also increase above-ground carbon stocks. Reliable estimates on how much carbon could be sequestered in soils under various management practices and farming patterns in the developing world are still sparse. The estimates proposed by Lal *et al*. (1998) for tropical areas are about twice as high as those for drylands.

The effects on carbon sequestration of modifications to cropping practices can differ dramatically by practice and by location. Studies in selected locations in India and Nigeria simulating the impact of land-use changes over a 50-year period suggest that under current practices soil carbon will continue to decline at a slow pace, but that changes in land use could significantly increase soil carbon in the long term (Figure 4) (FAO, 2004a). The range of sequestration potential for the different practices considered is large, from negative for continuous cultivation practices to around 40 tonnes per hectare with the retention of crop residues and substantial addition of farmyard manure. For the practices with the highest sequestration potential, carbon sequestration continues for the entire duration of the simulation and even then does not reach equilibrium, suggesting that carbon sequestration through changes in agricultural practices requires considerable time for the full impact to take effect.

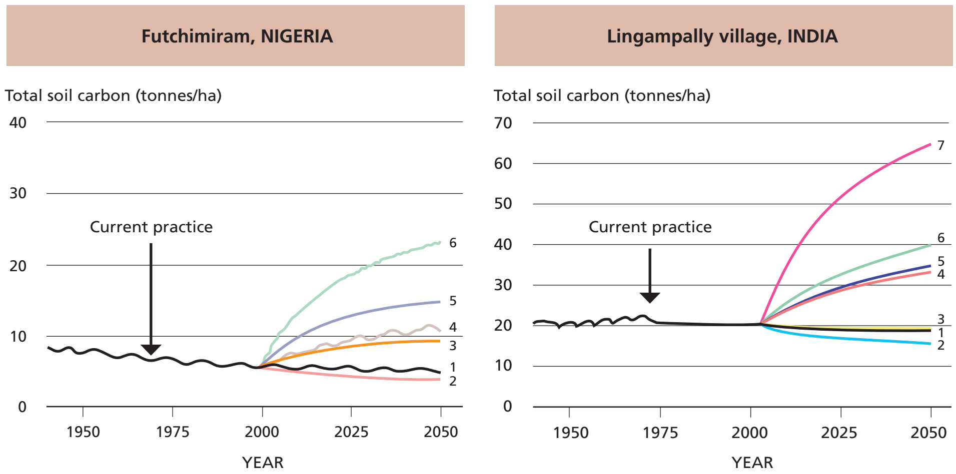
Water quantity and quality

Watershed protection services are physically delimited by watershed boundaries. In contrast with carbon sequestration and many biodiversity conservation services, therefore, they are primarily of interest to local and regional users (Landell-Mills and Porras, 2002).

Water quantity

Water use has grown rapidly over the past century, increasing more than sevenfold between 1900 and 2000 while the human

FIGURE 4
Changes in soil carbon for different cropping systems



LAND-USE PRACTICES (Futchimiram, Nigeria)

1. Current practice: extensive agropastoral with slash and burn
2. Continuous cultivation
3. 100 kg/ha urea, no grazing residues
4. Five-year fallow, five-year cultivation, two applications farmyard manure (FYM) 3 tonnes/ha, grazing residues
5. Continuous cultivation, FYM 1.5 tonnes/ha/year, grazing residues
6. Continuous cultivation, FYM 1.5 tonnes/ha/year, plant residues 0.5 tonne/ha/year, no grazing

LAND-USE PRACTICES (Lingampally village, India)

1. Current practice: rainfed cropping, FYM applied at 3.9 tonnes/ha/year
2. FYM 3 tonnes/ha/year
3. FYM 3 tonnes/ha/year, green manure 500 kg/ha/year, vermicompost 250 kg/ha/year
4. As current practice but incorporating crop residues into soil
5. FYM 3 tonnes/ha/year, leave plant residues
6. FYM 3 tonnes/ha/year, plant residues, green manure, vermicompost
7. FYM 6 tonnes/ha/year, plant residues, green manure, vermicompost

Source: FAO, 2004a.

population grew by about a factor of four (UNDP, 2006). Despite a decline in per capita consumption since the 1980s, global water use continues to increase (Shiklomanov and Rodda, 2003).

Table 2 reports two indicators related to the use of freshwater resources. The "water crowding index" measures the number of people served per million cubic metres per year of accessible runoff. The relative water use or "water stress index" expresses the ratio of water withdrawals to supply. At the global level, current water use represents about 13 percent of annual supply (Millennium Ecosystem Assessment, 2005b) with an overall upward trend, indicating increasing pressure on freshwater resources.

The Millennium Ecosystem Assessment (2005b) projects an increase of 13 percent in the global water crowding index by 2010. Projections reported in the *Human Development Report 2006* (UNDP, 2006) suggest that, by 2025, over 3 billion people are likely to be experiencing water stress and 14 additional countries might be classified as water-scarce (i.e. having less than 1 000 cubic metres per person per year).

Most water for human use is drawn directly from rivers or from groundwater. The latter may originate from renewable or "fossil" aquifers. Each source presents its own management issues. Renewable groundwater is directly linked to the cycling of freshwater through the atmosphere and soils and is thus replenished by precipitation and certain agricultural practices. Fossil groundwater is found in deep underground aquifers with little long-term net recharge. The use of fossil groundwater is similar to the mining of minerals: once extracted, it, effectively, cannot be replaced as replenishment times can reach thousands of years (Margat, 1990).

TABLE 2
Indicators of freshwater provisioning services, 2010

Geographic region/country grouping	Water crowding index (People/million m^3/year)	Water stress index (Percentage)
Asia	391	19
Latin America	67	4
North Africa/Middle East	2 020	133
Sub-Saharan Africa	213	3
Former Union of Soviet Socialist Republics	161	20
OECD countries	178	20
WORLD TOTAL	**231**	**13**

Note: These figures are based on mean annual conditions. The values for the relative use statistics shown rise when the subregional spatial and temporal distributions of renewable water supply and use are considered

Source: From *Ecosystems and human well-being: current state and trends* by the Millennium Ecosystem Assessment. Copyright © 2005 by the author. Reproduced by permission of Island Press, Washington, DC.

In addition to direct extraction from rivers and aquifers, three other technologies are used to increase freshwater availability: dams and other artificial impoundments, desalinization of ocean water and localized rainwater harvesting. Desalinized water currently supplies less than 1 percent of global water consumption. Water harvesting refers to a number of technologies, traditional and modern, that either harvest surface runoff or increase water infiltration. These include water channels and dams to catch and convey water, techniques to increase soil moisture content, and reservoirs for irrigation and household use and to reduce flood peaks.

Agriculture accounts for about 70 percent of all water use worldwide and up to 95 percent in many developing countries and thus influences both the quantity and quality of water available for other human uses (FAO, 2007b). Changes in agricultural practices could contribute to water quantity by promoting the recharge of groundwater aquifers, but perhaps the most important contribution agriculture could make to improving the quantity and quality of available water resources is through more efficient use of the water it requires. A further possibility is the reuse of wastewater for agricultural purposes; currently, about 2 million hectares are irrigated using this method (Comprehensive Assessment of Water Management in Agriculture, 2007), and the potential exists to increase this area significantly.

Pretty *et al*. (2006) analysed 144 projects in developing countries where a combination of resource-conserving management practices, such as integrated pest and nutrient management, conservation tillage and agroforestry, had been introduced. It was found that these practices also provide a notable improvement in water productivity, especially for rainfed agricultural systems. Average increases in water productivity ranged from 16 percent for irrigated rice and 29 percent for irrigated cotton to 70 percent, 102 percent and 108 percent for rainfed cereals, legumes, and roots and tubers, respectively.

Numerous studies have established the positive impact of zero tillage on water infiltration capacity, soil moisture content, soil erosion and water-holding capacity. In the United States of America, for example, no-till systems were found to reduce water runoff by 31 percent; increase water infiltration, depending on soil type, by between 9 percent and 100 percent; and reduce soil erosion by up to 90 percent, which in turn reduced sediment loads in rivers and pollutants in water bodies (Hebblethwaite, 1993). Also Guo, Choudhary and Rahman (1999) reported improved percolation owing to better soil structure in no-till systems, which resulted in decreased soil erosion. In various Brazilian locations, soil losses were reduced by up to 87 percent under conservation agriculture, while runoff was reduced by up to 66 percent under wheat–soybean rotations (Saturnio and Landers, 1997).

The exact quantification of aquifer recharge through improved water infiltration requires further research. To date, there is mainly anecdotal evidence that the introduction of conservation agriculture and other soil and water conservation practices improves watershed services. In the state of Paraná, Brazil, it was reported that, after the introduction of a no-till system, a pond that had been habitually dry for most parts of the year had refilled and that the nearby river had begun to carry water also in the dry season (FAO, 2003b). In India, Agarwal and Narain (2000) reported that the Avari and Ruparel rivers began to contain water all year round after a set of water-harvesting practices and soil conservation measures were implemented in the watersheds. With respect to livestock management, rotational grazing, improved livestock distribution and increased tree cover on pastures have been found to improve water recharge (FAO, 2006a). Nevertheless, more research is needed on the exact relationships and time lags between the introduction of improved agricultural management for water conservation and improvements in water quantity.

Table 3 summarizes in qualitative terms the likely impacts of major changes in land use on water availability. Unfortunately, the hydrological relationships between land use and the generation of more and cleaner water are complex and site-specific, and scientific evidence is often lacking (Robertson and Wunder, 2005; FAO, 2004b).

TABLE 3
Brief overview of hydrologic consequences associated with major classes of land cover and use change

TYPE OF LAND-USE CHANGE	CONSEQUENCES ON FRESHWATER PROVISIONING SERVICE	CONFIDENCE LEVEL
Natural forest to managed forest	Slight decrease in available freshwater flow and a decrease in temporal reliability (lower long-term groundwater recharge)	Likely in most temperate and warm humid climates, but highly dependent on dominant tree species Adequate management practices may reduce impacts to a minimum
Forest to pasture/agriculture	Strong increase in amount of superficial runoff with associated increase in sediment and nutrient flux Decrease in temporal reliability (floods, lower long-term groundwater recharge)	Very likely at the global level; impact will depend on percentage of catchment area covered Consequences are less severe if conversion is to pasture instead of agriculture Most critical for areas with high precipitation during concentrated periods of time (e.g. monsoons)
Forest to urban	Very strong increase in runoff with the associated increase in pollution loads Strong decrease in temporal reliability (floods, lower long-term groundwater recharge)	Very likely at the global level with impact dependent on percent of catchment area converted Stronger effects when lower part of catchment is transformed Most critical for areas with recurrent strong precipitation events
Invasion by species with higher evapotranspiration rates	Strong decrease in runoff Strong decrease in temporal reliability (low long-term groundwater recharge)	Very likely, although highly dependent on the characteristics of dominant tree species Scarcely documented except for South Africa, Australia and the Colorado River in the United States of America

Source: From *Ecosystems and human well-being: current state and trends* by the Millennium Ecosystem Assessment.

Most studies in this area have focused on the impacts of forest protection and reforestation in the proximity of water sources, but even in these studies the results have often been ambiguous. Increasing tree cover can reduce, as well as increase, the availability of water. Because a typical watershed is affected by the activities of many farmers, improved agronomic practices would need to be adopted widely in order to have a measurable impact, and the long-term monitoring needed to assess the changes in large watersheds can be costly. Nevertheless, although scientific evidence on the influence of improved management on water levels and groundwater recharge is scarce, research has clearly established the opposite – that soil degradation and deforestation cause water tables to decline.

Map 3 (p. 23) shows croplands in South Asia and Southeast Asia with high levels of sheet erosion, indicating potential off-site impacts in the form of siltation and sedimentation in waterways. The map is based on the findings of the Assessment of the Status of Human-Induced Soil Degradation in South and Southeast Asia conducted between 1994 and 1997 by the International Soil Reference and Information Centre (ISRIC) and FAO (van Lynden and Oldeman, 1997). Not all the areas shown will necessarily have the potential to play a strong role in providing watershed services through land-use change, depending on their location with respect to hydrological functions, but those that do are still likely to represent a significant area and a considerable number of agricultural producers.

Water quality

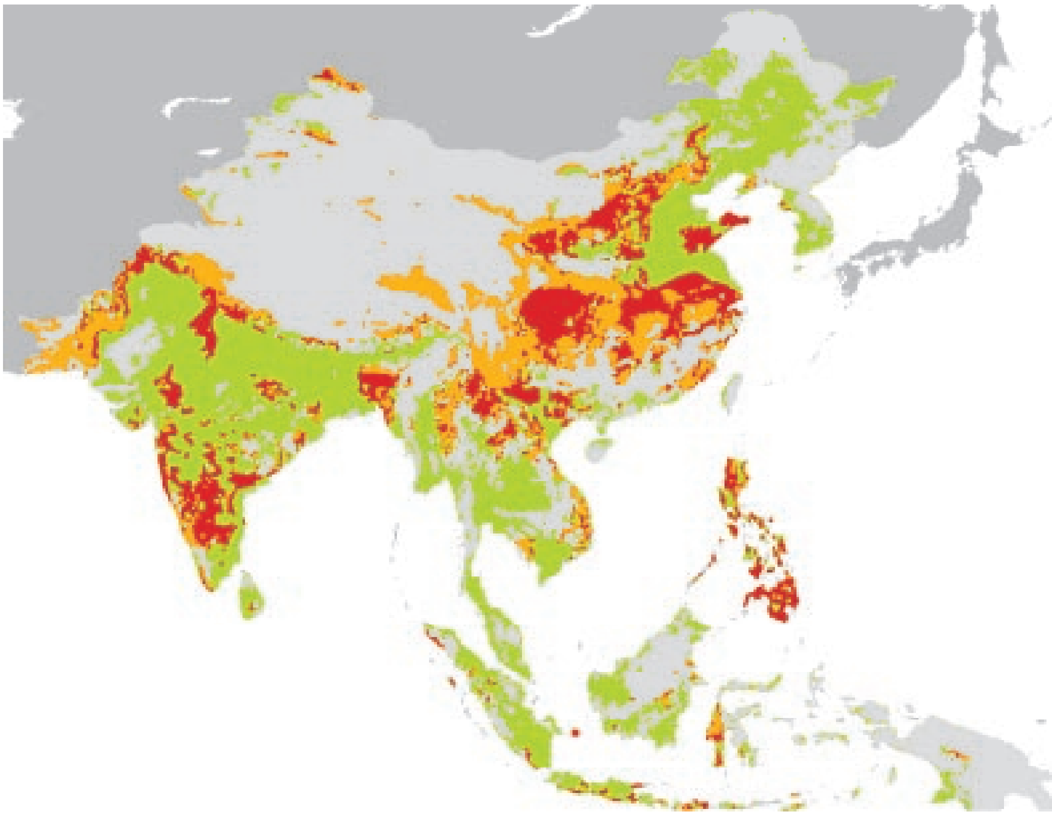
The United Nations Economic Commission for Europe (UNECE) defined water quality as the "physical, chemical, and biological characteristics of water necessary to sustain desired water uses" (UNECE, 1995, p. 5). Most aquatic species are able to adapt to natural changes in water quality, but human activities have added pollutants that threaten many species and require treatment to supply potable water.

Most of the human impacts on water quality globally have occurred over the last century (Millennium Ecosystem Assessment, 2005b). While, in the past, the main sources of contaminants comprised organic and faecal pollution from untreated wastewater (this continues to be the case in many developing countries), today, the most prevalent contaminants can be traced to agricultural and industrial production. Within agriculture, contamination associated with soil erosion, nutrient runoff and pesticides predominate. Livestock production is a major source of pollution in many countries, with nutrient contamination from wastes representing a growing problem (FAO, 2006a). A distinction should be made between point source pollution (a specific, confined discharge of pollutants into a water body) and non-point source pollution (a more diffuse discharge of pollutants). In most cases, agriculture is a non-point source of pollution, where the exact sources are diffuse and difficult to detect. An exception is large, highly concentrated livestock operations where impacts can be traced back to an identifiable source.

Improving water quality through changes in agricultural production systems generally involves reducing salinization and harmful runoff from agricultural fields in the form of soil erosion, pesticides and other agricultural chemicals or livestock waste. One means is the improvement of nutrient-use efficiency by matching more closely the application of fertilizers with the capacity of plants for nutrient uptake. Soil testing and improved timing of fertilizer application, as well as the use of cover crops and reduced tillage, are all useful means for this purpose (Tilman *et al*., 2002). Measures to improve the management of livestock waste can also contribute to enhanced water quality. Such measures include changes in the production process (feed management) and the collection, storage, processing and utilization of manure (FAO, 2006a).

A successful example of measures to reduce non-point source water pollution from livestock production is found in France. The Vittel bottled water company entered into agreements with farmers, encouraging them to modify their land-management practices to reduce nitrates in the water source (Perrot-Maître, 2006). The modified farming practices included the elimination

MAP 3
Croplands with high rates of human-induced erosion



Croplands with high rates of human-induced sheet erosion

Other lands with high rates of human-induced sheet erosion

Other croplands

Note: available at
http://www.fao.org/geonetwork/srv/en/google.kml?id=31153&layers=croplands_humaninduced_erosion
Source: FAO.

of maize cultivation for animal feed and application of agrochemicals, the use of extensive cattle ranching with reduced animal numbers, and the modernization of farm buildings to minimize nutrient runoff.

As this example illustrates, measures to reduce pollution caused by livestock production involve changes both to cropping practices in feed production and to techniques for raising livestock. The pollutants concerned include nutrient excretions of excess levels of nitrogen, phosphorus and heavy metals. Livestock waste can also include a variety of micro-organisms that are a potential hazard to human health.

Biodiversity conservation

The Convention on Biological Diversity (CBD) defines biological diversity as “the variability among living organisms from all sources including ... terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, among species and of ecosystems” (CBD, 1993, Article 2).

Biodiversity is commonly measured at the genetic, species and ecosystem levels, although it is difficult to define "units of biodiversity" for the purpose of carrying out transactions. Within any of these three levels, conservation of biodiversity involves maintaining the following dimensions (Millennium Ecosystem Assessment, 2005b):

- *variety,* reflecting the number of different types;
- *quantity and quality,* reflecting how much there is of any one type;
- *distribution,* reflecting where that attribute of biodiversity is located.

The Millennium Ecosystem Assessment concluded that human activities have led to a more rapid loss of biodiversity on Earth over the past 50 years than ever before in human history. It identified five key drivers of biodiversity loss: habitat change, climate change, invasive alien species, overexploitation and pollution. The Assessment argued that the loss of species and the progressive homogenization of many ecosystems continues to be one of the main threats to the survival of our natural as well as socio-economic systems (Millennium Ecosystem Assessment, 2005b).

The biodiversity associated with agricultural ecosystems is known as agricultural biodiversity, and is generally regarded as the multitude of plants, animals and micro-organisms at genetic, species and ecosystem levels, indispensable in sustaining key functions for food production and food security (CBD, 2000). It provides the basis of the food security and livelihoods of everyone (FAO, 1997).

Agricultural biodiversity is the outcome of the interactions among the environment, genetic resources and the management systems and practices used by farmers and is the result of careful selection and inventive development over millennia. It includes genetic diversity of crops and livestock as well as crop-associated biodiversity (e.g. pest-suppressive biodiversity pollinators, soil biodiversity).

Concerns have been raised in recent years over the loss of agricultural biodiversity through homogenization of agricultural production systems (FAO, 1997). For crop and livestock genetic diversity, two major concerns have been voiced: increasing levels of genetic vulnerability and genetic erosion (FAO, 1997). Genetic vulnerability occurs where a widely used crop or livestock variety is susceptible to a pest or pathogen that threatens to create widespread crop losses. Genetic erosion is the loss of genetic resources through the extinction of a livestock variety or crop. The main cause of genetic erosion is the replacement of indigenous varieties with improved ones. Loss of ecosystem services useful to food security is a further concern. Without proper management of agricultural biodiversity, some key functions of the agro-ecosystem may be lost, such as maintenance of nutrient and water cycles, pest and disease regulation, pollination and land erosion control.

The conservation of crop and livestock genetic diversity may be ensured either *ex situ* or *in situ*. *Ex situ* methods include seed and gene banks, while *in situ* conservation takes place in farmers' fields, ponds or forests. The two approaches are complementary; the *ex situ* collections preserve a static set of genetic resources, while *in situ* efforts preserve a dynamic process of evolution, as genetic resources adapt to changing pressures from natural and human selection.

The approaches used to conserve agricultural biodiversity link conservation to sustainable use by humans. Given the specific features of agricultural biodiversity, the mechanisms and tools used to guarantee its sustainable management, including conservation, are often specific and differ from those traditionally used for wild biodiversity (such as protected areas).

How can agricultural producers conserve biodiversity? The necessary measures depend not only on the type of biodiversity to be conserved but also on production systems and location. The sections that follow explore three main ways in which agricultural producers can contribute to biodiversity conservation: reducing agricultural expansion into biodiversity-rich lands; adopting agricultural production systems that support the joint production of biodiversity conservation and agricultural products; and conserving agricultural biodiversity.

Minimizing agricultural expansion into areas rich in wild biodiversity

Agriculture can contribute to wild biodiversity conservation by refraining from using land and water resources that are rich in species diversity. This approach includes both maintaining areas with relatively undisturbed ecosystems and retiring land or water areas currently in production located near species-rich areas, especially if they have limited suitability for agriculture. These areas can then be incorporated into protected areas such as national parks and reserves, which are the cornerstones of wild biodiversity conservation. The approach may also involve eliminating, reducing or improving agricultural production practices and overall land management in areas that have been identified as important "corridors" for wildlife migration and ecosystem connectivity.

Map 4 is one of several generated by a study of land-use change in the neotropics (Wassenaar *et al*., 2007) and provides an indication of areas at risk of conversion to agriculture in parts of South America. The study identified the areas at highest risk of conversion to pasture and croplands using a model that explicitly incorporates dimensions such as location, suitability and various factors affecting the relative economic values of land uses. The map identifies deforestation hotspot areas in red (at risk of conversion to pasture) and orange (at risk of conversion to cropland). Many of the ecoregions that would be affected by the projected deforestation are part of the WWF (World Wide Fund for Nature) Global 200 priority ecoregions (a collection of the most biologically diverse and representative habitats on earth) and others fall into the Conservation International biodiversity hotspot zones (Wassenaar *et al*., 2007; WWF, 2007). These are areas where crop and livestock producers could supply significant biodiversity conservation services by avoiding their conversion to agricultural use or by facilitating conservation in agricultural areas (e.g. by providing wildlife corridors linking habitat areas).

Conserving wild biodiversity in agricultural ecosystems

Agricultural producers can also conserve biodiversity within agricultural ecosystems. McNeely and Scherr (2002) outline a set of possible measures:

1. enhance wildlife habitat on farms and establish farmland corridors that link uncultivated spaces;
2. mimic natural habitats by integrating productive perennial plants;
3. use farming systems that reduce pollution;
4. modify resource management practices to enhance habitat quality in and around farmlands.

An example of the first case is found in Costa Rica, where windbreaks formed by planting a mix of indigenous and exotic tree species were established on 150 hectares spanning 19 farming communities. The windbreaks served as biological corridors connecting remnant forest patches in the area, and they also benefited farmers by reducing wind damage (McNeely and Scherr, 2002). Other examples that could fall into this category include the establishment of hedgerows and agroforestry. Schroth *et al*. (2004) provide a comprehensive review of the role of agroforestry for conserving biodiversity by providing corridors and new habitat for wild species, among other measures.

Shade-grown coffee is a prominent example of the second type of strategy. Shade-grown coffee is produced under the shelter of a canopy of trees of varying heights, providing an environment that tends to be attractive to migratory birds. In contrast, coffee grown under conventional systems has low levels of biodiversity (Pagiola and Ruthenberg, 2002).

Many examples exist that can illustrate the third category, that of a change in farming practices to reduce pollution. In Viet Nam, rice farmers' overuse of pesticides was generating off-farm pollution that harmed local habitats. An education campaign led to reduced pesticide use, benefiting the many species of frogs and fish that inhabit rice paddies. In China, intensive pesticide use to control the rice blast disease was substantially reduced by planting a diverse set of rice varieties. In the Philippines, soil erosion and subsequent pollution of waterways were avoided by introducing natural vegetation contour strips (McNeely and Scherr, 2002).

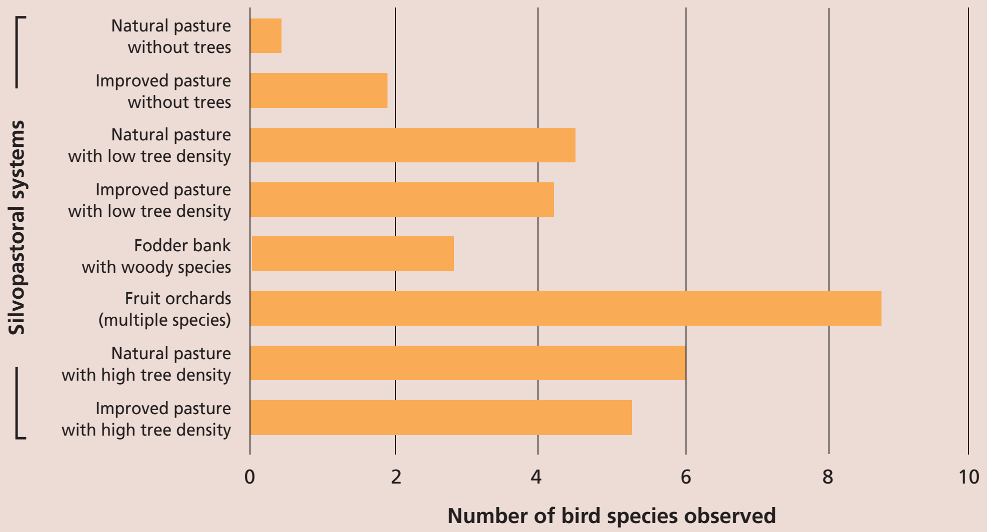
MAP 4
Projected expansion of cropland and pasture, 2000–2010

Note: available at
http://www.fao.org/geonetwork/srv/en/google.kml?id=31154&layers=cropland_pasture_expansion
Source: Wassenaar *et al*., 2007.

The reintroduction of short-term (over one to two years) improved fallow systems into smallholder agricultural systems in Kenya and Zambia provides an example of the fourth category. This measure not only helped to restore soil fertility but also provided a habitat for wild species (McNeely and Scherr, 2002).

In certain areas, silvopastoral practices can offer an alternative to cattle production systems based solely on pasture. Such practices include planting high densities of trees and shrubs in pastures, cut-and-carry systems whereby livestock are fed with the foliage of specifically planted trees and shrubs in areas previously used for other agricultural practices, and using fast-growing trees and shrubs for fencing and wind screens (Pagiola *et al*., 2007). The on-site benefits of silvopastoral practices to land users include additional production from the tree component, such as fruit, fuelwood,

FIGURE 5
Biodiversity impact of adopting silvopastoral systems in Esparza, Costa Rica



Source: Pagiola, 2006.

fodder or timber; maintaining or improving pasture productivity by increasing nutrient recycling; and diversification of production (Dagang and Nair, 2003).

As Figure 5 illustrates, silvopastoral practices also have important biodiversity benefits. They have been shown to play a major role in the survival of wildlife species by providing scarce resources and refuge; to have a higher propagation rate of native forest plants; and to provide shelter for wild birds. They can also help connect protected areas (Dennis, Shellard and Agnew, 1996; Harvey and Haber, 1999). In addition, silvopastoral practices can fix significant amounts of carbon in the soil and in the standing tree biomass (Fisher *et al*., 1994; Pfaff *et al*., 2000) and have a beneficial effect on water services (Bruijnzeel, 2004).

Conserving agricultural biodiversity

A wide range of methods exist for conserving agricultural biodiversity, depending on the specific component that is focused upon. Methods differ in terms of the degree of human intervention in the natural system, ranging from highly managed *ex situ* gene and seed banks to maintaining wild relatives of cultivated species in wilderness areas. Measures also include the on-farm conservation and utilization of so-called "landraces", or traditional varieties of crops and livestock, which are often highly adapted to their local environments. Diversity can be promoted by providing incentives to maintain a heterogenous set of crop varieties in production, particularly rare landrace varieties, or by managing field margins to encourage pest-suppressing natural enemies and pollinators. Jarvis, Padoch and Cooper (2007) provide an extensive overview of the tools used by farmers to conserve and further develop biodiversity in their fields.

Because agricultural biodiversity is directly linked to agricultural production, working within agricultural market channels to provide incentives to farmers to conserve agricultural diversity is an important strategy. In recent years, the international community has provided support to farmers for conserving agricultural biodiversity *in situ*. These programmes seek to increase the availability and productivity of diversity in production systems, or enhance the returns to maintaining diverse systems. Increasing the demand for diverse products through the establishment of labelling, certification or origin schemes and niche market development is one strategy (Bioversity International, 2006). Increasing the diversity of agricultural seed supply systems is another (FAO, 2006b). One example that involves direct payments to farmers for maintaining diverse crop varieties is the GEF-funded project "A Dynamic Farmer-Based Approach to the Conservation of African Plant Genetic Resources" implemented in Ethiopia from 1992 to 2000 (GEF, 2007a).

Other environmental services agricultural producers can supply

The sections above have focused on three different, but very important, environmental services. However, it should be underlined that, apart from these, agricultural producers can and do supply many other environmental services. Landscape aesthetics is one service from which some farmers are already receiving significant economic benefits in the form of ecotourism and agrotourism (Box 3). Other services for which some farmers are being paid include pollination services and reduction in the spread of animal diseases, crop diseases and invasive species. For example, some farmers in affected areas have received payments to cull chickens as a measure to prevent the spread of avian influenza.

Importance of scale, location and coordination in supplying environmental services

As the above discussion has shown, agricultural producers can implement numerous changes to improve the balance of services provided by agricultural ecosystems. The focus has been on the changes that individual farmers can make to increase the supply of each of three environmental services. However, particularly in cases of watershed management and biodiversity conservation services, both scale and location

BOX 3
Landscape aesthetics

Managing landscape aesthetics is another environmental service for which markets are developing, but which is not covered in detail in this report. Landscape aesthetics, or "rural amenities", involves the pleasure people gain from seeing, visiting or even knowing of the existence of certain landscape features. The pleasure can come from novelty (watching a geyser erupt), diversity (a hillside cultivated using a variety of practices), natural beauty (vistas of the Himalayas), culture (visits to a sacred place) or the continued existence of an endangered species in a far-away place.

Landscapes thus have distinct values in themselves that can be of different types. People may be interested simply in ensuring the continuing existence of certain landscapes, habitats or ecosystems, even if they are not benefiting from them directly in any other way. However, landscapes can also have more direct use values, exploited through activities such as nature tourism, ecotourism or agritourism. Nature tourism is any visit to a location with the primary goal of appreciating some element of nature. The term "ecotourism", in this context, is used to describe visits to places with unique flora and fauna, such as the Amazon watershed or the Serengeti Plains. Agritourism (or agrotourism) involves visits to landscapes where humans have practised agriculture in ways that result in attractive scenery and distinctive products and cuisine.

Provision of landscape aesthetics services often has important synergies with the provision of other environmental services, especially conserving biodiversity. Some destinations are set up to allow visitors to see unique collections of diverse species. Many of these destinations are protected, which increases the likelihood that they will maintain species lost in surrounding areas or regulate water quality and quantity. Nature tourism can enhance the conservation of biological diversity, especially when local communities are directly involved with tourism operators. If local communities receive income directly from a tourist enterprise, they are more likely to provide greater protection for, and conservation of, local resources.

Agriculture can have distinct, but differing, roles in ensuring the provision are highly relevant for the effectiveness of the changes, which in turn has implications for coordination requirements. Indeed, changes on the part of one producer aimed at improving a habitat or reducing erosion in a watershed are unlikely to be sufficient to provide these environmental services, unless the producer controls a large proportion of the land and water resources important for the service provision. This means that considering change at a landscape level is as important as it is at the scale of the individual production unit. It also means that the effectiveness of any given change may depend critically on coordinating the actions of a number of producers.

Table 4 (pp. 30–31) summarizes a set of management changes agricultural producers can implement to increase the supply of the three environmental services under discussion. It presents them in the context also of the associated landscape-level management and the degree of coordination among producers required for effective supply.

Technical versus economic potential to supply environmental services

The preceding sections have discussed the technical potential for agriculture to provide environmental services. This, essentially, tells us how much of an environmental service farmers *could* provide, but it is important to recognize that this is not the same as what they *are likely to* provide in the absence of additional incentives. The distinction corresponds to the difference between the technical and economic potential for supplying environmental services.

of landscape aesthetics services. These roles range from bringing or maintaining specific areas or landscapes under agricultural production to managing lands under agricultural production. Farmers may not necessarily take into account that their land may provide rural amenities when managing and deciding how to develop it. Indeed, in several developed countries, the provision of rural amenities is one of the main motivations behind the implementation of various publicly funded farmland protection programmes (Nickerson and Hellerstein, 2003).

There is an increasing private market for landscape aesthetics services. Ecotourism is growing rapidly, driven by higher incomes around the world, increasing ease and falling cost of travel and expanding information. World tourism spending is expected to grow over 6 percent per year (UNWTO, 1998, as referenced in Hawkins and Lamoureux, 2001) and is increasingly focusing on natural environments.

The overall size of the market for the landscape aesthetics and recreation services that agricultural landscapes provide seems likely to remain smaller. Payments to farming communities are likely to be limited to those living in or adjacent to areas of high tourist attraction. In many developed countries, a sector of the tourism industry has formed around pastoral, agrarian landscapes and the aesthetics and activities they offer, but a comparable industry has not yet formed in developing countries.

The most important buyers of landscape aesthetics and recreational services are likely to be private tour operators and related businesses, either directly or in aggregate groups working in a particular area of high scenic aesthetics. Private recreational hunters and fishers and private park visitors could also become buyers of landscape aesthetics and recreation services. There are many models now for using public park visitor fees to benefit community groups who protect landscape and recreational values. Some of these models could become significant in the future.

TABLE 4
Management options and coordination requirements for three environmental services

	ENVIRONMENTAL SERVICE	FARM-LEVEL MANAGEMENT OPTIONS	LANDSCAPE-LEVEL MANAGEMENT OPTIONS	DEGREE OF COORDINATION REQUIRED[1]
Carbon sequestration and greenhouse gas offsets	Carbon sequestration in soils	Soil organic matter management and enrichment, reduced frequency of cultivation, adoption of conservation agriculture, soil conservation practices, improved grassland management		Low
	Carbon sequestration in perennial plants	Increased area/use of perennial crops, farm forest management, agroforestry, natural regeneration, lengthened fallow periods, silvopastoral systems	Afforestation, natural regeneration of trees and forests	Low
	Carbon emission reduction	Agricultural machinery emission management, avoided deforestation	Reduced forest and fallow burning	Low
	Methane emission reduction	Improved livestock feed, peat soil management	Protection of peat areas from disturbance	Low
Watershed protection	Water flow regulation	Increased irrigation-use efficiency, protection of wetlands, farm drainage, range management	Well-designed road and path construction, revegetation of bare lands	Low
	Water quality maintenance	Reduced agrochemicals, filtering of agricultural runoff, improved nutrient-use efficiency	Maintenance of perennial vegetative filters protecting waterways	High
	Erosion and sedimentation control	Soil conservation and runoff management, perennial soil cover, adoption of conservation agriculture, range management	Road, path and settlement construction; revegetation of stream banks	Moderate
	Salinization and water table regulation	Tree-growing	Strategic tree-growing in the landscape	Moderate
	Aquifer recharge	Plot- and farm-level water harvesting	Community/ subwatershed water harvesting	Moderate
	Flood control	Diversion and storage ponds	Drainage channels and storage ponds, maintenance of natural floods	High
Wild biodiversity conservation	Protection of habitat for wild terrestrial species	Breeding area protection, maintenance of pure water sources, wild food sources in and around farm plots, timing of cultivation, increased crop species/varietal diversity	Natural area networks in and around farms, public and private protected areas	Moderate

TABLE 4 *(cont.)*

Management options and coordination requirements for three environmental services

	ENVIRONMENTAL SERVICE	FARM-LEVEL MANAGEMENT OPTIONS	LANDSCAPE-LEVEL MANAGEMENT OPTIONS	DEGREE OF COORDINATION REQUIRED[1]
Wild biodiversity conservation	Connectivity for mobile species	Farm hedgerows, windbreaks, removal of impenetrable barriers	Natural area networks in and around farms	Moderate to high
	Protection of threatened ecological communities	Restoration or protection of farm patches of natural habitat	Maintenance of corridors connecting natural habitat fragments through farm and other lands	Moderate to high
	Protection of wild species	Elimination of threats from toxic chemicals, breeding area protection, non-lethal pest control practices	Barriers to exclude wildlife from farmlands, compensation to farmers for wildlife damage to stocks and crops	Low to moderate
	Protection of habitat for aquatic species	Prevention of waterway pollution by crop and livestock wastes and agrichemicals, protection or restoration of on-farm wetlands	Natural revegetation along stream banks, protection or restoration of wetlands	Low to moderate

[1] Reasons for coordinated action may include the need for collective investments (e.g. to establish a community-wide windbreak), the indivisibility of investment (e.g. to restore a major gully), or the need for spatial coordination to produce the desired outcome (e.g. the re-establishment of riparian vegetation would only produce higher water quality if all landowners along the waterway participate).

Source: adapted from FAO, 2007c.

For example, from a purely technical perspective, improved land management over the next 50–100 years could theoretically make a major contribution to global carbon sequestration. Thus, Lal (2000) has estimated that the annual increase in atmospheric carbon dioxide concentration *could* be balanced out by the restoration of 2 billion hectares of degraded lands to increase their average carbon content by 1.5 tonnes per hectare in soils and vegetation through improved soil management practices such as reduced tillage and fertilization (see also Rasmussen, Albrecht and Smiley, 1998; Sa *et al*., 2001). However, the actual amount of carbon sequestration that farmers *will* supply depends on how much they will be paid for the soil carbon and on the costs they would bear in supplying it. Economic studies undertaken in the United States of America show that, at carbon prices in the range of US$50–100 per tonne, the economic potential falls far below the technical potential (Lewandrowski *et al*., 2004; Paustian *et al*., 2006).

The economic potential for supplying environmental services is a critical criterion when assessing the effectiveness of payments for environmental services in increasing the economic and environmental benefits available from agro-ecosystems. As stated in the opening paragraphs of this chapter, this potential is a function of the conditions of the agricultural economy in question. Population density, agro-ecological conditions, level of market integration and primary technology employed in agriculture are all important determinants of the current returns to land and labour in agriculture and the potential costs and benefits of introducing changes that would generate additional environmental services. These same factors also affect the level of economic development and thus the demand and willingness to pay for environmental services at the local level.

Conclusions

Agriculture has the potential to increase significantly the provision of environmental services such as climate change mitigation, biodiversity conservation, watershed protection and others, but this will require changes in the way in which agro-ecosystems are managed. How environmental services can be generated varies by the service, the type of production system and the agro-ecological context. The types of change needed to enhance the provision of ecosystem services range from shifts in land or water use (e.g. out of crops or fishing and into less intensive uses such as grasslands or forests) to changes within a given production system (e.g. the adoption of farming systems that provide higher levels of environmental services).

The biophysical processes involved in different ecosystem services have significant implications for policy responses. For example, there are no geographic limits for carbon emission reductions or mitigation; a tonne of carbon sequestered by a poor farmer hundreds of miles from any road has exactly the same value as a tonne sequestered by a commercial plantation near the capital city. In contrast, biodiversity conservation and watershed protection services are generally location-specific, with the former providing global benefits and the latter being primarily of interest to local and regional users.

Synergies often exist between the provision of different ecosystem services. Production practices adopted to enhance one ecosystem service may enhance others at the same time. For example, increasing soil carbon sequestration through the adoption of conservation agriculture can have beneficial implications not only for climate change mitigation and water quality but also for the provisioning services of food production. However, there are often trade-offs between the delivery of different ecosystem services, which are important to understand.

This chapter has focused on the technical potential of agriculture to supply enhanced levels of environmental services. Whether the necessary changes are economically feasible is central to determining if they can be achieved and what level of payments would be required to realize them. The next chapter takes up the issue of demand for environmental services: who would pay for environmental services, why would they pay for them and how much would they be willing to pay?