4. Supplying environmental services: farmers' decisions and policy options

Given the importance of environmental services, why are they not provided at higher levels? Environmental services are produced (or degraded) through the interaction of natural processes and the actions of individual decision-makers, including agricultural producers. For a variety of reasons, the full value of these impacts is not reflected in the incentives faced by ecosystem service providers. As a result, providers' actions may diverge from those desired by beneficiaries as a group.

Any approach to dealing with the unintended effects of agricultural production, whether negative or positive, must recognize the central role played by farmers. Each farmer is a natural resource manager, making decisions about how to use resources under his or her (or their) control to improve their well-being. It is farmers' collective decisions about how to transform natural and produced resources into desired goods that result in unintended outputs. Understanding their decision-making is crucial to enhancing ecosystem service delivery.

Agricultural policies play a key role in shaping the incentives to which farmers respond. Indeed, such policies – for example, through subsidizing farming activities, providing infrastructure such as roads and water supply, or more explicit incentives for land-use changes such as the conversion of wetlands or forest land to crop production – have often encouraged farmers to expand or intensify cultivation.

This chapter discusses the supply of environmental services, taking as its starting point the decision-making of the individual farmer. It then lays out policy options to enhance the supply of these services and explores the role that payment programmes can play. It also presents estimates of possible supply responses to payments for environmental services.

The role of individual farmers' decisions

The provision of all agriculture-based ecosystem services begins at the level of the plot of land that is managed by a single individual or group of individuals.[10] For the purpose of this discussion, this manager, whether individual or collective, is referred to as a farmer. Farmers' decisions about how to use the resources inherent in the plot of land are driven by the goal of improving their well-being and that of their families. Well-being is defined across many dimensions, including income, security of livelihood, health, leisure and cultural values.

Each plot embodies a set of natural and socio-economic resources. Natural resources include inherent geophysical characteristics (e.g. soil quality, slope and elevation, and climate) and constructed characteristics (e.g. bunds, irrigation systems and terraces). Socio-economic resources include characteristics such as the property rights under which the plot is held and used, the cost of access to markets and the prices at those markets. Farmers also have capital of different kinds – physical (e.g. equipment and animals), financial (e.g. cash, bank accounts and personal assets), human (e.g. education and on-the-job skills) and social (e.g. knowledge of the community and local community sources of support).

Farmers combine the natural and socio-economic resources at their disposal to produce goods and services. Their economic activities may include crop, livestock, fishery and forestry production as well

[10] The term "land" is used as the most easily understood unit of natural resource to illustrate the argument. It could also be substituted with other forms of natural resources – for example trees or water. However, in many cases decisions over these are also driven by land-use decisions.

as non-agricultural activities. Decisions farmers make about how to manage their resources are influenced by the relative return or benefit each activity provides, which, in turn, depends on available technology and prevailing market and environmental conditions. For example, the amount of agricultural production or carbon sequestration 1 hectare of land can produce depends on the agro-ecological characteristics of the site as well as the technology employed in the production process. The returns to the farmer from either activity depend also on market prices and on distance to market.

Agricultural, environmental and economic development policies all contribute to shaping farmers' decisions. Policies can have a significant impact on the prices of inputs (e.g. land, labour, credit, fertilizer and pesticides) as well as on output prices. These factors, together with the degree of integration into international commodity markets, contribute to decisions about what to produce and how. Policies on land taxes, zoning and settlement also influence farm-level decisions, as do the types of technology available to farmers, their relative accessibility, and their adoption. Policies also determine investment in infrastructure such as roads, irrigation facilities, markets and communication, which, in turn, is reflected in the balance of incentives and constraints farmers need to consider in making decisions.

The allocation of productive resources to economic activities generates a wide variety of outcomes, which may include private production benefits from land use (e.g. agricultural products), private benefits from wage income and positive or negative impacts on neighbours or on the environment (e.g. carbon sequestration or emissions, biodiversity conservation or losses, and watershed protection or degradation). These indirect effects are termed "externalities" (see Box 1 on p. 6).

In the absence of deliberate policy intervention, the amount of these externalities generated by farmers is coincidental – determined by the choices they make in managing agricultural ecosystems to generate intended outputs, such as agricultural products and/or wage income. There is no guarantee that the amount of any positive externality produced will be optimal from society's perspective; in many cases, negative externalities will be generated. If society wants farmers to provide more positive externalities and fewer negative ones, then mechanisms must be found to encourage their provision.

Constraints against the provision of environmental services

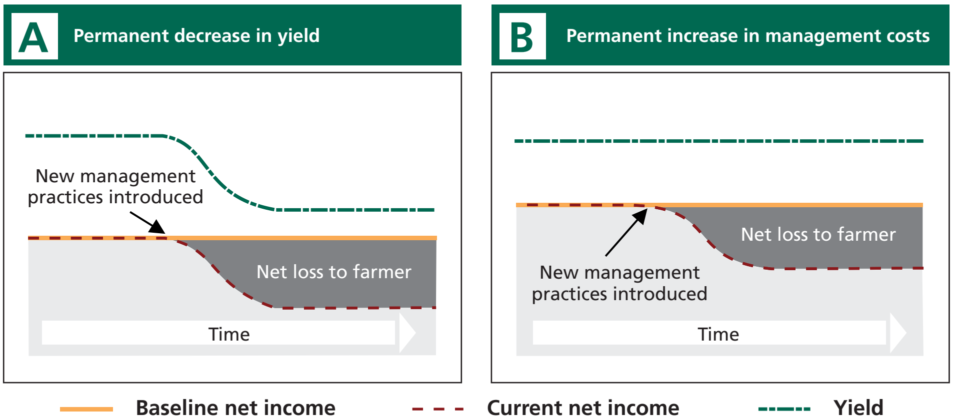
Why don't farmers, fishers and foresters manage natural resources in ways that increase the provision of environmental services? The answer to this is complex and varies according to the influence of a range of social, economic, political and technical factors. In some cases, practices that generate more environmental services may not be adopted because they would reduce farmers' net benefits (i.e. they involve significant opportunity costs). In other cases, improved practices that would be potentially profitable for farmers may not be adopted because of other barriers (e.g. lack of information or credit, or insecure land tenure).

Management changes that involve opportunity costs

In general, it is reasonable to expect that farmers will choose the mix of production practices that maximizes their well-being – given the resources and opportunities available to them. Many changes in resource use that could benefit the environment are not likely to be adopted by farmers in the absence of motivating policy measures, because they would result in lower benefits to the producers. For example, setting land aside from crop production and placing (or leaving) it under natural grass or forest cover could enhance carbon sequestration, water quality and biodiversity, but might result in lower returns to the farmer and his or her household. Reducing livestock numbers or managing manure to reduce nitrogen runoff to surface water, infiltration to groundwater or emissions to the atmosphere could benefit the environment but would probably increase costs or reduce returns to the farmer.

Figure 7 illustrates situations where farmers face such opportunity costs in the form of foregone benefits. In scenario A, high levels of environmental services can be

FIGURE 7
Barriers to the adoption of improved management practices: permanent decrease in farm income



Source: FAO, 2007c.

provided only by significantly reducing the intensity or extent of agriculture at the plot or farm level. Farmers thus face a permanent decrease in yields. They may continue to make a profit – especially given that the cost of inputs is likely to decline – but they would earn less than they could otherwise. In this case, payments would typically be needed to compensate farmers for the opportunity cost (i.e. foregone income) of the new practices; these payments would need to be maintained in perpetuity to ensure a continuing stream of environmental services. This scenario forms the basis for the majority of established agri-environmental payment schemes, including many United States and European conservation payment programmes. Conservation easements represent one alternative for providing environmental service payments indefinitely. These are legally binding agreements, sold by the landowner, that restrict the use of the land for certain environmentally damaging activities. However, permanent or long-term conservation easements on private lands are an established technique in only a handful of developing countries and, where they exist, they may be insufficiently prescriptive to guide agricultural management practices and may still involve significant ongoing monitoring and compliance costs (Wiebe, Tegene and Kuhn, 1996).

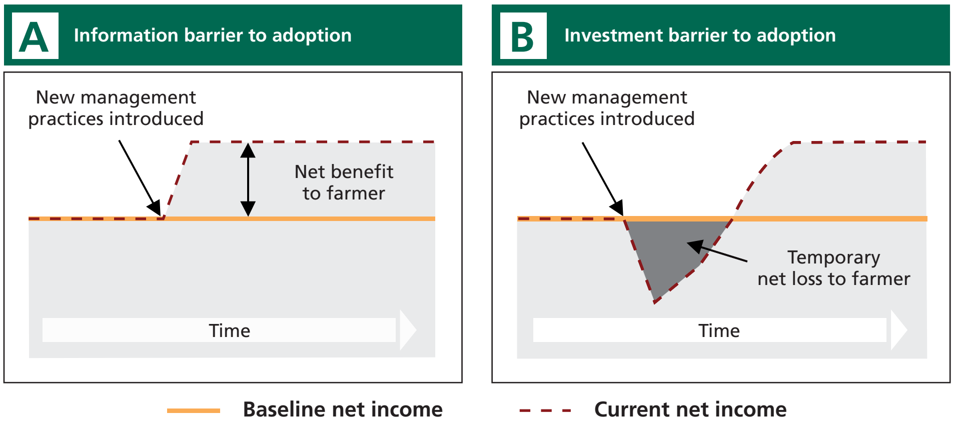
Beyond the decision of the individual farmer, a further consideration in this scenario is the potential impact on local or regional food security if large areas of agricultural land were to be taken out of food production completely to provide other ecosystem services (e.g. a switch from crops to forest plantations for carbon sequestration). Design options that maintain strategic areas of agricultural land or that pay for the establishment of alternative avenues for food security may need to be incorporated into the PES programme. These are discussed in more detail in Chapter 6.

In scenario B of Figure 7, land use or production is not affected by the new management practices, but enhanced provision of environmental services requires farmers or farming communities to incur continued additional management or investment costs over time (e.g. for protecting and managing forest fragments or managing wastes from production). As in scenario A, payments to compensate farmers for their opportunity costs would be required in perpetuity to ensure a continuing stream of environmental services.

Other barriers to adopting beneficial changes

An array of complicating factors, particularly in developing countries, serves to increase opportunity costs or raise other barriers to the adoption of new practices. Limited access to information, appropriate technologies and finance, as well as insecure property

FIGURE 8
Barriers to the adoption of improved management practices: information and investment constraints



Source: FAO, 2007c.

rights and legal or regulatory constraints, count among the most significant barriers farmers face. These constraints are often compounded by poorly functioning markets and infrastructure, risk and difficulties in the collective management of commonly held resources such as pasturelands or fisheries. Producers facing one or more of these problems will find it difficult to change their resource management practices in ways that could provide a higher output of environmental services – and in some cases of conventional agricultural commodities also. Sustainable land-management practices often fall into this category. These include cropping and livestock practices characterized by improved soil, plant nutrient and water management and often lead to higher farm productivity and income as well as increased provision of environmental services such as soil carbon sequestration, biodiversity conservation and watershed protection. Conservation agriculture, which encompasses a range of agricultural practices involving reduced tillage and increased ground cover, is a good example of a practice that is often privately profitable to farmers over time but whose adoption is hampered through lack of information, technology and inputs.

The following paragraphs discuss five types of barrier to adopting beneficial changes: lack of information, inability to afford investments, risk aversion, insecure property rights and poorly performing markets. The first two are illustrated by Figure 8.

Farmers may lack information on production technologies or practices that could both maintain or increase their own well-being and provide enhanced environmental services. In scenario A of Figure 8, the adoption of new management practices to increase the supply of ecosystem services is nominally a win–win situation that simultaneously increases farmers' net income and improves environmental quality. The new practices may increase net income by increasing production output (e.g. through enhanced soil fertility or water management), by reducing input costs (e.g. by reducing labour needs or the use of purchased chemical inputs), or both. Many traditional rural development programmes attempt to do just this, albeit not under the title of PES programmes and often without explicit contractual arrangements linking payments to provision of environmental services.[11]

In Brazil, the results of a survey of 70 producers in the Brazilian Cerrado region in 1993 identified lack of information as a barrier to adopting conservation agriculture

---

[11] One initiative to improve the access of farmers and technical advisers to information on improved technologies is the World Overview of Conservation Agriculture Technologies (WOCAT) project, which facilitates the sharing of information about soil and water conservation technologies. The project database is available at http://www.wocat.net/.

TABLE 8
Lack of information as an obstacle to adopting conservation agriculture

RESPONSES TO THE QUESTION "WHY DON'T FARMERS ADOPT ZERO TILLAGE?"[1]	POSITIVE RESPONSES[2]
1. Insufficient technical knowledge.	39
2. Know nothing at all about zero tillage.	35
3. Fear of trying and getting it wrong.	29
4. Think that it is necessary to buy an expensive zero-tillage planter.	24
5. Erosion losses under conventional cultivation are not significant.	9
6. Have not seen research results validating the technology.	9
7. Zero tillage is not accepted for crop insurance.	5
8. My agronomist does not recommend it.	3

[1] Data collected from a survey of small-scale farmers in the Cerrado region of Brazil in 1993.
[2] *n* = 70.
Source: adapted from FAO, 2001.

(including zero tillage) techniques that had been shown to be privately profitable (Table 8) (FAO, 2001). In this instance, demonstrations and technical information provided by NGOs and extension services succeeded in removing this constraint. Thousands of Brazilian farmers have subsequently adopted conservation agriculture, with an estimated 23.6 million hectares in production in 2004/05.

It has been established above that farmers can only be expected to adopt new management practices if they believe that their well-being (or that of their families) will be enhanced over a relevant time frame. Well-being depends critically on income. Nevertheless, even without the prospect of increased income, increased awareness of the external damage caused by certain production practices may lead some farmers to change their practices, motivated by notions of good stewardship (Box 9).

Inability to afford investments requiring financial expenditures in the short run in order to obtain benefits in the long run constitutes a second major reason why farmers sometimes fail to adopt practices that offer higher returns (Dasgupta and Maler, 1995; Holden and Binswanger, 1998). This problem is particularly acute for the poor, who may lack access to credit as well as reserves of wealth with which to finance such investments (Hoff, Braverman and Stiglitz, 1993; Sunding and Zilberman, 2001). Wunder (2006) cites the example of moving from slash-and-burn to perennial cropping systems, which are far more profitable for farmers and also generate higher levels of environmental services, but are not adopted because they require large capital investments and involve risks and market development costs.

In scenario B of Figure 8, the adoption of new land uses or management practices leads to a temporary decline in net farm income resulting from agro-ecological disequilibria associated with the transition. For example, a change to organic or no-till production may initially give rise to additional weed competition, nutrient deficiencies and similar problems. After a few years, however, previous production levels will be regained and then surpassed, eventually levelling off at a new, higher equilibrium of net income. The delay in benefits, combined with lack of wealth or access to credit, may be a barrier to adoption. Under this scenario, farmers might require environmental service payments during the transition period to offset their foregone revenue; after which payments may no longer be needed. Schemes for converting land use from low-value annual crops to higher-value tree plantations (for the provision of carbon offset or watershed conservation services) that provide payments

BOX 9

Environmental education and the supply of environmental services

Timothy J. Dalton[1]

Numerous studies have established the linkage between education and voluntary effort to produce environmental services. Extension education and information acquisition positively influence the adoption of technologies to abate soil and water quality damage caused by agricultural production (Feather and Amacher, 1994; Norton, Phipps and Fletcher, 1994; Baidu-Forson, 1999; Dasgupta, 1999; Lichtenberg and Zimmerman, 1999; Price 2001; Alrusheidat 2004). For example, Kenya's National Soil and Water Conservation Programme was successful in inducing as many as a million farm families to adopt soil conserving practices voluntarily over a 12-year period ending in 2000 (Longley *et al*., 2005). Likewise, limited attention to environmental education has been shown to be a factor in the low rate of adoption of soil conservation technologies in the Philippine uplands (Cramb *et al.*, 2000). Dietz and Stern (2002) argue that environmental education is critical to link private actions with desirable social outcomes and remove incentive barriers to the adoption of practices producing environmental services. Joint learning through environmental education programmes can be a cost-effective strategy for generating widespread environmental service supply by harmonizing the activities of heterogeneous individuals (Feather and Amacher, 1994; Glachant, 1999). Farmers may lack information on the long-run financial and environmental benefits of providing environmental services, and this may reduce their farm-level provision (Amacher and Feather, 1997).

[1] *University of Maine, United States of America.*

to enable producers to afford the investment necessary to establish tree nurseries fall into this category.

In both scenarios, the opportunity cost to farmers of supplying the environmental service is negative – indeed, they are better off with the new land-use system even in the absence of payments. The system generates sufficient private incentives to motivate farmers to maintain it, which increases the likelihood that the environmental service provision will be permanent even if payments for the services are discontinued. It should be recognized, however, that opportunity costs are dynamic and may shift with changes in economic conditions (e.g. the prices of agricultural inputs and products). Farmers may then have an incentive to abandon the practices in favour of others that are less environmentally benign. Thus, it cannot be assumed that temporary payments will result in high levels of environmental services being provided in perpetuity.

An unacceptable degree of risk (in terms of variability of outcome) constitutes a third barrier to the adoption of profitable innovations that also enhance environmental services. Perception of risk influences the way farmers manage their resources, particularly where insurance is not available or is ineffective. This is particularly pertinent for poor people, who are generally more risk-averse and likely to lack access to formal means of insurance, such as through financial markets (FAO, 1999). A major risk-coping strategy for many poor rural households is to meet their subsistence food requirements from their own production as a critical means of insuring against food insecurity (Fafchamps, 1992; Sadoulet and de Janvry, 1995). Insecurity may arise from either the household's lack of ability to buy food or the lack of food availability. Consequently, the impact of management changes on the security of the farm household's food supply is a critical issue that can prevent the adoption of changes that may be more profitable on average, but that incur higher risks.

Some farmers insure against risk by maintaining a set of assets that they can rapidly liquidate in times of trouble (Rosenzweig and Binswanger, 1993; Udry, 1994; FAO, 1999). A standing forest, for example, represents a potential source of income that can be accessed through logging in the case of sudden need. Holding livestock also represents a common form of insurance against possible future shocks. Farmers may thus be unwilling to introduce changes to their production systems that involve a loss of these means.

Property rights comprise a fourth key determinant of the incentives and constraints faced by land users in making land-use decisions. Lacking, conflicting or poorly defined property rights to land, water and other natural resources are a major barrier to introducing changes in the management of these resources – particularly when the changes would require up-front investment in order to obtain a return in the future. Producers who lack confidence in their ability to reap the future benefits of a change in land use will be reluctant to make such a change. Uncertain or complex property rights reduce the incentives of land users to adopt practices that offer increased private returns over the long term, even if they can afford the initial investment. Investments or practices that increase soil organic matter, for example, could both increase farm productivity and enhance carbon sequestration for climate change mitigation over the long term, but incentives to adopt such measures will be weak in the absence of secure property rights.

The need to coordinate group activities in managing a common pool resource such as communal pastures can also be a barrier to land-use changes (Dasgupta and Maler,

BOX 10

Land tenure and environmental services: insights from the Philippines and Nepal

Awarding land tenure to farmers can be an important means of generating environmental services as well as improving farm welfare. Case studies from land-tenure projects in the Philippines and Nepal provide insights into the way different tenure instruments may affect environmental service provision.

In the Philippines, community-based forest management is a development strategy for sustainable forestry and social equity in the uplands. It was adopted formally in 1995 in response to rapid deforestation caused by excessive and indiscriminate logging, shifting agriculture and inefficient forest management. The two primary tenurial instruments are the Community-based Forest Management Agreement (CBFMA) and the Certificate of Stewardship Contract (CSC). The CBFMA is a production-sharing agreement between the Department of Environment and Natural Resources and the participating people's organization for a period of 25 years, renewable for another 25 years. The community commits itself to protecting the entire forest in the CBFMA area against illegal logging, slash-and-burn agriculture, forest and grassland fires and other forms of forest destruction, in return for the right to utilize forestland resources in a sustainable manner, using environment-friendly, labour-intensive harvesting methods for timber and non-timber resources. Communities are also allowed to harvest existing mature plantations of fast-growing hardwoods. CSCs are awarded to individuals or families actually occupying or tilling portions of forest lands within an existing CBFMA. CSCs also cover a period of 25 years, renewable, and cover a maximum of 5 hectares. Soil and water conservation measures (vegetative and physical) are mandatory on CSC land, and agroforestry is common. CSCs are transferable to next of kin and can be sold with the prior consent of the people's organization.

In Nepal, leasehold forestry was designed to achieve the dual goals of poverty reduction and ecorestoration targeted specifically at degraded forestland areas. Forest leases are awarded for a maximum of 40 years, renewable. Poor communities are exempt from the leasehold fee and have so far

1995; Bromley, 1998). In addition, property rights for a given land area may overlap, such as rights to trees, water or post-harvest residue collection (Dasgupta, 1993). In some cases, the influence of specific land uses on property rights may constitute a barrier. In some areas, for example, failure to cultivate crops may be seen as a relinquishment of rights and result in land being allocated to other farmers; conversely, tree planting may be seen as an assertion of long-term property rights and trigger conflict. Either situation could complicate the adoption of practices that enhance environmental services.

Inexistent or poorly defined property rights to land and water are particularly problematic for poor rural land users, preventing them from making the necessary investments to achieve a sustainable pattern of natural resource management (Dasgupta, 1996; Deininger, 1999; Lipper, 2001; FAO, 2005b). Where the poor do hold rights over resources, they are often held as common property. A diverse range of programmes that address the issue of property rights have been implemented in developing countries, including agrarian reform, community forestry and land-titling programmes. Box 10 describes two examples and their implications for environmental service supply.

A final category of barrier that farmers may face in adopting new production systems is a failure of agricultural input or output markets to transmit demand effectively. Many consumers would be willing to pay a premium for products that have been produced in accordance with environmentally friendly standards, such as organically labelled produce. Even though price premiums might, in theory, compensate farmers for the costs of

been the main beneficiaries of leasehold forestry. Leaseholds may be granted for producing raw materials for forestry industries, selling or distributing forest products from afforestation, operating tourism, agroforestry and maintaining insects, butterflies and wildlife.

In both the Philippine and Nepalese studies, tenure programmes resulted in increases in economic well-being and environmental benefits, but these were highly site-specific, depending upon the physical and ecological context as well as vicinity to settlements and ease of market access. In the Philippine study, for example, direct use values of forest conservation ranged from 31 to 90 percent of overall benefits. In the Nepalese study, wide variation in the profitability of the sites was found, also affected by their access to markets.

The case studies indicate that the provision of environmental services such as biodiversity conservation and carbon sequestration increased under both programmes, but improved tenure alone is not likely to be sufficient to induce increased supply. One important reason is that barriers other than lack of tenure inhibit the potential supply response; indeed, farmers' lack of capacity to make the investments necessary to maintain a productive forest and enforcing the management agreements were problematic in both cases. In the Philippine study, the tenure to single households was much more effective than the community tenure instruments in generating both private returns and environmental services. However, that may have been a result of allowing a significantly greater utilization of resources under the private tenure than under the community-based instruments. Finally, both studies indicate that, as project costs were substantial, awarding tenure is a relatively expensive means of generating environmental services, although potential long-term social benefits may justify the expense.

Source: FAO, 2006d.

BOX 11
Can high-value agricultural exports enhance environmental services? One example

Almost 10 000 farmers in the Highlands of Madagascar produce vegetables, mostly hand-picked fine French beans for supermarkets in Europe, where they fetch a price that is up to three times higher than the price for the more industrially produced French beans.

As is increasingly common in international trade, the firm that contracts with the farmers and exports the produce is obliged to meet the requirements of European buyers related to a variety of characteristics including the quality of the product (length of the beans, colour, etc.) and ethical standards (no use of child labour, for example). The exporting company has set up an elaborate system of contracting and on-farm monitoring. The imposition of the product and process standards and requirements calls for a major organization in terms of monitoring and control. In this global supply chain, small farmers' microcontracts are combined with extensive farm assistance and supervision programmes to fulfil complex quality requirements and phytosanitary standards.

One of the benefits to the Malagasy farmers of contracting with the exporting firm is that it teaches them how to make compost. Its main benefit on the fields is in maintaining the soil structure, providing nitrogen and other minerals that promote healthy crop growth and in enhancing the soil's ability to retain moisture. The benefits spill over to other crops; 93 percent of the farmers report that they have changed the way they cultivate their other off-season crops. Composting may also have beneficial impacts on carbon sequestration and on water quality and quantity. Small farmers who participate in these contracts have higher welfare, more income stability and shorter lean periods.

Source: adapted from Minten, Randrianarison and Swinnen, 2007.

compliance, these niche markets are often characterized by greater price volatility and non-price marketing barriers (Regouin, 2003; Smit, Driessen and Glasbergen, forthcoming). In other instances, specific market outlets may motivate farmers to adopt environmentally progressive management practices. Retailers may encourage the application of environmentally beneficial technology in the production of high-value products for a number of reasons (see Box 11). However, environmental benefits will only be realized if farmers are able to comply with buyers' terms and find it worthwhile to do so.

Poorly performing input markets can also serve as a barrier: some inputs, such as non-conventional seed varieties or organic fertilizers, may not be available for farmers to purchase because the input markets are poorly developed (FAO, 2006c). Input prices may also be distorted artificially by policies, as in the case of fertilizer subsidies common throughout Asia, which provide incentives for overuse (Pingali *et al*., 1998).

Policy options to shape farmers' incentives

Many options are open to policy-makers for enhancing the incentives for resource users to supply services desired by society. In the past, non-market instruments such as regulations or taxes predominated. Today, market-based approaches, such as payments for environmental services, are increasingly being used to complement these earlier instruments. This section briefly examines five possible approaches to addressing the situation in which farmers face opportunity costs in providing the desired level of an environmental service. This is followed by a more detailed description of the PES approach.

- **Command-and-control**. In this approach the government uses its regulatory powers to mandate certain behaviours, proscribe others, and impose penalties for non-compliance. Command-and-control is the norm for pollution control in industrial settings. It has also been used indirectly to provide services related to wetlands and to protect biodiversity. The creation of a national park is one example of this approach. Implementation requires continuous and effective monitoring to supervise compliance and a functioning legal system to punish non-compliance.

- **Financial penalties and charges**. This approach modifies behaviour through the financial signals of taxes and fees. Such an approach does not prohibit certain activities outright; rather, it makes them more expensive (e.g. applying a charge per kilogram of chlorofluorocarbon [CFC] purchased). To be most effective, the penalty would be applied directly to the negative externality (e.g. the quantity of nitrogen or methane emitted from livestock production), but where the administrative costs of the direct approach are high, which is often a defining characteristic of externalities, the penalty can be applied to the activity that generates the externality (e.g. the production of livestock). Again, this approach requires a functioning taxation and legal system, as well as effective monitoring and enforcement.

- **Removing perverse incentives**. In some cases, policy measures generate incentives to produce negative externalities. Some measures to support the agriculture sector can create incentives for environmentally damaging responses on the part of farmers. One example is fertilizer subsidies that create incentives for farmers to apply excessive amounts of chemical fertilizers, leading to runoff and water contamination, or energy subsidies that increase groundwater withdrawals. Much of the impact of support policies depends on how they are formulated, i.e. whether they are linked or "coupled" to specific practices or inputs, or take the form of direct payments. Generally, a switch from price supports for either inputs or outputs to direct income payments for agricultural support policies is considered to be less likely to cause environmental damage. However, even direct payments may lead to incentives for generating negative externalities if they are based on past production or input levels (OECD, 1998).

- **Establishing property rights to the externality**. This instrument relies on the privatization and allocation of rights to generate an externality. Examples are permits to emit a defined quantity of air pollution or carbon. In "cap-and-trade" programmes, such as the sulphur dioxide trading programme in the United States of America and the flexible mechanisms under the Kyoto Protocol, these entitlements may be traded. In practice, property rights instruments often work in combination with other instruments. Trading programmes, for example, rely on regulations to limit the total number of permits or quantities of emissions that are allowable.

- **Payments for environmental services**. Payments for environmental services compensate the producer for the benefits foregone as a result of switching systems to generate a different combination or higher levels of environmental services. In many cases, payments are made to producers who undertake to reduce the environmental damages they inflict on others through their production decisions – for example by causing erosion, which affects local water systems. However, PES programmes may also be used to reward agricultural producers for generating environmental services that offset damages from other sectors, or they may simply be a way of motivating farmer behaviour to match consumer demands for specific environmental attributes.

Each of the above policy measures combines attributes of market and regulatory approaches. Market-based approaches are sometimes thought of as distinct and separable from "non-market" approaches. This is a false dichotomy. No market exists in isolation from social, political and legal rights and institutions (whether or not these are formally defined). And no social, political or legal intervention occurs without implications for markets. Both – together – create interests and incentives that motivate individual (and sometimes collective) actions that, in turn, determine individual and collective well-being.

Payments for environmental services can be seen in this light. On the one hand, they can be described as a market-based approach in that they involve direct financial incentives to encourage actions that would not otherwise be rewarded, generating benefits that would not otherwise be realized. Alternatively, they might be seen as a political or legal intervention in which farmers are endowed formally with rights to use natural resources in specified ways, and allowed to sell some or all of those rights if they wish. Whichever way they are described or perceived, payments for environmental services involve both institutional interventions and market implications.

Other approaches do likewise, to varying degrees, and each implies a particular distribution of property rights. For example, command-and-control measures and approaches involving taxes and user fees both imply that society (in the form of the government) holds the right to the resources or services in question; the difference is that in the second case society is willing to sell or rent those rights to other users. In the case of cap-and-trade programmes, society may grant an initial allocation of permits to existing producers (explicitly or implicitly acknowledging that the producers hold those rights initially), or society may sell those rights to existing producers (if society claims those rights initially).

Why payments?

When are payments the right policy instrument to generate higher levels of environmental services from agricultural producers? To answer this it is necessary to distinguish between situations where farmers are asked (i) to enhance the provision of certain environmental services that may be degraded or undersupplied as a result of current agricultural practices, and (ii) to offset pollution generated in other sectors. The issue of the appropriateness of payments is different for each case. In the first case, the basic question is whether farmers should be paid to reduce negative externalities rather than be required to bear the cost themselves. In the second, the important question is how efficient offsets are in meeting the intended objective.

Reducing negative externalities from agriculture

When should farmers be paid to reduce the negative impacts of their actions on others, rather than required to bear the cost of changing practices? The appropriateness of the PES approach depends fundamentally on whether the rights to use or degrade the environmental services in question are held initially by the producers or by society. If those rights are held by producers, society must pay producers if more or different environmental services are desired. If those rights are held by society, the producers must pay society if they degrade those resources or services.

There are no simple answers to this question of the allocation of property rights, and the answer may well differ from one service to the next, and from one context to the next. In the case of negative side-effects from industrial production, it is generally accepted that the polluter should pay, whereas in the case of negative side-effects from agriculture this has not historically been the case. The difference may have to do with scale of production, or historical precedent, or equity considerations, or relative difficulty in identifying the source or magnitude of negative side-effects. Regardless, the distinction is blurred where agricultural production occurs on a large and concentrated scale, as in the case of large concentrated livestock operations; in fact, such operations are increasingly treated more like industrial point sources of pollution.

In the case of smaller farmers, whom society has historically allowed to use resources in ways that may have adverse environmental impacts, changing circumstances may raise new questions. For example, if farmers have been using certain practices for generations and the impacts of those practices are being felt downstream for the first time because of population growth or changing preferences downstream, who should pay the cost if society wishes farmers to change their practices? Is the situation different if downstream impacts increase because the number of farmers upstream increases, even if their practices do not? What if society's preferences change because of new information about the consequences of impacts that have been occurring all along?

Equity and power relationships also enter into the calculation. When polluters have sufficient political power, they may influence the government to move away from taxes or direct control (Buchanan and Tullock, 1975). On the other hand, if farmers do not have the resources to invest in pollution control, payments may be politically preferable to the possibility of reduced income (Hochman, Zilberman and Just, 1977) – especially if the providers of environmental services are poorer than the beneficiaries (Pagiola and Platais, 2007).

Economic theory suggests that paying farmers to change their practices or requiring them to bear the costs should be equally efficient in controlling pollution problems – *if* markets are competitive, property rights are enforceable and there are no transaction costs (Coase, 1960). In reality, these conditions rarely apply. The degree to which these conditions do not hold has implications for how efficient payments for environmental services could be, as well as for their distributional implications.

In practice, producing environmental services by reducing agricultural pollution often requires a cumulative effort by producers who are spatially dispersed and operating under a wide range of land uses and land types. In such cases a command-and-control approach to pollution control is difficult to implement (Pagiola, 2006; Wertz-Kanounnikoff, 2006).

A major advantage of PES programmes is their capacity to manage externalities. This is particularly important where information about the source of the problem is lacking and there are multiple potential producers of a benefit with different marginal costs of provision (Weitzman, 1974; Pagiola, 2006; Wertz-Kanounnikoff, 2006). Price-based mechanisms are more efficient than quantity-based measures (such as mandating behaviour) in this situation because they "screen out the high cost producers, encouraging them to produce less, and encourage low cost units to produce more" (Weitzman, 1974, cited in Wertz-Kanounnikoff, 2006).

Agriculture as a source of offsets for negative externalities generated in other sectors

When payments are made to agricultural producers to offset or mitigate negative externalities generated in other sectors, the non-agricultural polluter is paying the agriculture sector to meet a compliance requirement. This situation arises under cap-and-trade types of environmental regulation, such as the flexible mechanisms of the Kyoto Protocol, whereby industries under obligation to reduce carbon emissions are allowed to purchase emission offsets from agricultural producers in the form of increased carbon sequestration in their land use. In this case, agricultural producers themselves do not have any legal obligation to reduce emissions, but they do have an opportunity to offset the emissions of others – and to gain financially by doing so.

Similarly, under the practice of wetlands mitigation banking in the United States of America, developers must obtain a permit in order to dredge or fill a wetland (see Box 12). For issuance of the wetlands permit the government agency requires mitigation of destroyed wetlands to ensure no net loss. On-site mitigation has had a poor success record, so, in the 1990s, government regulators began to allow the use of a market mechanism that would, in principle, ensure wetlands conservation at minimum economic and political cost.

The agriculture sector may also supply biodiversity offsets for losses generated by mining or oil operations. The appropriateness of payment programmes depends on their effectiveness in generating the desired environmental services. Here, part of the difficulty lies in establishing equivalent values where service provision is location-specific (e.g. the biodiversity conserved in one site is not the same as that in another site). Another issue is risk. In the negotiations leading to the establishment

BOX 12
Biodiversity offset programmes around the world

Biodiversity offset programmes can take a variety of forms, and are found in both developed and developing countries. The general principle they are built upon is "no net loss" of biodiversity. In some cases, the principle is ensured through a legal requirement, in others through a voluntary response.

One of the most well-known regulatory cases is wetlands mitigation banking in the United States of America. Under this programme, a "bank" of wetlands habitat is created by restoration or preservation of wetlands. These are then made available to developers of wetlands habitat, who must "buy" mitigation as a condition of government approval for development. The ratio of destroyed wetland to mitigated wetland can vary, but generally the developer must restore more wetland than the amount being destroyed (often at ratios of more than two to one).

Another example is the European Union's Habitats Directive, according to which developers can offset any damage that projects may have caused on designated conservation priority sites by undertaking positive conservation measures in other conservation priority sites (ten Kate, Bishop and Bayon, 2004). Australia, Brazil, Canada and Switzerland are other examples of countries with a legal framework for biodiversity offsets. An example of a voluntary offset comes from the Chad to Cameroon oil pipeline project, where partners of a US$3.5 billion project (ExxonMobil, Petronas, and Chevron), together with the World Bank, established an environmental foundation, two new national parks and a plan to provide benefits to indigenous people who may be affected by the project, as a means of offsetting potential social and environmental damages of the project (ten Kate, Bishop and Bayon, 2004).

While attractive in principle, mitigation programmes have a mixed record in two respects. The first is the quality of the mitigated habitat. In the early years of the United States wetlands mitigation, enforcement was poor and many restored wetlands were not viable. Second, how to assess the "success" of a mitigation programme needs careful consideration. One issue relates to how well any specific ecosystem's services can be replaced by those of another. Ecosystems differ by type, location and the services they deliver. Guidelines on setting the requirements for an offset vary by programme and in some cases are not well defined. How well these programmes actually do promote conservation remains controversial (ten Kate, Bishop and Bayon, 2004; FAO, 2007d).

of the CDM, concerns over the risk of reversibility of emission reductions from sequestration (e.g. the possibility that trees could be cut or burned, thus reversing the climate change mitigation benefits obtained), resulted in caps on the amount of credits allowable from this source and in narrow definitions of the types of land-use change that could qualify.

Potential suppliers may also have concerns related to offset markets. Loss of national sovereignty or increased dependence on payments from rich countries count among the problematic issues surrounding the supply of globally important environmental services such as climate change mitigation or biodiversity conservation. Criticism of PES programmes as "rents against development", i.e. compensating the poor for not developing, has also been voiced, particularly in cases where the environmental service requires a strict conservationist approach (Wertz-Kanounnikoff, 2006).

Supply response to payments for environmental services

How will agricultural producers respond to payments for environmental services? Payment programmes typically seek to increase provision of the services through changes in farmers' land-use practices.

In the Silvopastoral Project in Nicaragua, for example (see Box 26 on p. 109), over 24 percent of the project area underwent some form of land-use change during the project's first two years – a level far higher than those observed in surrounding communities (Pagiola *et al.*, 2007).

From a farmer's perspective, supplying more of a service involves costs in terms of foregone benefits. Such benefits can include the market value of crop production, food security provided by producing one's own food, insurance against risk in the form of liquid assets, flexibility in type and amount of labour and leisure time, and cultural preferences for a certain way of life. The foregone benefits, or opportunity costs, involved in making a change in production system are crucial to understanding where and when farmers will respond to payments for environmental services.

The following section examines the relative profitability of environmental service production systems versus baseline production systems. Estimates of the opportunity costs farmers face in making proposed changes are then developed as a key indicator of what it would take to provide incentives to producers inducing them to change.

A framework for assessing the opportunity costs of supplying environmental services

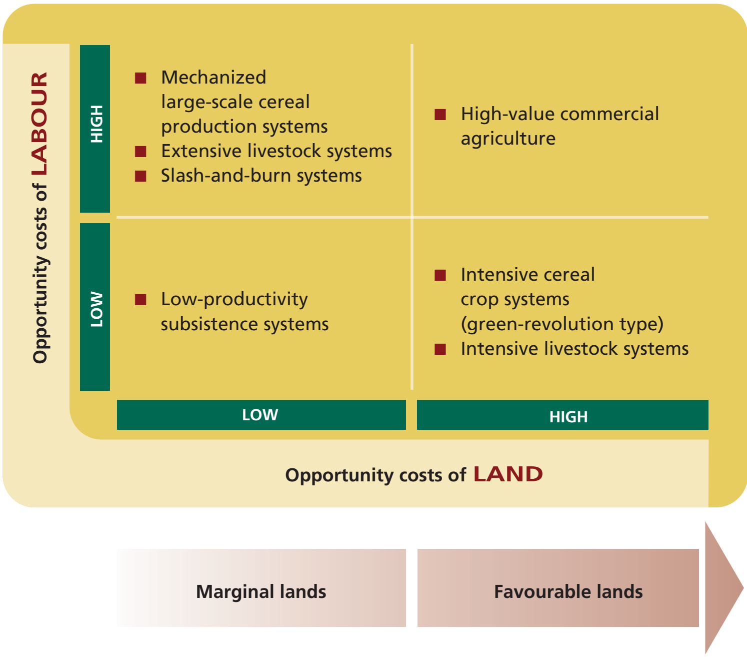
The opportunity cost involved in changing production systems is a function of the change in the use of inputs, including land and labour, and the resulting outputs, such as agricultural products or ecosystem services, as well as the prices of both. Costs vary significantly by agro-ecological conditions, agricultural technology employed, level of economic development and policy environment. The relative abundance of productive resources such as land, labour and water is a key factor affecting their relative prices and the types of technology most likely to be adopted (Hayami and Ruttan, 1985). In densely populated areas, the opportunity cost of labour will generally be lower than in areas where labour is scarce relative to land. The level of economic development, both in agriculture and other sectors, also affects input and output prices and is thus critical for opportunity costs. For example, increasing economic development in the non-agricultural sector of a country can raise the opportunity costs of labour by providing new opportunities for employment and income generation. Rising labour costs will also enhance the incentives for farmers to seek and adopt labour-saving technologies.

Lipper, Pingali and Zurek (forthcoming) have developed a framework for classifying farming systems according to the opportunity costs of land and labour (Figure 9). Subsistence farming systems based on the production of traditional staple crops on lands with poor natural productivity, as in many sub-Saharan African countries, exemplify systems with low opportunity costs of both land and labour. Where labour is abundant but land is scarce, intensive cereal systems have developed, relying on high-yielding varieties and fertilizers to increase productivity while saving land. Typical examples are the intensively managed rice–wheat production systems in the Indian Punjab or the intensive rice-production systems found in Southeast Asia. Intensive livestock production, generally associated with stall feeding, is also common.

In areas where land is abundant but labour is scarce, farming systems dependent on labour-saving technology, such as the mechanized cereal production systems of Australia, Canada and the United States of America, prevail. Extensive agropastoralist and slash-and-burn systems often fall into this category. In contrast, high opportunity costs of both land and labour can be found in areas with high population density and dynamic, well-functioning manufacturing and/or services sectors that provide off-farm labour opportunities. Examples include the intensively managed fruit and vegetable production areas around the Mediterranean (e.g. Egypt, Israel and Spain).

The four categories of farming systems in Figure 9 provide a point of departure in analysing the opportunity cost to a farmer of making a shift in land use in order to enhance environmental service provision. At the beginning of Chapter 2, three major types of changes were identified: changes in production systems (where land remains in agriculture); land diversion (where land is converted from agriculture to other uses);

FIGURE 9
Dryland farming system types: a classification framework according to opportunity costs of land and labour



Source: adapted from Lipper, Pingali and Zurek, forthcoming.

and avoided land diversion (such as avoiding the conversion from forest to agriculture).

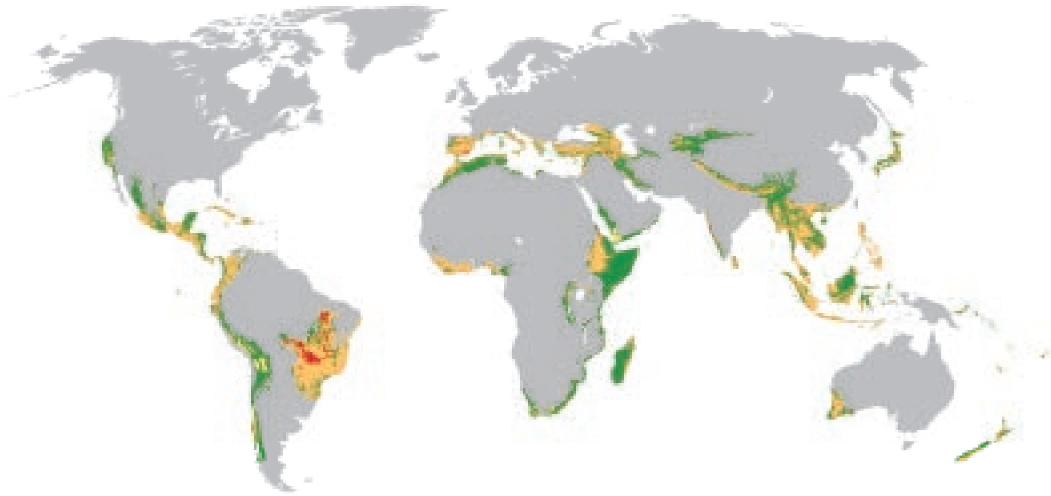
Land-diversion programmes would be most relevant where the opportunity costs of land are low in agriculture. In land-abundant areas, including areas where rising off-farm employment opportunities have drawn populations out of rural areas, the potential for setting aside land for non-agricultural uses is high. In such areas, the trade-off with food and fibre production is limited, particularly when transport infrastructure is a constraining factor for competitive agricultural production. In land-scarce environments, on the other hand, the trade-off between agricultural and non-agricultural services is significant, and changes within production systems that retain a fairly high level of agricultural production alongside environmental service provision will tend to have lower opportunity costs. When considering the labour dimension, labour-increasing changes in production systems (e.g. a move from pasture to agroforestry) will be most suited in areas with low opportunity costs of labour. Conversely, labour-saving changes would be called for in areas of labour scarcity.

Map 5 overlays information about areas considered as biodiversity "hotspots",[12] with information on suitability for agriculture and on current land-use patterns.[13] Hotspots are often associated with high willingness to pay for biodiversity conservation. For example, partly because of the proximity of a

[12] Biodiversity hotspot maps are generated by Conservation International. They hold especially high numbers of endemic species, yet their combined area of remaining habitat covers only 2.3 percent of the Earth's land surface. Each hotspot faces extreme threats and has already lost at least 70 percent of its original natural vegetation. Over 50 percent of the world's plant species and 42 percent of all terrestrial vertebrate species are endemic to the 34 biodiversity hotspots. The Biodiversity Hotspots Species Database is available at www.biodiversityhotspots.org.

[13] Because biodiversity hotspots are based on both biodiversity of endemic species and threat, they may conflate other variables such as land values and agricultural suitability, as expansion of agriculture is a key source of threat. Thus, overlaying hotspots with areas of low agricultural suitability may generate a lower estimate of areas that are high in biodiversity and low in agricultural values than those generated by approaches that use other measures of biodiversity (Wilson *et al.*, 2006).

MAP 5
Biodiversity hotspots in croplands poorly suited to rainfed agriculture



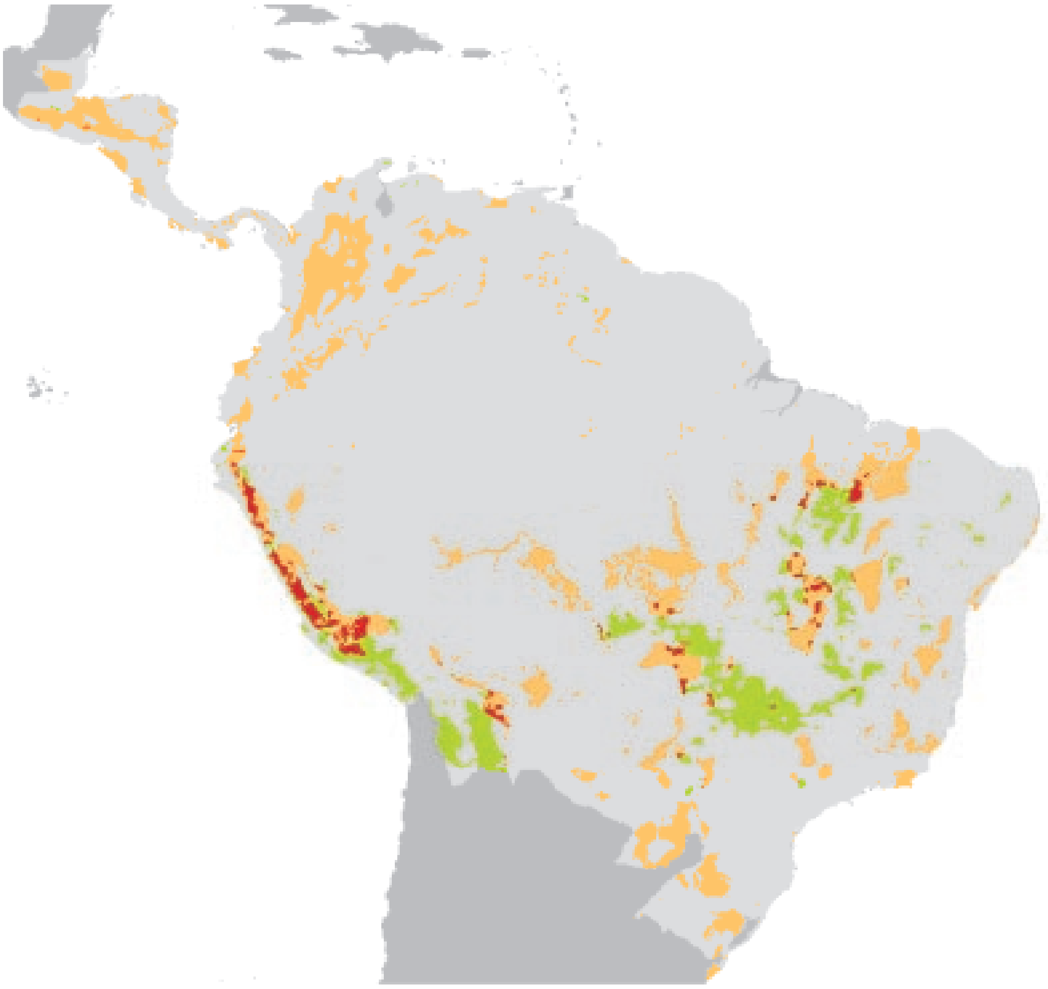
Note: available at
http://www.fao.org/geonetwork/srv/en/google.kml?id=31155&layers=biodiversity_hotspots
Source: FAO.

large, relatively highly educated population, there are many private and civil society-backed schemes to conserve the Atlantic Forest hotspot in Brazil. The map indicates areas where the opportunity costs are potentially low for supplying biodiversity conservation services by either avoiding conversion of land to agriculture or changing farming system practices on lands currently in agricultural production. The red areas represent croplands in biodiversity hotspot regions with low suitability for rainfed production.[14] In these areas, the costs of taking land out of agriculture or changing the production system within agriculture to supply biodiversity conservation are likely to be low and the returns to conserving biodiversity high. Indeed, they combine low opportunity costs of making the change with high productivity of environmental services provision. In these areas, farmers would be expected to respond to relatively low levels of payments for biodiversity conservation, because they are giving up relatively low levels of potential agricultural production to provide the service.

Gorenflo and Brandon (2006) identified priority locations for biodiversity conservation efforts by looking at the potential social and financial costs of conserving biodiversity through maintaining a non-agricultural land use. According to their analysis, nearly three-quarters of the priority locations for biodiversity conservation coincide with large tracts of sparsely populated lands with limited suitability for agricultural production. Main clusters of such sites were found in southern Africa and Madagascar, the Andes, the coastal area of Brazil, Central America, various locations in east and southeast China and the western Indian coast. Their identified locations coincide with several of the yellow shaded areas in Map 5, which show biodiversity hotspots of low agricultural suitability not currently in croplands. They also noted that in areas of high population densities and potential for crop production, a variety of conservation tools will be necessary

[14] The suitability for rainfed production is based on the Global Agro-Ecological Zones model for intermediate level of inputs. Irrigated areas are excluded.

MAP 6
Projected expansion of cropland and pasture to lands poorly suited to rainfed agriculture, 2000–2010



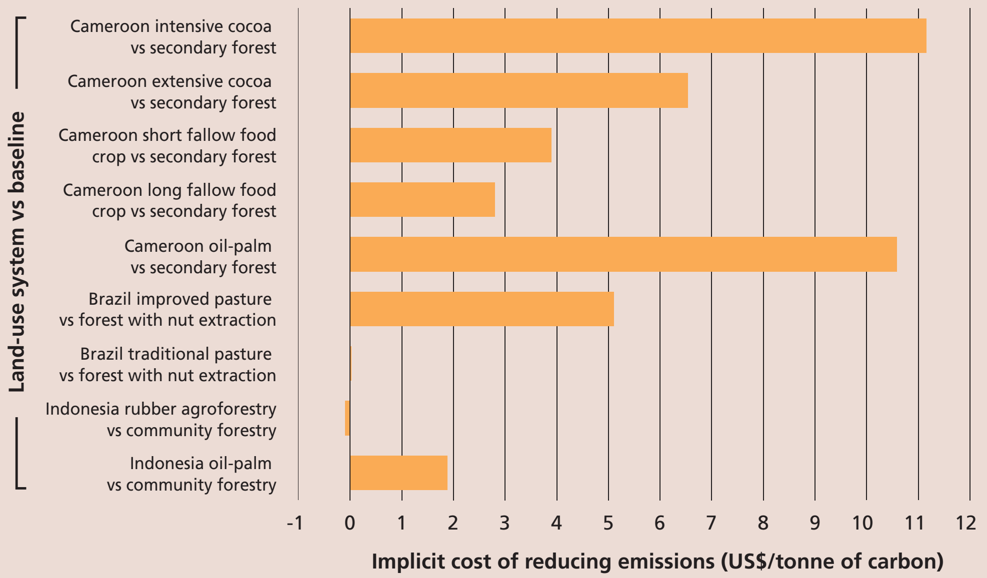
- Projected expansion of cropland and pasture in areas with low agricultural suitability
- Other areas with projected expansion of cropland and pasture
- Other areas with low agricultural suitability
- Non-study area

Note: available at
http://www.fao.org/geonetwork/srv/en/google.kml?id=31161&layers=cropland_pasture_expansion_low_def
Source: FAO.

to achieve biodiversity conservation, including conservation incentive agreements.

Map 6 builds further upon Map 4 (p. 26) by adding information on suitability for rainfed production. In many areas, a combination of economic, agro-ecological and spatial characteristics suggest a high probability of their conversion from forest to agriculture. Yet many of these areas are not likely to be very productive for rainfed agriculture – these areas are shown in red. Here, irrigated agriculture may be productive but will require investment. To the extent that these areas are important for biodiversity conservation or other environmental services, higher returns to the land may be obtained by avoiding conversion.

FIGURE 10
Level of carbon payments required to provide incentives for reducing emissions by avoided deforestation



Source: Chomitz, 2007, based on data from Tomich *et al.,* 2005a.

Empirical evidence on the supply response to payments for environmental services

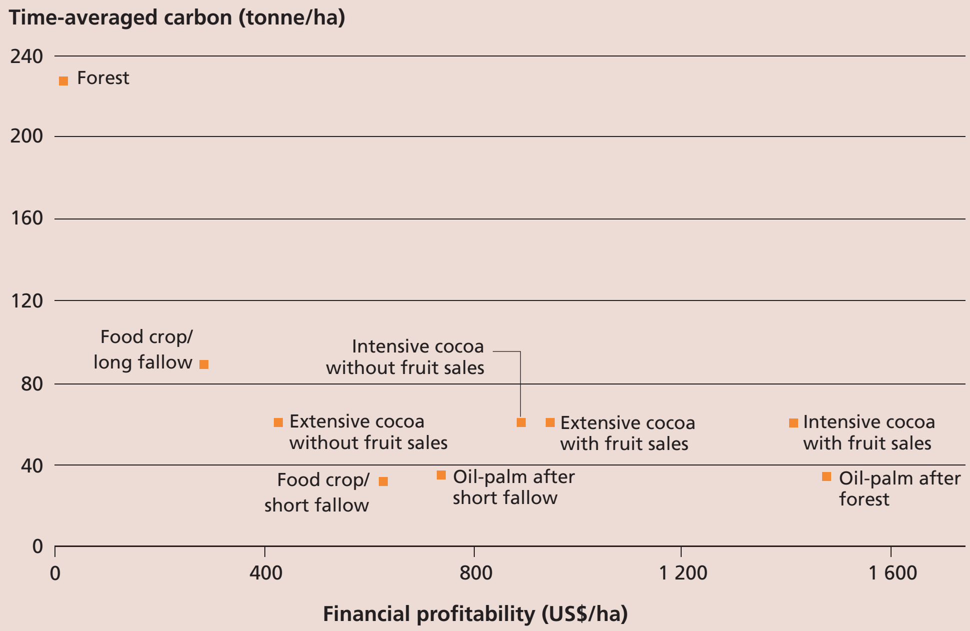
Several studies have examined the level of payments needed to induce farmers to adopt cropping systems that increase the supply of environmental services. Most have focused on carbon sequestration (or in some cases avoided emissions) in response to varying payment levels. Generally, they indicate that the economic potential is considerably lower than the technical potential but that it varies considerably according to location and the type of farming system or land-use change considered.

Chomitz (2007) estimated the cost of reducing deforestation using data on the return to common alternative land-use systems in the selected areas. Figure 10 shows that relatively low carbon prices of around US$11 per tonne would be sufficient to provide incentives to producers to reduce deforestation. The changes in land use that result in reduced deforestation at the lowest costs are those that also generate other sources of income from the land, such as community forestry and nut extraction.

The trade-offs faced by farmers in adopting potential land-use changes were the focus of the "Alternatives to Slash and Burn" (ASB) initiative by national, international and non-governmental organizations in several countries in Africa, Asia and Latin America.[15] The ASB initiative has conducted detailed assessments in Brazil, Cameroon and Indonesia of the trade-offs involved in generating biodiversity conservation and carbon sequestration – along with their implications for income and food security. Figure 11 presents results from a case-study site in Cameroon comparing the financial returns to various agricultural production systems with the carbon they sequester. From a carbon sequestration perspective, the largest gains are indisputably achieved through leaving the forest intact; however, this option generates essentially no financial returns. Moving from food crop/short fallow to food crop/long fallow significantly increases carbon sequestration, but reduces profitability. However, moving from food

[15] For further information, see www.asb.cgiar.org.

FIGURE 11
Profitability and carbon sequestration in Cameroon



Source: Tomich *et al*., 2005b.

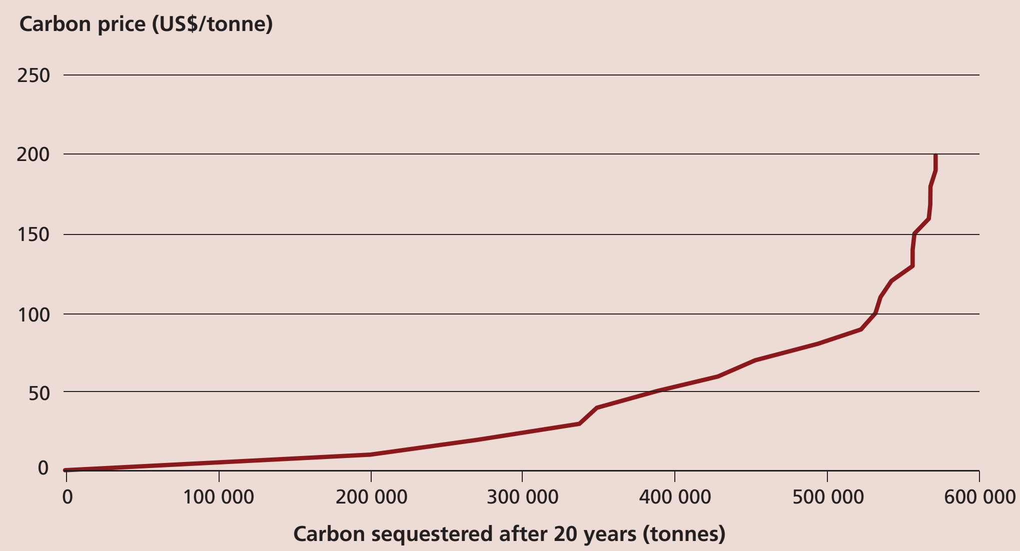
crop/short fallow to intensive cocoa (with or without fruit sales) increases yields in both carbon sequestration and agricultural profitability.

The International Energy Agency Greenhouse Gas Research and Development Programme (IEA GHG) conducted an assessment of the potential and cost of enhanced carbon sequestration in soils for five countries and regions, including southeastern Australia, India, northern Kazakhstan, Sweden and Uruguay. Two types of land-use change were considered, depending on technical feasibility at the location: the adoption of minimum or no-tillage in cropping systems and the conversion of cropland to permanent grass or pasture. According to the assessment, which also included estimates of transaction costs, at relatively low carbon prices (less than US$50 per tonne) only about 16 percent of the total technical potential would be realized over a 20-year period. However, at a price of US$200 per tonne (equivalent to approximately US$55 per tonne of carbon dioxide), 61 percent of the technical potential was supplied, with farmers entering into contracts on 80 percent of the available land (IEA GHG, 2005).

Lewandrowski *et al*. (2004) modelled supply response for carbon sequestration in the United States of America under varying land-use and payment options. At low levels of payments, additional soil carbon sequestration would be achieved primarily through the adoption of conservation tillage, for which, indeed, private returns are very similar to those of the baseline; that is, opportunity costs are low. Only at incentive levels of US$125 per tonne would producers be willing to shift from cropping to grasslands.

Diagana *et al*. (2007) analysed farmers' supply response to payments for soil carbon sequestration for the Nioro region of Senegal's Peanut Basin. Soil and climate data were used to estimate crop yields and changes in soil carbon stocks under nine scenarios of increased fertilizer use and increased incorporation of crop residues in a peanut–millet rotation system. An economic model was used to simulate a carbon payment scheme requiring farmers to apply higher fertilizer rates and incorporate some crop residues into the soil. Figure 12 shows the carbon sequestration supply curve for the scenario that incorporates half of the peanut residue. The vertical axis shows the price paid

FIGURE 12
Carbon supply response in Nioro Region, Senegal



Source: adapted from Diagana *et al.*, 2007.

per tonne of carbon sequestered and the horizontal axis indicates the corresponding average annual quantity of carbon sequestered over the 20-year life of the contract in the Nioro region. At a payment of US$100 per tonne, more than 500 000 tonnes of carbon were estimated to be supplied by the region.

The potential supply response of small landholders in the central highlands of Chiapas in Mexico to payments for above-ground carbon sequestration obtained by switching to forestry and agroforestry were estimated by De Jong, Tipper and Montoya-Gómez (2000). According to their estimates, a positive supply response to payments would be obtained at prices between US$5 and US$15 tonne of carbon with the adoption of community forestry and improved fallow systems. Their findings indicate that improved management of natural forests and secondary vegetation will be the most important elements of any large-scale carbon sequestration programme in the area.

FAO (2003c) modelled the cost of switching from cassava to agroforestry systems in Indonesia and the break-even carbon price needed to generate such shifts. Table 9 shows the net present values of four agroforestry systems, assuming a 70-year time frame and poor quality lands. The results indicate that cinnamon production

TABLE 9
Financial performance and costs of selected agroforestry systems on poor land: modelling results for Sumatra, Indonesia over 70 years

	AGROFORESTRY SYSTEM			
	Rubber	Cinnamon	*Damar*[1]	Oil-palm
Net present value *(US$/ha)*	−96.35	114.99	−36.46	−91.10
Average carbon stock *(tonnes/ha)*	21.18	11.35	51.34	13.31
Opportunity cost[2] *(US$/ha)*	132.35	−78.99	72.46	127.10
Sequestration cost *(US$/tonne carbon)*	6.25	−6.96	1.41	9.55

[1] The *damar* system is a complex agroforest developed by the Krui people of Lampung, south Sumatra. The system consists of a sequence of crops building up to a "climax that mimics mature natural forest" (ASB, 2001). The main tree species is *damar (Shorea javanica),* a source of resin that provides a flow of income.
[2] Cost (in terms of net present value) of switching land use from cassava to agroforestry.

Source: FAO, 2003c.

TABLE 10
Cost-effectiveness of the PES approach under different circumstances

	HIGH environmental service benefits	LOW environmental service benefits
LOW OPPORTUNITY COSTS	**1.** PES approach likely to be cost-effective	**2.** PES approach may be cost-effective
HIGH OPPORTUNITY COSTS	**3.** PES approach may be cost-effective	**4.** PES approach unlikely to be cost-effective

Source: FAO.

would be profitable even without carbon payments, whereas *damar* (an indigenous management system) would require very low levels of carbon payments to support.

In general, the supply response to payments for environmental services will depend on the opportunity costs of changing practices, which depend, in turn, on the degree to which the land-use or farming-system change reduces agricultural production and income. In cases where high environmental service benefits can be achieved with little reduction (or even a gain) in agricultural production and income, low payments can trigger significant supply response, and thus PES programmes are likely to be cost-effective. This situation corresponds to case 1 shown in Table 10. In the opposite case, where environmental service benefits are low but opportunity costs are high (case 4), PES programmes are unlikely to be cost-effective.

In the intermediate cases, environmental service benefits are proportional to opportunity costs. For example, in many areas the adoption of conservation agriculture in place of conventional tillage systems involves relatively low levels of opportunity cost for producers, because the change does not result in a major decrease (and may even lead to an increase) in agricultural output, but environmental service benefits are correspondingly low. This situation corresponds to case 2. In contrast, when changes in production systems to enhance the supply of environmental services result in a large decrease in agricultural production and income, producers face significant opportunity costs. Here, for a change to be attractive to producers, either the quantity of the environmental service that can potentially be supplied or its price must be high (case 3). Cost-effectiveness in these intermediate cases depends on the precise magnitudes of per-hectare payment levels and environmental service benefits provided.

In the case of carbon sequestration, this suggests two situations (cases 1 and 2) where a positive supply response can be expected from agricultural producers even at relatively low levels of carbon prices, and a third situation (case 3) where a positive supply response would require a higher carbon price but could still be cost-effective because a higher level of carbon sequestration would be generated. Shifting from conventional to conservation agriculture and generating soil carbon sequestration is an example of the former two situations, while reforestation on degraded pastureland could be an example of the latter.

What has experience from PES programmes in the field shown us about producers' supply response to payments? Not surprisingly, evidence suggests that supply response has been positive in the case of land-use changes that have no or only low opportunity costs. In Costa Rica, for example, payments for forest conservation – which essentially reward the provision of environmental services regardless of whether they are incremental to a baseline supply – were very popular among landowners, and the supply of forest conservation services exceeded the funding capacity of the programme (Pagiola, 2006). This outcome was in large part attributable to the low opportunity costs landowners faced (Pagiola, 2006; Ortiz, Sage and Borge, 2003). De Jong, Tipper and Montoya-Gómez (2000) noted that substantial shifts in land uses were obtained under the Scolel Té pilot project for above-ground carbon sequestration even with only modest incentive payments, precisely because conventional agricultural production was only marginally profitable.

Assessments of supply response to date have not taken into account the recent rapid growth in the market for bioenergy, which is likely to result in substantial changes in the opportunity costs of supplying environmental services. Bioenergy, defined as energy produced from organic matter or biomass, has recently become one of the most dynamic and rapidly changing sectors of the global energy economy (UN-Energy, 2007). The use of biomass in the form of plants and trees increases demand for land and water resources. The extent to which the growth of the bioenergy sector will affect the provision of other ecosystem services, including food production as well as climate regulation and other environmental services, is the subject of considerable interest and attention. While significant impacts are possible, their nature and magnitude remain uncertain (UN-Energy, 2007).

Conclusions

Given the importance of ecosystem services, why are they not provided at the levels desired by society? Ecosystem services are produced (or degraded) through the interaction of natural processes and the actions of individual decision-makers, including agricultural producers. For a variety of reasons, the full value of all ecosystem services is not reflected in the incentives faced by the service providers. As a result, providers' actions may diverge from those desired by beneficiaries of the ecosystem services.

Many possible changes in resource use that would benefit the environment are not likely to be adopted by farmers in the absence of motivating policy measures, because they would result in lower benefits to the producers themselves. For example, setting land aside from crop production and placing (or leaving) it under natural grass or forest cover could enhance carbon sequestration as well as provision of biodiversity, water quality and, possibly, other ecosystem services. Likewise, reducing the number of livestock or managing manure to reduce nitrogen runoff to surface water, infiltration to groundwater or emissions to the atmosphere could have beneficial impacts on the environment but would probably increase costs or reduce returns to the producer.

Many farmers, particularly in developing countries, also face a wide array of constraints that increase opportunity costs and raise additional barriers to the adoption of new practices: constraints on access to information, appropriate technologies and financing, as well as inexistent or insecure property rights and legal or regulatory constraints. These constraints are often compounded by poorly functioning markets and infrastructure, risk and difficulties in the collective management of commonly held resources, such as pasturelands or fisheries. The presence of one or more of these problems makes it more difficult for producers to change their resource management practices in ways that could increase their output of environmental services – and in some cases of conventional agricultural commodities.

Policy-makers have several options for providing resource users with incentives for farmers to change their behaviour in order to supply the services society desires. In the past, non-market instruments such as regulations or taxes predominated; today, market-based approaches, such as payments for environmental services, are increasingly complementing these earlier instruments.

When are payments the right policy instrument to generate higher levels of environmental services from farmers? To answer this question, a distinction must be made between the two cases where farmers are being asked (i) to enhance the provision of certain ecosystem services that may be degraded or undersupplied as a result of their current agricultural practices or (ii) to offset pollution generated in other sectors.

In the first case, the critical issue is whether farmers should be paid to reduce the negative externalities they generate rather than requiring them to bear the cost themselves. A fundamental issue is whether the rights to the environmental services in question are held initially by producers or by society. If they are held by producers, society needs to compensate the producers if more or different environmental services are desired; if they are held by society, the cost of degrading the resources or should be borne by the responsible producers. There are no simple solutions to determining which situation applies. The answer may well differ from one service to the next, and from one context to another.

In the second case, the appropriateness of payments depends on the efficiency of offsets in meeting the intended objective. Here, the PES approach may be conceptually straightforward with regard to carbon sequestration, where benefits are independent of location. For location-specific environmental services, however, establishing equivalent values of service provision may be difficult (for example, biodiversity conserved in one location may differ from that of another location).

Whether and where farmers will make changes in production systems in response to payments for environmental services depends on the opportunity costs or foregone benefits implied in making the change. These vary significantly by agro-ecological conditions, type of technology employed, level of economic development and policy environment. Land-diversion environmental service programmes are most likely to be effective where opportunity costs of land are low in agriculture. In land-abundant areas, including areas where rising off-farm employment opportunities have drawn populations out of rural areas, the potential for setting aside land for non-agricultural uses is high. In land-scarce environments, on the other hand, the trade-off between agricultural and non-agricultural services is high, and changes to production systems that generate returns to both agricultural and environmental services are therefore more relevant. The opportunity cost of labour is also important for determining the suitability of changes. In situations where labour is scarce, production changes that reduce labour use are more likely to be accepted.

In general, the supply response to payments for environmental services will depend on the opportunity costs of changing practices as well as the environmental service benefits that can be generated. In cases where high benefits can be achieved with little reduction (or even a gain) in agricultural production and income, low payments can trigger significant supply response, and thus PES programmes are likely to be cost-effective. Where environmental service benefits are low but opportunity costs are high, PES programmes are unlikely to be cost-effective. In intermediate cases, where opportunity costs and environmental benefits are either both low or both high, cost-effectiveness will depend on the precise magnitudes of per-hectare payment levels and the environmental service benefits provided.