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THE STATE OF FOOD AND AGRICULTURE

PAYING FARMERS FOR ENVIRONMENTAL SERVICES

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Foreword

Despite unprecedented global economic growth, 1.1 billion people continue to live in extreme poverty and more than 850 million people suffer from chronic hunger while ecosystems are being threatened as never before. Poverty reduction, food security and environmental sustainability have all moved to the top of a crowded international agenda, as reflected in the Millennium Development Goals. At the same time, the close relationships among poverty, hunger and ecosystem degradation are becoming ever clearer. Most of the world's poor people live in rural areas, many of them in marginal environments, and depend on agriculture for their livelihoods. Agricultural development is therefore crucial for alleviating poverty on a large scale. Such development would also require that the natural resource base on which the poor depend for their livelihoods be preserved and enhanced.

Services provided by ecosystems are essential, not only for poverty reduction, but indeed for human survival. 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), have painted a stark picture of current ecosystem degradation and the potential consequences of a continuation of current trends.

Agriculture often lies at the centre of the complex set of problems surrounding ecosystem degradation. It contributes to the problems and suffers from many of the consequences, but at the same time it offers possible solutions. Modern agriculture has been very successful in providing the ecosystem services for which markets exist – crops, livestock, fish, and forest products – in ever greater quantities. But the expansion of these services has often been achieved at a high cost to other ecosystem services, such as regulation of climate, water and biodiversity, which are necessary to sustain human life. Enhancing these services, while producing a further doubling of conventional output to meet the demands of a growing global population, is one of the great challenges facing world agriculture in the twenty-first century.

The State of Food and Agriculture 2007 highlights the potential of agriculture for enhanced provision of ecosystem services that are not usually compensated for by the market. When we think of farmers, we typically think of the food and fibre that they produce and that they either consume or sell on markets to generate an income. But the production processes can also result in impacts on other ecosystem services that are not traded in markets, referred to in this report as "environmental services". Some may be positive, such as groundwater recharge and scenic landscapes; others may be negative, such as water pollution by plant nutrients and animal waste, and soil erosion from poorly managed croplands or overgrazed hillsides. As agricultural production expands, these negative effects can develop into increasingly serious problems. A fundamental question concerns how farmers can be encouraged to reduce negative side-effects while meeting the growing demands for food and fibre. At the same time, changes in agricultural practices may also contribute to addressing environmental problems generated outside agriculture, for example, by offsetting greenhouse gas emissions from other sectors. A relevant question, therefore, is how farmers can be induced to increase their provision of this type of service.

Farmers constitute the largest group of natural resource managers on Earth. They both depend on and generate a wide array of ecosystem services. Their actions can both enhance and degrade ecosystems. Thus, understanding what drives their decisions is critical in designing new strategies that enhance ecosystem services and contribute to sustainable growth.

Paying farmers for the environmental services they provide is an approach that

has generated growing interest worldwide from policy-makers and non-governmental and private decision-makers. This strategy is akin to viewing environmental protection as a business transaction. This perspective is not without controversy, but it must be kept in mind that many services are degraded precisely because they are free to use but costly to provide.

Payments for environmental services have also attracted attention for their potential to mobilize new sources of finance to support sustainable environmental management in developing countries and to contribute to poverty reduction and agricultural development.

This report examines this approach to enhancing environmental services through the lens of managing agriculture to meet the agricultural and environmental demands of the future. In addition, it examines the potential of this mechanism to contribute also to poverty reduction. Of the numerous services to which agriculture can contribute, this report highlights three: climate change mitigation, enhanced quality and quantity of water provision and the preservation of biodiversity.

One of the points made in this report is that agriculture can be an important source of improvements in the environmental services provided to humanity by ecosystems. Agriculture employs more people and uses more land and water than any other human activity. It has the potential to degrade the Earth's land, water, atmosphere and biological resources – or to enhance them – depending on the decisions made by the more than 2 billion people whose livelihoods depend directly on crops, livestock, fisheries or forests.

Ensuring appropriate incentives for these people is essential. More and better information can influence farmers' decisions about their practices in ways that lead to environmental improvements, especially when changes in farming and land-management practices that enhance ecosystem services would also be profitable for the farmers themselves. However, should such changes imply a reduction in farmers' incomes, they will only be implemented through effectively enforced regulations or, voluntarily, when some form of compensation is provided. In the latter case, payments to farmers from the beneficiaries can provide an answer. The relative merits and effectiveness of the different approaches vary for different environmental services. Key challenges in implementing the payments approach lie in creating a mechanism for valuing the relevant service where none exists, identifying how additional amounts of the service can be provided most cost-effectively, and deciding which farmers should be paid for providing more of it and how much they should be paid.

Payments for environmental services can increase the incomes of farmers who produce the services. Other poor households may also benefit, for example from increased productivity of the soils they cultivate or improved quality of the water they drink. But the distribution of benefits depends on who produces the environmental services and where. Environmental service payments can contribute to alleviating poverty, but such poverty-reducing effects are neither automatic nor universal. In some cases, payments may also have adverse impacts on poverty and food security, for example if they reduce agricultural employment or increase food prices. Furthermore, the administrative costs of payment schemes that fully integrate the poorest farmers may be large, while other barriers, such as absence of clearly defined property rights, may prevent the poor from participating. A major challenge is to design payment schemes in such a way as to avoid negative impacts on the poor and to enable poor farmers to participate.

In order to maximize the benefits in terms of enhanced provision of environmental services, minimize the costs in terms of foregone production and income and ensure the broadest possible participation by poor farmers, careful analysis of the underlying science – both natural and social sciences – will be required, as well as innovative institutions.

Confronting the interrelated challenges of eradicating poverty and hunger and preserving the world's ecosystems will continue to require purposeful and decisive action on a range of fronts. Payments for environmental services are not widely

implemented in developing countries at present, and much work remains to be done to unlock their full potential. In conjunction with other tools, however, they hold significant promise as a flexible approach to enhancing the role of farmers worldwide in sustaining and improving the ecosystems on which we all depend. By clarifying the challenges that need to be addressed in implementing such an approach, it is my hope that this report will help illuminate the way forward.

Jacques Diouf
FAO DIRECTOR-GENERAL

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Abbreviations and acronyms

ASB	Alternatives to Slash-and-Burn
CATIE	Tropical Agricultural Research and Higher Education Center (Costa Rica)
CBD	Convention on Biological Diversity
CDM	Clean Development Mechanism
CER	certified emission reduction
CIFOR	Center for International Forestry Research
CRP	Conservation Reserve Program (United States of America)
EU	European Union
FSC	Forest Stewardship Council
GEF	Global Environment Facility
GDP	gross domestic product
ICRAF	World Agroforestry Centre
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
ISRIC	International Soil Reference and Information Centre
IUCN	World Conservation Union
LULUCF	land use, land-use change and forestry
NGO	non-governmental organization
OECD	Organisation for Economic Co-operation and Development
PES	payment for environmental services (programme)
PSA	Pago de Servicios Ambientales – Payments for Environmental Services (Costa Rica)
PSAH	Pago por Servicios Ambientales Hidrológicos – Payment for Hydrological Services (Mexico)
UNCTAD	United Nations Conference on Trade and Development
UNECE	United Nations Economic Commission for Europe

UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USDA	United States Department of Agriculture
WHO	World Health Organization
WTO	World Trade Organization
WWF	World Wide Fund for Nature (formerly World Wildlife Fund)

Explanatory note

The statistical information in this issue of *The State of Food and Agriculture* has been prepared from information available to FAO up to July 2007.

Dates and units

The following forms are used to denote years or groups of years:

2004/05 = a crop, marketing or fiscal year running from one calendar year to another

2004–05 = the average for the two calendar years

Unless otherwise indicated, the metric system is used in this publication.

"Billion" = 1 000 million

Maps

The State of Food and Agriculture 2007 includes a set of four global and four regional maps produced by FAO using geographic data layers generated internally as well as externally. The maps are composed of intersections of data layers representing indicators of environmental service supply, agricultural production and productivity and poverty. They are intended to give an indication of the spatial distribution of agro-ecological and socio-economic conditions relevant to the potential supply of environmental services. The resolution of the maps is 5 arc-minute. The low resolution precludes any definitive conclusions about the actual on-the-ground conditions in specific sites. However, the maps can provide a broad indication of the geographic distribution of selected indicators. The maps are made available for viewing on Google Earth via the FAO GeoNetwork and can be accessed using the URL for each map. JPEG images of the maps can also be downloaded from the GeoNetwork. Further technical information on the data layers used in constructing each map can be obtained from: http://www.fao.org/es/esa/en/pubs_sofa.htm

Statistical annex

The statistical annex contains a selection of data from the *FAO Statistical Yearbook 2005/06*. A mini-CD-ROM containing the full *Yearbook* is attached to the inside back cover of this report. A new edition of the *Yearbook* will be available in early 2008 and can be accessed at http://www.fao.org/es/ess/yearbook. The source for the data on food and agriculture is the FAOSTAT database (http://faostat.fao.org). More information on concepts, definitions, country notes, etc., can be found at the same address. Non-FAO sources are indicated in the notes on individual tables.

Part I

PAYING FARMERS FOR ENVIRONMENTAL SERVICES

Part I

1. Introduction and overview

Ecosystems sustain human life. They supply food and drinking water, maintain a stock of continuously evolving genetic resources, preserve and regenerate soils, fix nitrogen and carbon, recycle nutrients, control floods, filter pollutants, pollinate crops and much more. Despite their importance to human well-being, many of these services are under threat throughout the world.

Agricultural ecosystems are by far the largest managed ecosystems in the world. Of the total land area of about 13 billion hectares, crops and pasture occupy almost 5 billion hectares. Forests and woodlands add another 4 billion hectares. Inland, coastal and marine fisheries ecosystems also generate crucial services for humans.

Today, the provision of ecosystem services generally, and agriculture-based services in particular, is being challenged as never before by the combined effects of expanding populations, rapid economic growth and greater global integration. Agriculture is being asked to provide an ever-growing supply of ecosystem-based goods and services.[1] The world's population is expected to increase by 50 percent between 2000 and 2050, with the developing countries home to almost all of that growth. Analyses indicate that there is likely to be sufficient overall food production at the global level to meet expected increases in effective demand, although such analyses have not yet incorporated the recent surge in demand for biofuels. About 80 percent of the increase in land-based agricultural production is expected to derive from increased input use and improved technology on existing agricultural land, while area expansion in parts of South America and sub-Saharan Africa is expected to account for the remaining 20 percent (FAO, 2003a). Both sources of increased production can exacerbate damage to land-based ecosystems. Expansion in environmentally fragile areas is especially harmful to biodiversity. Poorly managed intensification can result in soil erosion pressure on water supplies, rising nitrate levels in ground- and surface water, salinization, and growing air and water pollution from livestock wastes. Coastal and marine ecosystems are also under pressure.

In response, the search for ways to enhance ecosystem services is gaining attention from policy-makers as well as non-governmental and private decision-makers. This search provides the motivation for this report. The chapters that follow examine the incentives farmers face when making choices that affect the provision of ecosystem services and focus particularly on a mechanism that has generated growing interest in recent years – direct payments to farmers to enhance the delivery of selected ecosystem services.

Agriculture's role in the provision of ecosystem services depends critically on the incentives available to farmers. Such incentives currently tend to favour the provision of conventional outputs such as food and fibre over that of other services that are generally produced jointly with them, in varying degrees, such as water

[1] The term "agriculture" is used to include the production of crops, livestock, fish, and forest products, and the term "farmer" to include all producers of agricultural products.

filtration and climate regulation. Incentives can be influenced by policies; it is the goal of this report to shed light on policy measures that can modify the incentives available to farmers to induce them to provide a mix of ecosystem services that better addresses society's changing needs.

Of the myriad of ecosystem services, this report concentrates primarily on three that have attracted the most interest in payment programmes to date: climate change mitigation, enhanced water quality and quantity, and biodiversity preservation.

Ecosystem services and agriculture

Healthy ecosystems provide a variety of critical goods and services that contribute, directly or indirectly, to human well-being. Ecosystem services are created by the interactions of living organisms, including humans, with their environment. These services provide the conditions and processes that sustain human life. A specific landscape might provide a range of ecosystem services. A forest at the top of a watershed not only provides timber but also facilitates or enhances soil retention and water quality (filtering contaminants from the water as it flows through roots and soil), flood control (regulating the movement of water through the watershed), pollination (provided by the pollinators inhabiting the edge of the forest), carbon sequestration (in the form of additional biomass), biodiversity conservation (including the forest habitat and the wide range of species it harbours) and landscape aesthetics.

While ecosystem services can be categorized in any number of ways, the most common approach is the one employed by the recent Millennium Ecosystem Assessment.[2] The Assessment classified ecosystem services into four broad categories, namely provisioning services, regulating services, cultural services and supporting services (Figure 1). Biodiversity, while not classified under any of the four categories, plays an important overarching role in the provision of ecosystem services. For example, biodiversity is directly related to food production, the maintenance of genetic resources and the aesthetic value of a landscape, and changes in biodiversity have direct implications for the production of all ecosystem services.

Of the 24 provisioning, regulating and cultural services examined by the Millennium Ecosystem Assessment, 15 were identified as being degraded or used unsustainably (Millennium Ecosystem Assessment, 2005a). Only four services were identified as having been enhanced over the past 50 years, and three of those (crops, livestock and aquaculture) were related to food production. In the report's words (p. 1):

> *Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel.*
>
> *...*
>
> *The changes that have been made to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people.*
>
> *...*
>
> *The degradation of ecosystem services could grow significantly worse during the first half of this century and is a barrier to achieving the Millennium Development Goals.*

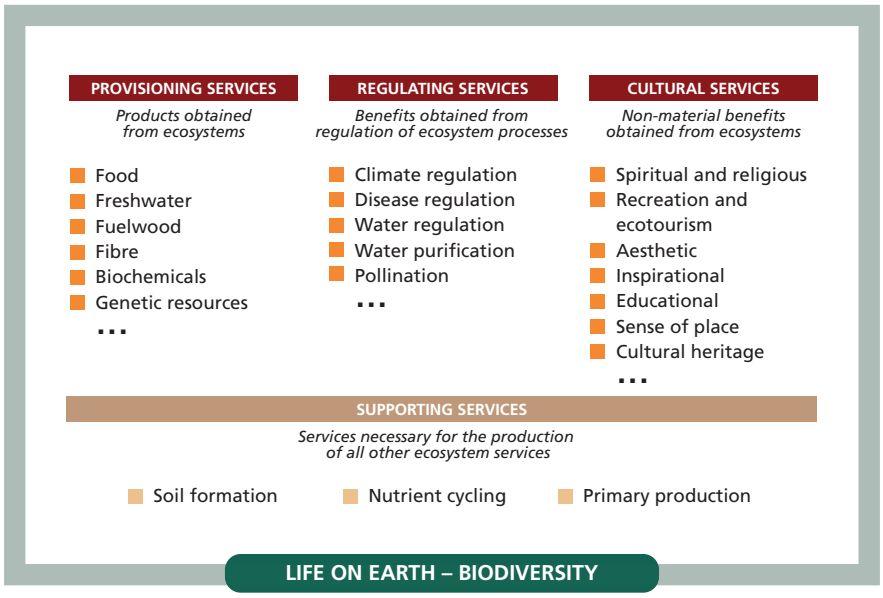
In essence, human ingenuity applied to the production of food and other commodities has allowed production to keep pace with population growth and income-driven demand, but at the cost of considerable degradation of other ecosystem services.

The role of farmers

Ecosystems and ecosystem services can be considered as nature's equivalent to produced capital stocks (e.g. roads, buildings,

[2] The Millennium Ecosystem Assessment was called for by the United Nations Secretary-General Kofi Annan in 2000 and undertaken during the period 2001–05, drawing on the contributions of more than 1300 authors and reviewers worldwide. Its objective was to assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being.

FIGURE 1
Ecosystem services categories



Source: Adapted from *Ecosystems and human well-being: a framework for assessment* by the Millennium Ecosystem Assessment. Copyright © 2003 World Resources Institute. Reproduced by permission of Island Press, Washington, DC.

machinery) and the services deriving from these stocks. In most regions of the world, per capita income is rising, but this trend has often been accompanied by the drawing down of natural capital stocks, thereby jeopardizing the future provision of ecosystem services. Furthermore, many of the world's poorest people live in marginal ecosystems and depend on ecosystem services for their food and livelihoods. If poverty is to be reduced, ways must be found to enable these people to increase their productivity and that of the natural resources they depend on.

Degradation of ecosystems differs from depreciation of produced capital in several important ways. The key difference, and the most important source of ecosystem degradation, is the perception that many of nature's services are free – in the sense that no one owns them or is rewarded for them. Examples include carbon storage, flood control, clean water provision, habitat provision and biodiversity conservation. While these services have great value to society, individuals have little incentive to protect them. In addition, subsidies that explicitly encourage the production of marketed goods at the expense of other ecosystem services can cause ecosystem degradation.

Farmers constitute the largest group of natural resource managers on Earth. They both depend on and generate a wide array of ecosystem services. Their actions can enhance and degrade ecosystems. Thus, understanding what drives their decisions is critical in designing new strategies that enhance ecosystem services and contribute to sustainable growth.

Farmers derive most of their agricultural income from the food and fibre they produce. In producing these goods, however, they may also generate other impacts – positive or negative – on ecosystem services. Positive effects could include the preservation of scenic rural landscapes or ensuring groundwater recharge; negative effects could include the runoff of harmful nitrates from cropland to downstream catchments or soil erosion from overgrazed hillsides. Whether positive or negative, these impacts are not typically reflected in farmers' incomes; therefore their provision is not a key consideration in most farmers' choices. Such impacts, in economists' terms,

BOX 1
Ecosystem services, environmental services and externalities

The report uses the Millennium Ecosystem Assessment (2003, p. 3) definition of ecosystem services as "the benefits people obtain from ecosystems". Ecosystem services include all outputs from agricultural activities, including outputs as diverse as food production and climate regulation.

Outputs such as food are generally produced intentionally for sale or direct consumption, and buyers or consumers can influence the production of these outputs through the prices they are willing to pay for them. Many other ecosystem services, however, are provided only as "externalities", in that they are unintended consequences of the primary activity (e.g. food production), and the individuals who are affected by these consequences cannot influence their production. Externalities typically involve "off-site" impacts that affect others, in contrast to "on-site" impacts felt directly by farmers. Externalities can be either positive or negative, according to the perspective of those affected by them.

This report examines the incentives available to farmers when deciding what mix of outputs to produce and how to produce them. It focuses on the use of payments to providers of ecosystem services from beneficiaries of those services as a way of reducing negative externalities and enhancing the provision of positive externalities.

The term "ecosystem services" is sometimes used interchangeably with the term "environmental services". In this report, the term environmental services is used to refer specifically to the subset of ecosystem services characterized by externalities. Programmes to implement payments for these services are variously referred to as payment for ecosystem services programmes, payment for environmental services programmes, or simply PES programmes.

are described as "externalities". In this report, the subset of ecosystem services characterized by externalities are referred to as "environmental services" (Box 1; see also Swallow *et al.*, 2007a). It is precisely because markets typically fail to reflect their value that this report focuses on environmental services.

As demand for food and fibre increases, fuelled by growing populations, rising incomes and global integration, the magnitude of these effects on environmental services also increases. A key question, therefore, concerns how society can motivate farmers to reduce negative side-effects while continuing to meet the increasing demand for agricultural produce. Whether payments are an appropriate tool in this context depends partly on who holds the rights to the services in question. In the case of negative side-effects from industrial production, it is generally accepted that the polluter should pay; in the case of agriculture, this has not historically been the case. The difference may stem from the relative difficulty of identifying the source or magnitude of negative side-effects, historical precedent or equity considerations. Regardless, the distinction becomes blurred where agricultural production occurs on a large and concentrated scale, as in the case of large concentrated livestock operations, and in fact such operations are increasingly treated more like industrial "point sources" (see p. 22) of pollution (Ribaudo, 2006). The focus in this report is on payments to smaller farmers whom society has historically, at least in practice, allowed to use resources in ways that may have adverse environmental impacts.

But the issue extends beyond reducing negative effects from agriculture. Could it also be effective to pay farmers to change their agricultural practices to address environmental problems generated in other sectors of the economy? The growth in effective demand and emergence of market institutions for ecosystem services

such as carbon sequestration or biodiversity conservation may create new income-generating opportunities for farmers in the short term as well as longer-term productivity benefits.

Either way, altering agricultural production systems to enhance the provision of hitherto uncompensated environmental services may entail costs in terms of agricultural productivity growth and local food security. Understanding whether trade-offs exist and, if so, what is at stake, is crucial in designing effective interventions to enhance environmental services.

Payments for environmental services

The concept behind payments for environmental services is straightforward. Because producers of environmental services are not usually compensated for providing them, they tend to be undersupplied or are not supplied at all. Payment for environmental services (PES) programmes are an effort to "get the incentives right" by sending accurate signals to both providers and users that reflect the real social, environmental and economic benefits that environmental services deliver.

It is important to emphasize that payments are only one of the potential tools for increasing the provision of environmental services. Others include information provision, policy reforms to reduce market distortions, command-and-control regulations and taxation. Assessing the potential of PES programmes to improve the environmental and economic benefits from agricultural ecosystems, identifying the circumstances where these benefits are most likely to be obtained, defining key challenges for designing efficient programmes, and evaluating the implications for poverty reduction are the key issues addressed in this report.

For the purposes of this report, PES transactions refer to voluntary transactions where a service provider is paid by, or on behalf of, service beneficiaries for agricultural land, forest, coastal or marine management practices that are expected to result in continued or improved service provision beyond what would have been provided without the payment. The payment may be monetary or in some other form. PES transactions can involve a wide range of parties – including farmers, communities, taxpayers, consumers, corporations and governments – across a wide range of transaction types – from direct payments between downstream beneficiaries and upstream providers to consumers paying for a cup of "shade-grown" coffee beans produced on the other side of the world.

This definition of payments for environmental services is considerably broader than that used by some practitioners, who focus on direct voluntary payments by service users to service providers (Pagiola and Platais, 2007; Wunder, 2005). This broader definition, in contrast, also includes payments by governments to service providers on behalf of society (which may include some members who benefit from a particular environmental service as well as others who do not), together with other tools. Both broader and narrower definitions recognize the importance of financial incentives in influencing farmers' decisions concerning production practices that affect the provision of environmental services. An important difference between the two is that more narrowly defined PES transactions can be sustained if, and only if, private demand supports them, while other approaches (such as government payment programmes) depend in part on political criteria. The two definitions can have significantly different implications for sustainability, efficiency and equity.

While the concept of payments for environmental services is fairly simple, their implementation can be challenging. Many of these services arise from complex processes, making it difficult to determine which actions affect their provision, to identify precisely who the providers and beneficiaries are and to agree on who holds the rights to enjoy those services. Beneficiaries not used to paying for a service might show resistance to doing so. Suppliers may need to adopt novel practices with some degree of uncertainty. Key challenges in implementing a PES approach include creating a mechanism for valuing (or at least measuring) a service

where none currently exists, identifying how additional amounts of that service can be provided most cost-effectively, deciding which farmers to compensate for providing more of the service and determining how much to pay them.

The report closely examines this policy instrument in terms of its possible role in managing agriculture in such a way as to meet current agricultural and environmental demands and its potential to contribute to poverty alleviation. Although the PES approach is not yet implemented widely in developing countries, important lessons can be learned from the experiences to date in developed countries and some developing countries.

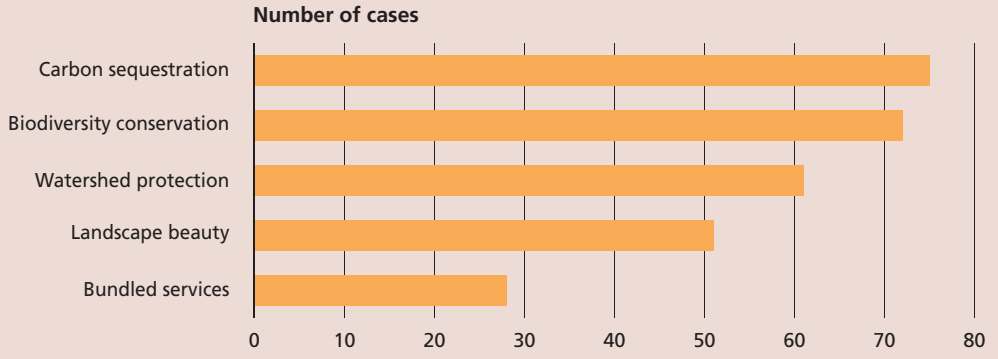
Current experience with payments for environmental services

PES initiatives currently in operation have two main origins: agricultural policy in Organisation for Economic Co-operation and Development (OECD) countries, dating from the 1980s, and forest conservation initiatives in Latin America, which began in the 1990s (FAO, 2007a).

PES programmes implemented in OECD countries represent a response to environmental degradation resulting from intensive farming practices (Regouin, 2003). For example, the Conservation Reserve Program (CRP) in the United States of America was introduced in 1985 with the aim of preventing soil erosion in cropland (see Box 5 on p. 38). Landowners enrolling in the voluntary programme receive annual rental payments in exchange for retiring their farmland from crop production for 10 to 15 years. Similarly, in the United Kingdom, through the Environmentally Sensitive Areas Scheme created in 1987, farmers in eligible areas receive direct payments as compensation for adopting less intensive farming practices that conserve landscape and wildlife values. Generally, agri-environmental payments in OECD countries are designed to compensate farmers for forgoing more intensive and more profitable farming practices. Environmental cross-compliance is also an important tool used in many OECD countries to leverage compliance with existing environmental legislation.

The first PES programmes implemented in developing countries formed part of forest conservation initiatives in Latin America, following the limited success of the traditional regulatory approach that emphasized protected areas (Landell-Mills and Porras, 2002). One of the most notable programmes, initiated in Costa Rica in 1996 (FAO, 2002a; FONAFIFO, 2005; Pagiola, 2002; Rosa *et al.*, 2003), was designed to enhance various forest environmental services (carbon sequestration, hydrological services, biodiversity conservation and provision of scenic beauty) through compensation payments to land and forest owners in exchange for multiyear contracts for reforestation, sustainable forest management

FIGURE 2
PES programmes in the forest sector: breakdown by service



Source: Landell-Mills and Porras, 2002.

and forest protection. The main sources of financing for this programme have been proceeds from a fossil fuel sales tax, revenues from hydroelectric companies, loans from the World Bank and grants from the Global Environment Facility (GEF). Mexico, also, has recently initiated a national PES programme for forest-based environmental services.

The growing role of the PES approaches today reflects underlying changes in environmental policy and the private sector worldwide. "From a situation dominated by centralized regulatory approaches to environmental governance, there is now a greater emphasis on decentralization, flexible mechanisms, the private sector as a provider of public services, corporate self-regulation, consumer sovereignty, and civil regulation. Greater flexibility opens opportunities for PES mechanisms, with both the public and the private sectors taking advantage of this flexibility" (B. Swallow, personal communication, 2007).

Hundreds of PES schemes are now being implemented, in both developing and developed countries, primarily for forest-based environmental services. A global review conducted by Landell-Mills and Porras (2002) examined 287 cases of market-based initiatives in the forest sector. Figure 2 shows the breakdown of these cases by service.

To date, relatively few PES programmes have targeted farmers and agricultural lands in developing countries. Of those that have, one of the most prominent is China's Grain for Green programme, initiated in 1999 by the central government to address concerns about erosion, water retention and flooding (see Box 17 on p. 83). The goal is to convert 14.67 million hectares of cropland to forest by 2010. Farmers are paid to plant forests on sloping and degraded lands (Bennett and Xu, 2005).

There have also been relatively few examples of private payment mechanisms for the provision of environmental services in agriculture. One is the Scolel Té project in Chiapas, Mexico, in which farmers and rural communities are paid by private individuals and firms for voluntary carbon emission offsets, generated by the adoption of agroforestry practices (Tipper, 2002). Other examples include ecolabelling schemes such as the SalvaNATURA certification for shade-grown coffee from El Salvador.

Implications for poverty

There are considerable expectations about the potential for PES programmes to contribute to poverty reduction as well as improved environmental management, based largely on the perceived links between the two. Where poverty is associated with environmental degradation, paying poor producers to adopt production systems that are more environmentally friendly is likely to generate a "win–win" outcome, with both poverty reduction and environmental benefits obtained. However, such a positive outcome is not the only potential impact of PES programmes on the poor. Indirect effects on agricultural wages and food prices might adversely affect poor labourers and consumers. Increased land values following the implementation of PES programmes could create greater competition for lands to which the poor have, at best, only an informal right of access, with a resultant loss of control to more powerful interests. Even among groups of the poor, PES programmes may favour some more than others, with implications for overall poverty reduction as well as the welfare of certain segments of poor populations.

The impact of a PES approach on the poor is highly dependent on who holds the rights to use resources; this, in turn, depends on the distribution of land ownership. In some countries, land ownership is highly skewed; in others it is not. A more even distribution is likely to result in more of the benefits accruing to the poor.

Main messages from the report

The following chapters review the issues introduced above in greater detail. Chapter 2 provides an overview of the technical relationship between agriculture and environmental services and discusses how agriculture can increase its supply of environmental services. Chapter 3 discusses the basis of the demand for environmental services, the differences between public- and private-sector programmes and the current market situation for the three main services focused on in this report. Chapter 4 addresses the supply of environmental

services, starting from the farmers' decision-making process; it lays out policy options to enhance the supply of these services and the role that payment programmes can play. Chapter 5 reviews in detail the various issues involved in designing PES programmes in agriculture with an emphasis on cost-effectiveness. Chapter 6 examines more closely the implications of PES programmes for poverty and possible synergies between environmental service provision and poverty alleviation. Finally, Chapter 7 pulls together the conclusions of the report and lays out the main issues involved in developing the potential of PES programmes.

The main messages emerging from the report can be summarized as follows.

- **Demand for environmental services from agriculture will increase**. Two forces are generating a growth in demand for these services: a greater awareness of their value; and their increasing scarcity, arising from mounting pressures on the Earth's ecosystems. At the same time, environmental policy worldwide is increasingly characterized by greater emphasis on decentralization, flexible mechanisms, the private sector as a provider of public services, consumer sovereignty and civil regulation. Nevertheless, the question of who will bear the cost of providing environmental services remains difficult to resolve.
- **Agriculture can provide a better mix of ecosystem services to meet society's changing needs**. Farmers depend on, and generate, a wide range of ecosystem services. Their actions can enhance and degrade ecosystems. Through changes in land-use and production systems, agricultural producers can provide a better mix of ecosystem services, expanding the share of those characterized by positive externalities, to meet society's changing needs.
- **If farmers are to provide a better mix of ecosystem services, better incentives will be required. Payments for environmental services can help.** Farmers lack incentives to consider the impacts of their decisions on environmental services. Improved information and regulations can influence farmers' decisions in ways that enhance the environment – as can payments to farmers from those who benefit. The relative merits of the different approaches vary according to the different environmental services. Payment programmes range from highly competitive exchanges to public-sector programmes with strong equity objectives. Programmes also vary in terms of the source of payments, the transaction costs involved and the impacts on agricultural production and poverty reduction. The type of programme that is most suitable for any one context will vary. Policy-makers need to be clear as to what societies' priorities are, recognizing the synergies and trade-offs involved in alternative programme designs, as well as the need for careful monitoring and evaluation to ensure value for public expenditures.
- **Cost-effective PES programmes require careful design based on the characteristics of the service and the biophysical and socio-economic context.** Programme design involves four main steps: identifying what should be paid for, who should be paid, how much should be paid and what payment mechanism(s) should be used. These are challenging in practice and have important implications for programme results; careful, context-specific design of each PES programme is therefore critical, as are monitoring and enforcement to ensure compliance. Getting the science right is crucial and requires a clear understanding of the biophysical relationships between farmers' actions and their environmental consequences, as well as the economic motives and constraints facing suppliers and beneficiaries of environmental services. Equally important are the institutional innovations needed to link suppliers and beneficiaries as well as an appropriate enabling environment.
- **Payments for environmental services are not primarily a poverty reduction tool, but the poor are likely to be affected and implications for them must be considered.** Payments can increase the incomes of farmers who produce environmental services. Other poor

households may also benefit, for example from increased productivity of the soils they cultivate or improved quality of the water they drink. However, the distribution of benefits depends on who produces the environmental services, and where. In some cases, payments may also have adverse impacts on poverty and food security, for example if they reduce demand for agricultural employment or increase food prices. Nevertheless, PES programmes have been shown to be potentially accessible and beneficial to the poor if properly designed.

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:

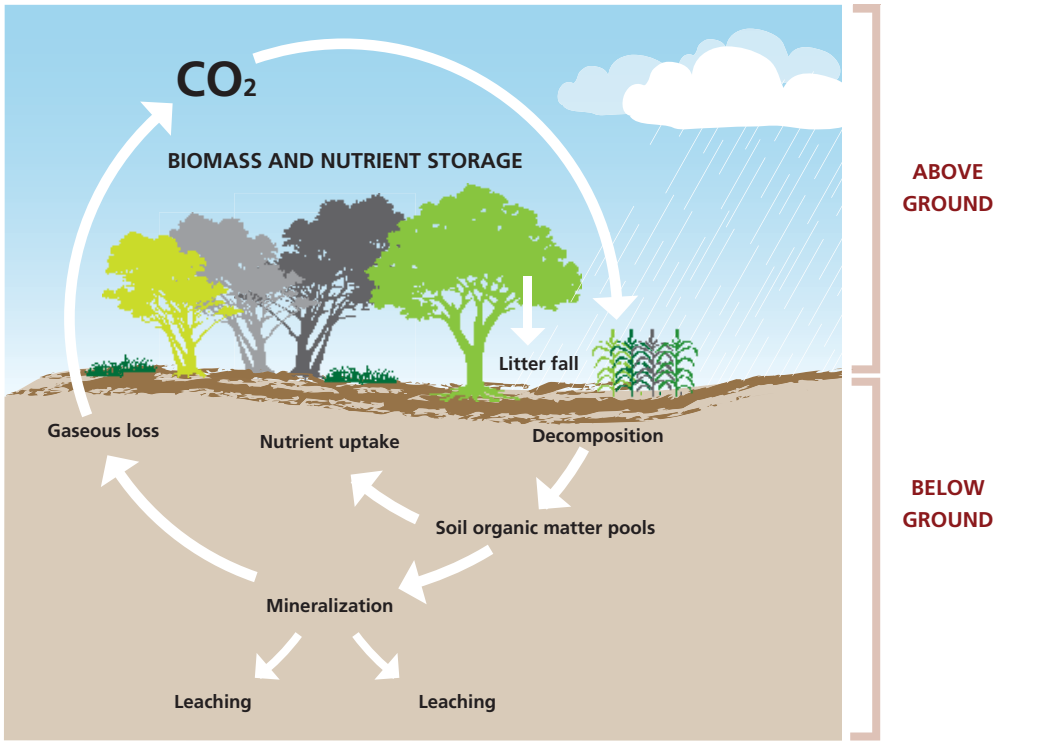
> *Continued greenhouse gas emissions at or above current rates would cause further warming and induce many changes in the global climate system during the 21st century that would very likely be larger than those observed during the 20th century.*
>
> (IPCC, 2007a, p. 13)

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.

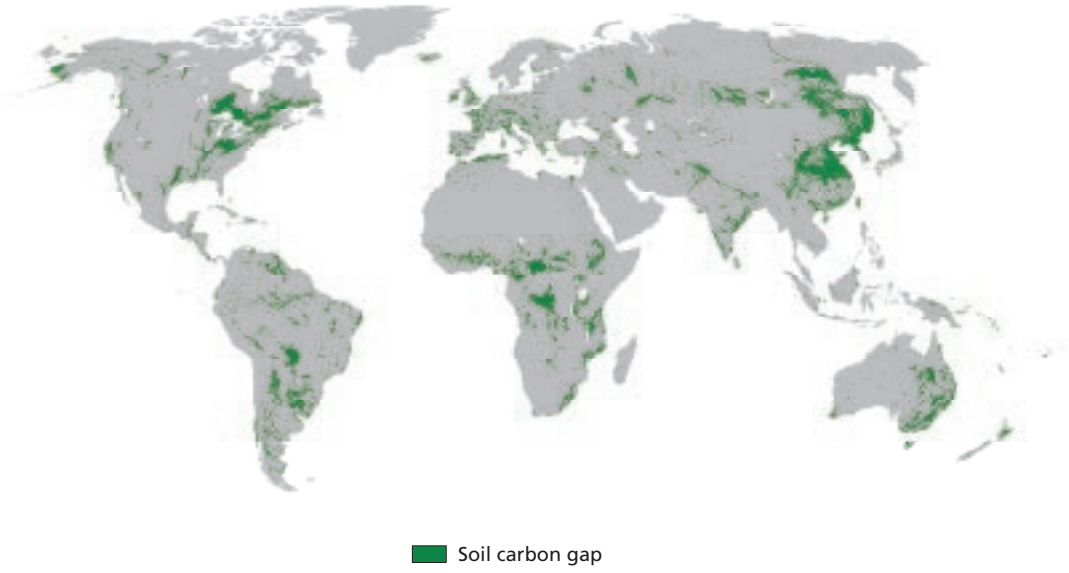
The highest average amount of carbon that can be sequestered per hectare per year is generally obtained by expanding forest area via afforestation or reforestation. Annual crops and pastures store a small fraction of that amount. Amounts achieved by logged forests, agroforests, tree crops, timber plantations 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.

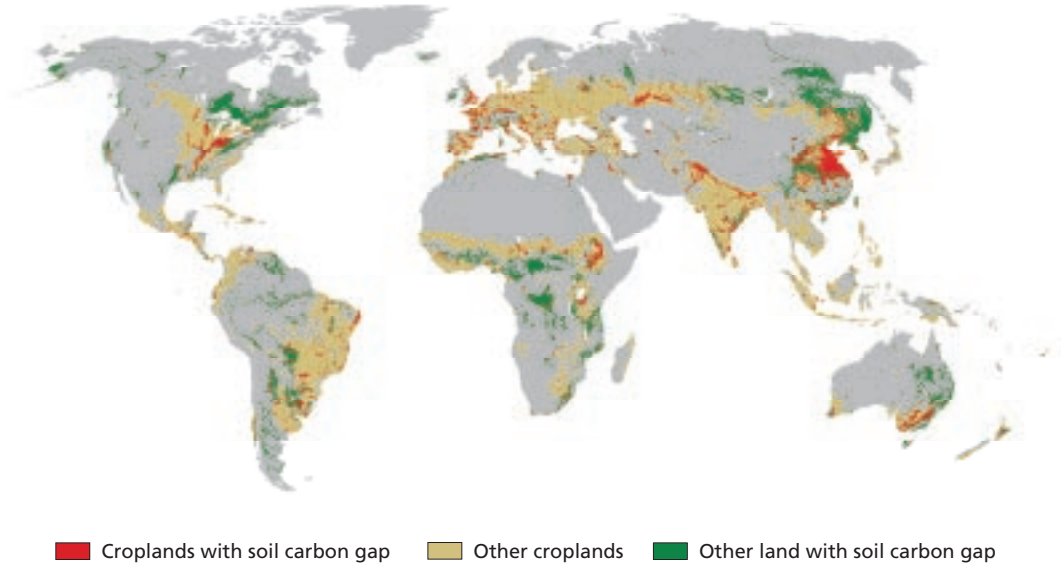
Map 2 indicates the location of croplands with medium-to-high technical potential to sequester carbon. This map provides a preliminary perspective on where cropping systems could be changed to achieve substantial soil carbon sequestration. It highlights the intersection of locations with medium-to-high 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.

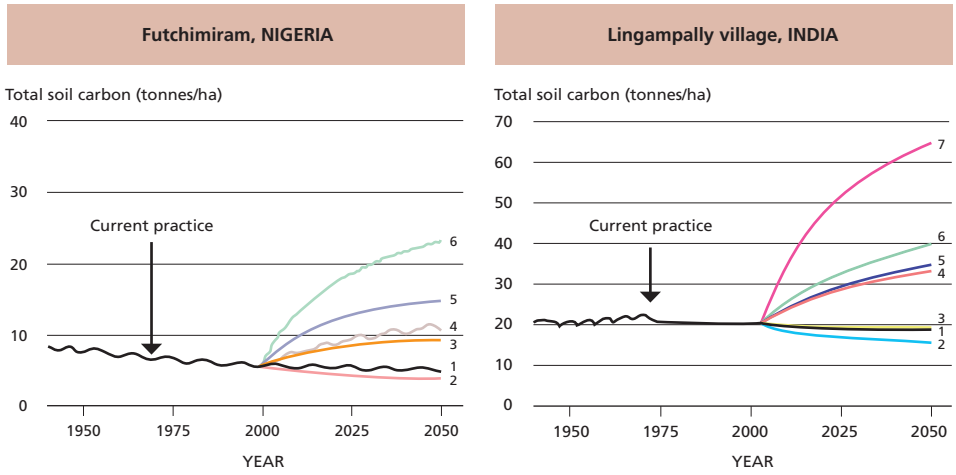
Water quantity and quality

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

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

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 m³/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

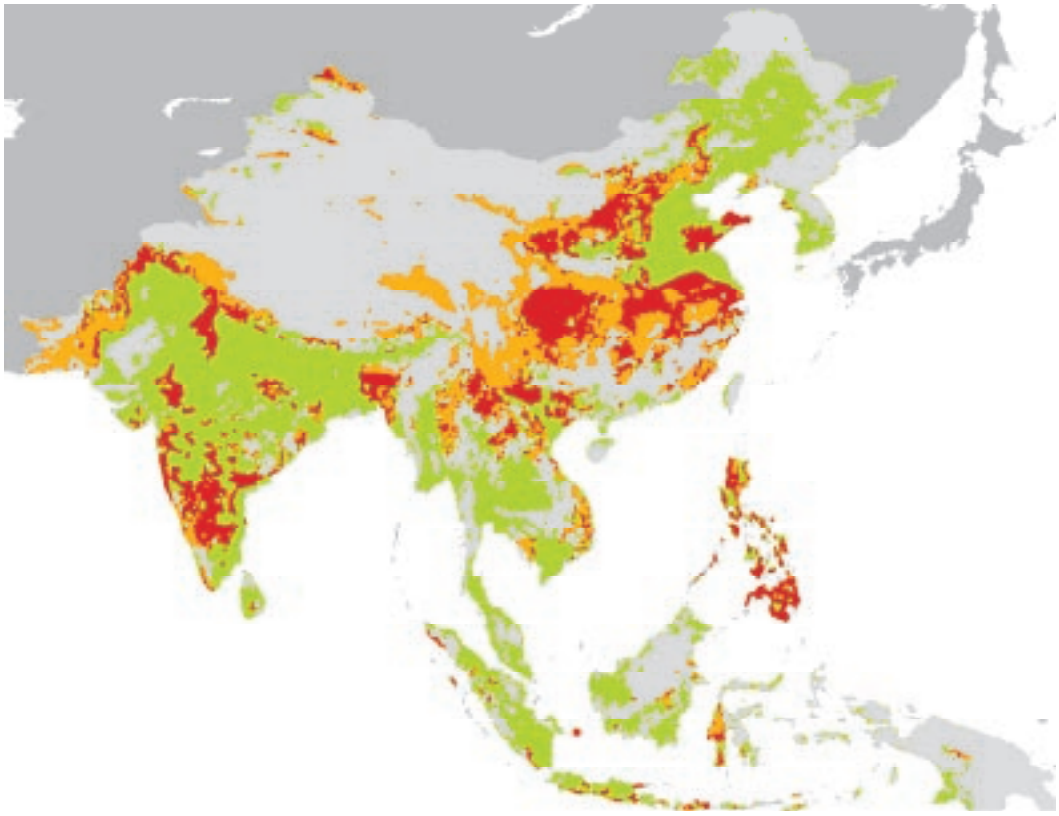
The United Nations Economic Commission for Europe (UNECE) defined water quality as the "physical, chemical, and biological characteristics of water necessary to sustain desired water uses" (UNECE, 1995, p. 5). Most aquatic species are able to adapt to natural changes in water quality, but human activities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



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).

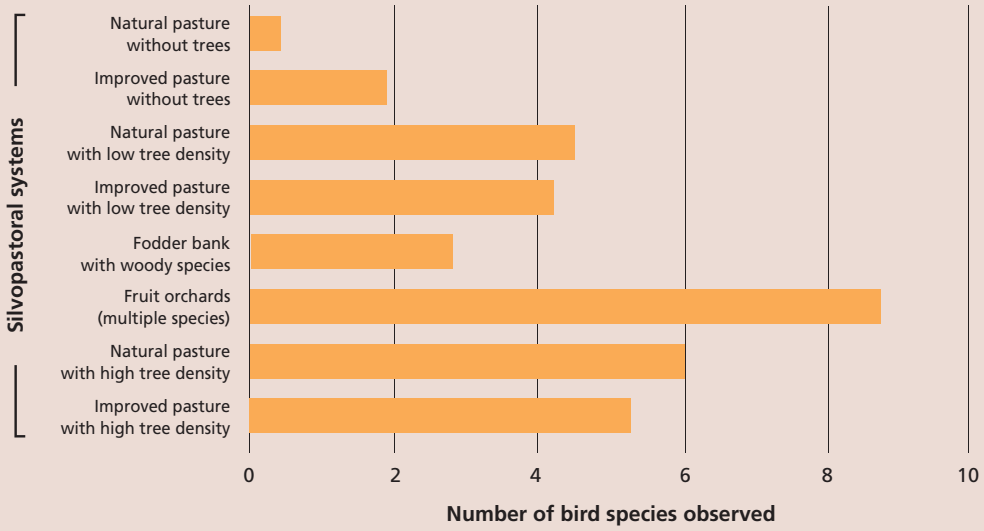
MAP 4
Projected expansion of cropland and pasture, 2000–2010

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?

3. Demand for environmental services

Several forces are stimulating a growth in demand and willingness to pay for environmental services. Public awareness of the value of environmental services and the costs of their depletion is growing and information on the issues is becoming more widely available.

Environmental and, to some extent, health regulations are an important outcome of this trend and are major drivers of the willingness to pay for environmental services. Individuals and firms are ready to pay for such services when they provide a low-cost way of complying with a regulation. In the early 1990s, for example, the city of New York in the United States of America concluded that the least-expensive means of meeting water quality standards for the city's water supply was through paying farmers in the upper reaches of the watershed to change their agricultural practices (Box 4). Similarly, payments for carbon sequestration are largely driven by regulations at the international, national and subnational levels limiting carbon emissions and creating a market for offsets.

Payments for environmental services beyond the regulatory requirements are also emerging. When the value of wetlands outside New Orleans in the United States of America became clear in the aftermath of Hurricane Katrina, the state of Louisiana started directing funds towards coastal wetlands restoration, reversing former policies that had actually degraded wetlands (Verchick, 2007). Consumers also have shown a marked willingness to pay for environmental services through their purchases of ecolabelled products. Swallow *et al*. (2007b) identify three important links between flexible and regulatory approaches to environmental governance:

- New environmental regulations that allow flexibility in the approach to compliance create institutional space for public utilities, local governments and private firms to innovate with regard to PES activities.
- Firms or industry groups may actively promote PES schemes as a way of demonstrating commitment to the environment in order to forestall environmental regulations.
- Firms may seek to establish or illustrate best practice in environmental management as a way of influencing the shape of future environmental regulation.

Most PES programmes are funded by the public sector. However, the private sector is increasingly becoming involved in purchasing environmental services. A recent survey identified more than 100 types of private environmental service payment programmes – with a relatively even distribution across the domains of carbon sequestration, water and biodiversity – and an estimated number of transactions totalling more than 1 100 (FAO/Forest Trends, 2007).

This chapter examines the basis for the demand for environmental services and the differences between public- and private-sector programmes.[4] It then examines the current market situation for three major services: carbon sequestration, watershed management and biodiversity conservation.

Value and beneficiaries of environmental services

To understand the basis for payments for environmental services provided by agriculture, it is first necessary to look at the benefits they generate and to whom they accrue.

[4] The chapter draws heavily on FAO, 2007c.

BOX 4

Demand for and supply of water services in Sukhomajri, India and New York, United States of America

Two well-known cases of payments for environmental services in the area of water quality from India and the United States of America illustrate the importance of assessing both demand and supply.

The small village of Sukhomajri in India provides an early and complex example of watershed development that has helped inspire modern watershed development programmes. In the 1970s, high rates of sedimentation in Lake Sukhna in the northern Indian state of Haryana created problems for the drinking water supply of the nearby town of Chandigarh (Kerr, 2002). Recreational benefits were threatened also. The source of the problem was traced to a small upstream village named Sukhomajri, where villagers were cultivating steep lands and allowing animals to graze freely throughout the watershed. Around 80–90 percent of the sedimentation in Lake Sukhna was found to originate from Sukhomajri (Sengupta *et al.*, 2003). The Sukhomajri farmers' agricultural practices were not only felt downstream; runoff water on one side of the watershed also flooded and destroyed agricultural lands in the village itself.

A central government agency, the Central Soil and Water Conservation Research and Training Institute (CSWCRTI) revegetated the watersheds and installed conservation structures such as check dams and gully plugs to stop the flow of silt. Villagers were asked to refrain from allowing grazing animals into the watersheds. Benefits to the villagers were twofold: not only reduced damage to agricultural lands, but also access to irrigation water stored by the check dams. Although no direct payments were involved, the villagers were thus indirectly compensated for providing the environmental service. At the time of the project implementation, the notion of markets for environmental services was little known, but in effect the project functioned as an environmental services payment scheme. A drawback was that only a minority of landowners in the village benefited from the scheme; other villagers, particularly the landless,

Valuing environmental services

For traded commodities and services, market prices indicate the value at which buyers and sellers agree to exchange them. For many environmental services, however, market prices do not exist, so quantifying their importance or estimating their value is difficult. Information is lacking regarding the underlying process that results in environmental services and their implications for human well-being. In many cases, the benefits may be uncertain and may occur only in the future, if at all. A common approach to estimating environmental values is the "total economic value" concept, which encapsulates the full range of economic values· that people attach to each type of land use.[5]

- **Direct use values** are those derived from marketed goods or services that normally involve private benefits, such as commodities, timber, fuelwood, non-timber forest products, recreation, education and tourism. These also generally correspond to the Millennium Ecosystem Assessment's category of provisioning services. Valuation of these types of service is usually straightforward.
- **Indirect use values** refer to benefits that people derive indirectly from the "ecological functions" performed, such as watershed protection, fire prevention, water recycling, carbon sequestration, biodiversity conservation, and pest and disease resistance. Environmental services often fall into the latter category of benefits, which relate to the Millennium Ecosystem Assessment's categories of regulating and supporting services.

[5] See, for example, Pearce, 1993; Johansson, 1990; Barbier, 1989; Pearce and Turner, 1990; Munasinghe and Lutz, 1993; Ayres and Dixon, 1995; Kumari, 1995; Adger *et al.*, 1995; Hearne, 1996; Andersen, 1997; Markandya *et al.*, 2002.

stood to lose from reduced access to grazing lands. The problem was solved by distributing rights to the water to all villagers and allowing them to trade among themselves – a system that was later abandoned in favour of user fees for water. The project resulted in a 95 percent decrease in siltation into Lake Sukhna, saving the town of Chandigarh about US$200 000 annually (Kerr, 2002).

In the second case, which was initiated in the early 1990s, a combination of federal regulations and cost realities in the United States of America drove New York City to reconsider its water supply strategy. Municipal and other water suppliers were required to filter their surface water supplies unless they could demonstrate that they had taken other steps, including watershed protection measures, to protect their customers from harmful water contamination. Ninety percent of the New York City water supply is drawn from a watershed that extends 200 km north and west of the city. City authorities concluded that managing land use in the watershed was more cost-effective than building a filtration plant. A filtration plant would have cost US$6–8 billion. Watershed protection efforts, including not only the acquisition of critical watershed lands but also payments to farmers to change practices so as to reduce contamination sources in the watershed, would have cost only about US$1.5 billion and would have provided the same level of water quality. New York City chose to invest in natural rather than produced capital. Farms that opt to participate in the Watershed Agricultural Program receive technical assistance in designing a strategy for controlling potential sources of pollution on the farm, with New York City covering all costs associated with the implementation, and become eligible for other elements of the compensation package for specific environmental services (Rosa *et al*., 2003).

Source: FAO, 2007d.

- **Option values** are based on the benefit of preserving the possibility of future direct or indirect use. They represent the insurance premium people are willing to pay today to secure environmental services in the future. Much of the importance of biodiversity conservation lies in option values: preserving ecosystems, species and genes for potential future use.
- **Non-use values** are benefits that are totally unrelated to any personal use of an ecosystem. Individuals may value environmental services without ever actually deriving any use value from them. Benefits in this category include the value of knowing that an ecosystem exists and will be conserved for future generations, as do securing the survival and well-being of biodiversity, endangered species and habitats (FAO, 2004c). They are also referred to as existence values.

Precisely because markets do not exist for many environmental services, estimating their value is difficult. If society has decided that an environmental service is worth protecting (or enhancing), even without a precise estimate of its monetary value, other methods – such as environmental benefits indices – can be used to prioritize spending in such programmes. These methods are discussed in greater detail in Chapter 5.

Identifying beneficiaries

Who actually benefits from these different forms of value from environmental services? The benefits from environmental services occur at local, regional and global levels. They may occur immediately, after a few years or well into the future. Establishing where and when the benefits from environmental services occur is fundamental to understanding the basis of demand and payments for them. Table 5 provides a

TABLE 5
Indirect, option, and non-use values associated with environmental services

	INDIRECT USE VALUE	OPTION VALUE	NON-USE VALUE
Off-site local benefits	■ Watershed, soil and flood protection ■ Water quality ■ Water and nutrient recycling ■ Soil fertility ■ Pest and disease resistance ■ Aesthetic, cultural and spiritual values	■ Conservation of agricultural biodiversity for potential future uses	■ Aesthetic, cultural and spiritual values
Global benefits	■ Climate change mitigation	■ Genetic material that can be used for agricultural, medical other future purposes	■ Biodiversity conservation and species preservation

Source: adapted from FAO, 2004c.

rough categorization of the benefits from environmental services, grouped according to scale and type of value.

Who are the potential buyers?

Owing to their nature, environmental services are not easily packaged and traded, and in many cases their benefits will occur mostly in the future. Many environmental services take the form of public goods (see Box 2 on p. 14). Coordination of purchasers of public goods is required in order to overcome problems of "free-riders" (those who benefit from the service without paying for it). Moreover, the actual purchaser of an environmental service is often not the same as the beneficiary (see Table 6). In many cases, the purchaser is the public sector, acting on behalf of individual beneficiaries. However, there are also other intermediaries who coordinate purchases for environmental services, including non-governmental organizations (NGOs) and product certifiers.

Public-sector funding of PES programmes

Public-sector funding for agriculture is the most frequent source of funds for PES programmes, whether it is the Grain for Green programme in China (see Box 17 on p. 83), the CRP in the United States of America (see Box 5 on p. 38), Costa Rica's Payments for Environmental Services programme (see Box 16 on p. 81) or Brazil's Programme of Socio-environmental Development of the Rural Family Production, known as Proambiente (May *et al*., 2004). Usually, public-sector programmes do not have a direct link between buyers and sellers; instead, governments use general tax revenues or external funds such as those provided as overseas development assistance. In some cases, however, revenues are generated by earmarking a share of taxes or fees charged to some users of the services, such as the water fee in Mexico (Muñoz-Piña *et al*., 2005), or the South African "water resource management fee" included in the water charges, to cover part of the costs of clearing "thirsty" invasive alien plants (see Box 22 on p. 97) (Turpie and Blignaut, 2005).

International public-sector funding is also an important source of finance for PES programmes in developing countries. One key player is the GEF, which has co-funded several PES projects in developing countries (see Box 6 on p. 39). GEF payments can reasonably be considered as payments from service users, in that the global community (through the Convention on Biodiversity Conservation and the United Nations Framework Convention on Climate Change [UNFCCC]) has empowered the GEF to act on its behalf in conserving global public

TABLE 6
Environmental services and examples of buyers

ECOSYSTEM SERVICE	BENEFICIARIES	BUYERS
Carbon sequestration	■ Global community	■ Local, regional and national governments ■ International organizations (World Bank – BioCarbon Fund) ■ National carbon funds (Italian Carbon Fund, The Netherlands CDM Facility) ■ Conservation groups ■ Land trusts ■ Corporations ■ Hedge funds and investment groups
Biodiversity	■ Global community	■ International and national NGOs ■ Private businesses (offsets)
Water quality	■ Local community (potable water) ■ Fishers (pollution) ■ Farmers (salinity)	■ Municipalities ■ Private water suppliers ■ Public water suppliers ■ Bottled water companies ■ Farming organizations
Erosion control	■ Local community (potable water) ■ Dam owners (sedimentation) ■ Fishers (sedimentation)	■ Hydroelectric energy providers

Source: adapted from FAO, 2007d.

goods (Pagiola and Platais, 2007). The BioCarbon Fund provides an example of an international source of payments for carbon emission offsets from land-use change that includes payments for activities allowable under the Kyoto Protocol (see p. 41), such as reforestation and afforestation, as well as a broader menu of options for offsets, such as soil carbon sequestration.

Overseas development assistance in the form of loans and grants has also been a significant source of funds for PES programmes. Loans from the World Bank have financed some of the most well-established PES programmes, such as the Costa Rican and Mexican national PES programmes. The critical role played by these projects has centred on helping both countries develop new, sustainable sources of finance from water users, the tourism industry and carbon buyers to improve programme efficiency and to support the participation of poorer landholders.

Private-sector purchasers of environmental services

The private sector is playing an increasingly active role in payment programmes in developing countries. Their motivation for paying to promote environmental service provision includes concerns about maximizing sales to environmentally aware consumers and pressures from shareholders and consumers for greater corporate social responsibility.

Examples of private-sector programmes include payments for voluntary carbon sequestration and biodiversity conservation, payments through intermediaries such as NGOs for the adoption of conservation practices, private purchases of water quality services and involvement in ecolabelling initiatives, including ecotourism. It is estimated that around 100 megatonnes of carbon have been sequestered through voluntary payments to landowners, many of whom are in developing countries (Bayon, Hawn and Hamilton, 2007). Some companies engaged in land development in developing

BOX 5
The United States Conservation Reserve Program

Created in 1985, the United States Conservation Reserve Program (CRP) is the largest payment scheme for environmental services in the world, providing annual rental payments and sharing the cost of conservation practices on farmland. First created to address problems of soil erosion and to support farm incomes at a time of declining crop prices, the programme has grown over the years and now pays for land-use changes that promote water quality and wildlife habitat, as well. Annual payments exceed US$1.4 billion for activities on over 32 million acres (approximately 13 million hectares) (USDA, 2007).

CRP contracts extend from 10 to 15 years. To be eligible for CRP support, farmland must have been planted in two of the five most recent crop years and meet a set of requirements to ensure it can provide services. The land must be physically and legally capable of growing an agricultural commodity or constitute marginal pastureland suitable for planting as a riparian buffer. In addition, the land must present some sensitive environmental characteristics, such as being highly erodible or a cropped wetland.

Farmers wishing to enrol in the CRP have their offers ranked by government field officers according to an Environmental Benefits Index (EBI) that includes such elements as erodibility, as well as wildlife habitat or water quality benefits. Farmers who are selected for enrolment receive annual rental payments (averaging US$49 per acre in 2006), as well as cost-share payments to establish approved vegetative cover. Topsoil loss on CRP land is estimated to have been greatly reduced, and benefits to water quality, wildlife and recreation have also been significant (Sullivan *et al.*, 2004).

Despite CRP's achievements, critics have raised several concerns. First, land withdrawn from crop production in the CRP may be partially offset by land brought into production elsewhere, although the precise magnitude is difficult to determine (Roberts and Bucholtz, 2006). Second, concerns have been expressed about fairness, in that participating farmers are paid to adopt practices that other farmers may have adopted voluntarily (without compensation). Finally, concerns have been raised about cost-effectiveness, as it is possible for owners of land with substantial environmental benefits (as reflected in a high EBI), but low agricultural productivity, to qualify for CRP payments well above what they would be willing to accept, in view of the low returns they would have were they to keep that land in production (Kirwan, Lubowski and Roberts, 2005). Considerations in programme design to address these concerns are discussed further in Chapter 5.

countries are voluntarily offsetting the negative effects of their activities on local biodiversity by restoring and enhancing habitat elsewhere.[6]

Consumers of ecolabelled products represent a further source of private-sector payments. The Forest Stewardship Council (FSC), which sets standards for sustainable forest management, and the Marine Stewardship Council (see Box 21 on p. 92), which provides standards for sustainable fisheries, are two notable sources of product certification. Both accredit independent certification bodies to carry out certification. In both cases, certification requires a management system that generates environmental services, particularly biodiversity conservation, as well as fish and forest products. In the case of the FSC, the global extent of certified forest area

[6] For more detailed discussion of the potential for biodiversity offsets see http://www.forest-trends.org/biodiversityoffsetprogram.

BOX 6
Global Environment Facility and payments for environmental services

Pablo Gutman[1]

Over the early 2000s, the Global Environment Facility (GEF) has built a portfolio of 22 projects that have some elements of an environmental services payments programme. The cumulative budget for these programmes is somewhat less than 3 percent of GEF cumulative investments. Most of the projects' total budgets are in the range of US$25–100 million. Almost all projects are part of the GEF biodiversity portfolio and are heavily concentrated in the Latin America and the Caribbean region. The ecosystem services they provide include all those discussed in this report. Thus far, GEF's role in the payments for environmental services arena has been small, but important in several ways: acting as the glue for other institutions to participate; increasing incentives for the recipient country; bringing in funds for institutional development and capacity building; promoting new ideas and approaches.

The current GEF payments for environmental services portfolio is largely focused on protection of natural forests and management of protected areas. Many projects anticipate the growth of international markets for biocarbon sequestration and avoided deforestation for future funding. Others hope to find local buyers for watershed protection services. Current payers are always the national government or international donors, both bilateral and GEF. With the exception of the carbon emission offsets projects, these projects do not rely on the markets of wealthier countries as a source of funding.

[1] *World Wildlife Fund.*

is small, accounting for only 7 percent of total global forest area, and most is located in developed countries. Certification has so far focused on public and large private forests. It can represent an additional cost that poorer countries and smaller producers find difficult to meet and thus they may be disadvantaged. Nevertheless, although both the demand for, and supply of, certified products is concentrated primarily in developed countries, some growth in supply is also beginning to occur in developing countries. For example, Argentina and China rank second and third in the world for their areas of certified organic land, while virtually all Rainforest Alliance certified crops are grown in Latin America (P. Liu, personal communication, 2007).

Considerable diversity exists in the certification of agricultural crop commodities in terms of products covered and types of environmental benefits associated with the standard. Organic agriculture is the largest certified product market in agriculture, with over 31 million hectares currently certified as organic and a market value of 25.5 billion euros in 2005 (IFOAM, 2007). Most types of organic certification are not directly tied to a specific environmental service, and evidence on the net environmental benefits remains mixed. They are based on criteria linked to environmental management and thus could be considered a form of payment for environmental service. While many types of certified product programmes exist, and they are increasing in number, there is considerable fragmentation in the range of crops and environmental services receiving attention. Rainforest Alliance certification for example, encompasses coffee, cocoa, fruits and flowers and requires ecosystem management, wildlife protection and the protection of waterways. The Biodiversity and Wine Initiative in South Africa (see Box 7) certifies vineyards that implement practices aimed at conserving biodiversity.

Finally, examples exist of environmental services that are provided to discrete beneficiaries. In such cases, individual private PES buyers may be willing to pay

BOX 7
The Biodiversity and Wine Initiative in South Africa

South Africa is the world's eighth largest producer of wine, 90 percent of which is produced in the Cape Floral Kingdom, a World Heritage site and global biodiversity hotspot. Since the late 1990s, a boom in wine exports has raised concerns over the expansion of vineyards. Conservation organizations, including The World Conservation Union, Conservation International and the South African National Biodiversity Institute, have teamed up with the South African wine industry to create the Biodiversity and Wine Initiative (BWI). Specific biodiversity best practice guidelines have been incorporated into the environmental guidelines of the Integrated Production of Wine, an industry-wide technical system of sustainable wine production. From the industry's point of view, highlighting sustainable natural resource management and efforts to conserve South Africa's natural heritage creates an important marketing opportunity.

The BWI now represents the conservation element of the Wines of South Africa brand. Participating producers agree to implement biodiversity best practices to reduce negative impacts on biodiversity and enhance habitat quality. In properties with priority habitats, growers can benefit from additional support from the Cape Nature Conservation's Conservation Stewardship Programme – a programme for the conservation of priority habitats in private lands.

Benefits include assistance with on-farm habitat management, alien plant clearing and property rate rebates. The BWI provides media coverage on its Web site and in wine and tourism magazines and also plans to establish a biodiversity wine tour during which visitors can enjoy both the wine and the biodiversity richness in the property of each participating producer.

By mid-2007, the BWI scheme already covers half of the total vineyard footprint in the Cape winelands – over 50 000 hectares, managed by 76 producers.

Source: adapted from BWI, 2007.

providers to ensure continuous provision. One such example is the French bottled water company Vittel mentioned in Chapter 2, which pays farmers to maintain specific land-use practices above the aquifers they use for bottling (Perrot-Maître, 2006). In Costa Rica, La Esperanza Hydroelectric Company pays landowners in the watershed of its power-generating reservoir to maintain their forests intact in order to control erosion.[7] Similarly, ecotourism operators sometimes pay local communities to ensure the conservation of attractive biodiversity in the surrounding areas (Teixeira, 2006).

[7] For further details, see http://ecosystemmarketplace.com/pages/marketwatch.transaction.other.php?component_id=1827&component_version_id=2951&language_id=12.

Demand for three main environmental services

The sections that follow examine more closely the trends in demand for the three main environmental services that are the focus of this report: climate change mitigation, watershed services and biodiversity conservation.

Climate change mitigation

The unique characteristic of carbon emission reductions or mitigation is the absence of geographic limitations. The location of carbon mitigation is irrelevant for its effectiveness. Furthermore, increasing carbon stocks in farm soils and vegetation can often be accomplished while simultaneously improving farm productivity. This represents a valuable opportunity for diversification

and risk-spreading, two crucial components of smallholders' livelihood strategies in developing countries.

Most demand for carbon emission reductions worldwide is driven by the Kyoto Protocol and the national and regional implementing policies and trading schemes enacted to carry it out. The Kyoto Protocol is an agreement under the UNFCCC that involves commitments on the part of a set of industrialized countries (referred to as Annex I countries) to legally binding limits or reductions to their greenhouse gas emissions from a base of the levels prevailing in 1990. The Kyoto Protocol became legally binding in 2005, with its first commitment period ending in 2012. Two flexible trading mechanisms were established to meet emission reduction requirements under the Kyoto Protocol: the Clean Development Mechanism (CDM) and the Joint Implementation Program. The first allows trading in emission reductions between Annex I countries and developing countries through the issuance of a certified emission reduction (CER). Joint Implementation allows trading between two or more Annex I countries. At present, the rules of the CDM restrict the type and amount of carbon emission reduction credits that can be obtained from carbon sequestration. Only afforestation and reforestation projects are allowed, and these can only make up 1 percent of the total base-year emissions. The rules for what will be allowed after 2012 are not yet clear and remain the subject of considerable debate.

Overall, the prospects for the market in carbon emission reductions are extremely promising, and the global carbon markets are expanding rapidly. In 2005, market volume was approximately US$10 billion, while in the first quarter of 2006 alone emissions-related business transactions were valued at US$7.5 billion (World Bank/IETA, 2006) and, by the end of 2006, the global carbon market had tripled to reach US$30 billion (World Bank, 2007). In 2006, 508 megatonnes of carbon dioxide equivalents were sold by developing countries to Annex 1 countries, for a total value of US$5.4 billion (including transactions within the CDM, Joint Implementation and voluntary markets) (World Bank, 2007).

However, only a small share of the market is for emission reductions from carbon sequestration, due to the CDM restrictions mentioned above and because the EU Emissions Trading Scheme – the largest market, accounting for US$25 billion in 2006 – does not allow credits from forestry carbon. Emission reductions from land use, land-use change and forestry (LULUCF) account for only 1 percent of volumes so far (World Bank, 2007), with only 0.3 percent of the CERs being issued for LULUCF projects, and more than half of these are generated from projects in China.

Currently, these regulated markets are unfavourable to small farmers for a number of reasons. First, the CDM excludes two of the major forms of carbon emission reductions that farmers can deliver relatively easily: reduced emissions from deforestation in developing countries (known by its acronym RED-DC) and soil carbon sequestration. Second, the process of certifying projects to be CDM-eligible is complex and costly, as is the process of delivering carbon credits to the market (see Box 20 on p. 90).

A third problem relates to the limits placed on the size of small-scale carbon projects. The CDM allows simplified procedures for establishing small projects; however, the maximum size of these projects is set at 8 kilotonnes of carbon dioxide that can be offset from sequestration per year, which is too small for the projects to be financially feasible at current market prices. Most country submissions to the UNFCCC in 2007 requested an increase in this cap to 32 kilotonnes in order to improve their feasibility.

Finally, for buyers who are not interested in social co-benefits and who are concerned about the risks associated with the reversibility of emission credits from agriculture-based projects, other energy projects and projects that capture potent industrial greenhouse gases are now considered those with the best prospects for the carbon-trading market. Nonetheless, regulated markets could still involve significant numbers of small farmers if the rules were changed to encourage their inclusion.

The prices that are being paid for credits for carbon emission reduction vary widely by source of demand and type of offset. The Ecosystem Marketplace reported prices of around US$7 per tonne of carbon dioxide in

BOX 8

Payments for reduced emissions from deforestation: what is the potential?

Heiner von Lüpke[1]

It is estimated that at least 18 percent of all greenhouse gas emissions originate from deforestation processes worldwide, making this the second largest emitting process, after fossil fuel combustion. According to the 2005 FAO Global Forest Resource Assessment, deforestation is taking place at a rate of 13 million hectares annually and is principally a result of conversion to other land uses, forest degradation, timber and fuelwood removals and shifting cultivation, as well as forest fires. Important underlying and proximate causes of deforestation are economic factors such as market growth, policy and institutional factors, and formal and informal policies, as well as issues related to land tenure and property rights.

At the eleventh Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 11), a group of countries led by Costa Rica and Papua New Guinea proposed the consideration of a framework to contribute to reducing greenhouse gas emissions through avoiding deforestation in developing countries. Developing countries would identify projects to achieve voluntary carbon emission reductions by reducing deforestation in return for international financial compensation. Other policy approaches besides payments, including capacity and institution building, have been included in the proposals, as well. A possible mechanism is currently being discussed and is to be addressed during COP 13 (Indonesia, December 2007). A common feature is the proposition that the international community would bear the costs of implementing the mechanism. Options under discussion include a mechanism based on existing carbon markets and a separate global fund.

Issues include the weak database on actual and historic trends of carbon stock changes in forests, the development of a baseline scenario, technical matters related to the monitoring of carbon stock changes in forests, strengthening capacities of institutions and the need to build institutional frameworks to implement a mechanism.

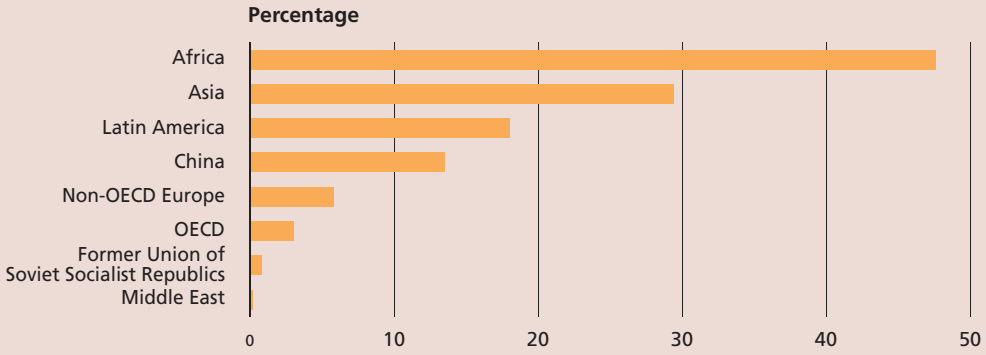
[1] *FAO Forestry Department.*

2007, up from a range of US$3–6.5 per tonne in 2004 (Walker, 2007).

The size of voluntary markets and public payments is likely to be smaller than for the regulatory carbon markets, but their interest to farming communities is likely to be greater, because they capture a much higher share of carbon sequestration projects (Bayon, Hawn and Hamilton, 2007). Voluntary buyers are often more interested in demonstrating positive social and economic co-benefits, and public-sector buyers can choose to invest in low-income areas and to utilize carbon payments to restore degraded lands and encourage agroforestry on a large scale.

Another potential source of payments for emission reduction currently under much debate is payments for reducing emissions from deforestation. Deforestation arising from conversion of land to annual crops or pasture is a major contributor to global emissions of greenhouse gases, and much of it occurs in developing countries. At its eleventh session in 2006, the Conference of Parties of the UNFCCC invited parties and accredited observers to submit their views on issues related to reducing emissions from deforestation in developing countries, including policy approaches and positive incentives. Payments to land users for reducing emissions from deforestation are one of the most important types of positive incentive measures being proposed, including by FAO in its submission (UNFCCC, 2007) (see Box 8). This source of payments,

FIGURE 6
Share of bioenergy in total primary energy supply



Source: based on data from OECD/IEA, 2007.

if it materializes, will have the potential to augment the flow of payments for emission reductions from the agriculture sector. In addition, emission reductions from LULUCF activities have been identified as having a high potential "development dividend", defined as benefits to developing countries. These benefits include economic growth, technological improvement and poverty reduction (Cosbey *et al*., 2006).

Bioenergy represents another potentially important source of carbon emission reductions. In 2004, bioenergy provided about 10 percent of total primary energy supply at the global level and approximately 35 percent in developing countries (Figure 6).

The share of bioenergy projects in the CDM market has been significant. In May 2007, bioenergy projects (excluding biogas) represented the fourth largest project type in terms of share of CERs but are expected to drop to the fifth largest share by the end of the first crediting period in 2012.

Full life-cycle greenhouse gas emissions of bioenergy systems depend on a range of aspects along the entire production chain, including land-use changes, choice of feed-stock, agricultural practices, refining or conversion process and end-use practices. Estimates of net emission reductions that can be obtained with bioenergy thus vary widely. Bioenergy can reduce emissions by substituting for transport fuels and replacing fossil fuels such as coal for power and heat generation. Bioenergy development can have impacts on water use, soil erosion and biodiversity conservation also, depending on the specific production system. These are important in assessing the sustainability of emission offsets from this source and could affect their eligibility for CDM credits.

A major problem with current patterns of biomass use for energy, particularly for traditional bioenergy systems in developing countries, is its low conversion efficiency, frequently as low as 10 percent (Kaltschmitt and Hartmann, 2001), and related degradation of carbon stocks in and outside forests.[8] Improving bioenergy efficiency is a fairly straightforward means of reducing carbon emissions and it represents a large potential source of carbon payments for those countries that currently depend on traditional bioenergy (i.e. almost all least-developed countries). The rules and modalities of the CDM have so far not allowed bioenergy projects that reduce emissions through improving efficiency or introducing renewable energy systems. This could be a key reason behind the very low share of CDM projects in sub-Saharan Africa and least-developed countries in general (Jürgens, Schlamadinger and Gomez, 2006).

Watershed services

Demand for watershed services appears to present a growing opportunity for farmers

[8] Wood removal for energy use represents a large share of total wood removals from forests, particularly in Africa and Latin America. See FAO, 2006b.

TABLE 7
Size of selected watershed service markets

Nature and location of market	Services paid for	Size of market *(Million US$)*	Price of service *(US$)*
Regulatory: COSTA RICA[1]	Water-based ecosystem services markets (1996)	89.0	40–100 per hectare of forest
Regulatory: MEXICO[2]	Payment for hydrological services (2003)	23.1	33 per hectare
Regulatory: UNITED STATES OF AMERICA	Water pollutant trading and offset (2003)	11.3	2.37 per pound sediment/ nutrients

[1] US$0.5 million of the Costa Rica funding was provided through voluntary agreements with water users, which includes public-sector water users such as the state power corporation Compañía Nacional de Fuerza y Luz (CNFL) and the public utility of the town of Heredia.
[2] Mexico is working to develop voluntary payments by water users to supplement funding from the central government, under the World Bank/GEF-financed Environmental Services Project.
Source: FAO/Forest Trends, 2007; Pagiola, 2004.

located in a critical watershed. Public watershed payment schemes, which currently represent by far the largest market for watershed services, are valued at US$2 billion annually, worldwide (Ecosystem Marketplace, 2005). Monetarily, these payments are concentrated mostly in China and the United States of America, but numerous smaller public watershed programmes are being established in Africa, Asia and Latin America. Private voluntary watershed programmes consist mainly of small, localized markets totalling about US$5 million annually, worldwide (Ecosystem Marketplace, 2005). Table 7 provides some estimates of the size of selected markets in the mid-2000s.

In contrast with carbon sequestration and many biodiversity conservation services, watershed protection services are primarily of interest to local and regional users (Landell-Mills and Porras, 2002). This characteristic is both an asset and a liability for the development of watershed payment programmes. On the positive side, it is relatively easy to identify the users or beneficiaries of watershed services; these include municipal water suppliers, hydroelectric facilities, industrial users and irrigation systems. Furthermore, the critical day-to-day use value of these services may make revenue streams less subject to market fluctuations than payment programmes driven by philanthropy, goodwill, public relations or long-term environmental well-being at the global level.

On the negative side, the local orientation of watershed service benefits is the limited scope for attracting payments from international beneficiaries. However, considerable external funding has been provided by the international community to assist in the establishment of watershed payment programmes. To date, US$108 million in approved World Bank loans and US$52 million in GEF grants have been made available for World Bank/GEF-supported PES projects involving water payments. Likewise, funding from The Nature Conservancy, an international NGO, has helped establish the FONAG (Fondo para la Protección del Agua) water fund in Quito, Ecuador; funding from Swiss Aid has helped fund the PASOLAC (Programa para la Agricultura Sostenible en Laderas de América Central) programme that helped many rural towns to establish local PES programmes in Central America; and the Inter-American Foundation has provided start-up funding for the PES mechanism in the Ecuadorian town of Pimampiro. Such external support has been used to cover start-up costs and, perhaps more importantly, technical support for mechanism design.

The development of local watershed PES programmes is difficult where the water users are poor and unable to afford payments to upstream stewards. For example, although funds collected from household water users in Pimampiro covered the payments made to upstream land users,

outside support was needed to cover the start-up costs of the programme and its ongoing administrative expenses (Echavarria *et al*., 2004).

Biodiversity conservation

Payment programmes for biodiversity conservation are in various phases of development around the world, addressing components of biodiversity ranging from the genetic to the ecosystem level and including both agricultural and wild biodiversity. In the United States of America, the conservation banking market is a biodiversity cap-and-trade system that allows for the sale and purchase of endangered species credits to offset negative impacts to endangered species and their habitat. Internationally, particularly in developing countries, payment mechanisms being developed include certification of biodiversity-friendly agricultural products, hunting concessions, ecotourism development, markets for biodiversity offsets and niche markets for products with high agricultural biodiversity value.

Regulated markets for biodiversity remain practically non-existent in the developing world at present, but might become significant if developing countries pass regulations that require corporate real estate and natural resource developers to offset their environmental impacts. Examples of biodiversity offsets have been documented, and models to mainstream this concept are being developed (ten Kate, Bishop and Bayon, 2004). Such programmes are unlikely to target agricultural lands in general but could do so when there is a preference for offsetting impacts locally and where local agricultural landscapes contain significant biodiversity.

Biodiversity markets aimed at protecting the services of wild pollinators and pest control agents are poorly developed, but have the potential for future expansion. The Millennium Ecosystem Assessment (2005b) quantified the high economic costs associated with loss of wild pollinators, a concern that has motivated a handful of projects to pay for pollinator habitat protection (McNeely and Scherr, 2002). A recent study by the United States National Academy of Sciences reported that more than 90 crops in North America rely on honeybees to transport pollen from flower to flower. These pollination services are worth an estimated $14 billion a year to the United States economy (Committee on the Status of Pollinators in North America, 2007).

Three factors currently hinder the development of biodiversity markets. First, many of the benefits of biodiversity will arise in the future and are highly uncertain. The market is therefore driven mainly by philanthropy, consumer preference and, to a lesser extent, by regulation. Second, it is difficult to define "units of biodiversity" for the purpose of carrying out transactions. Finally, the conservation community continues to debate the value of conservation funds being expended in agricultural settings, where native biodiversity may already be significantly degraded, or whether investment should focus on lands that have been less disturbed.

Farmers and landholders as buyers of services

Chapter 2 focused on the central role of farmers as providers of services, but it is also important not to overlook their potential as buyers. Almost all agricultural production still ultimately relies upon fertile soil, adequate water and protection against biological pests and natural disturbances. Most crops depend upon pollinating insects, whose recent declines have caused alarm within the agricultural community (Biesmeijer *et al.*, 2006; Committee on the Status of Pollinators in North America, 2007). In the long term, agricultural production will also depend on the maintenance of crop genetic diversity and other biodiversity that supports agriculture in numerous ways.

Thus far, individual farmers and farmer organizations are only minor buyers of environmental services (although the value of climate and soil fertility services is reflected in the price of agricultural land). Documented cases of voluntary private markets include mainly irrigators paying for upstream water-flow management, fruit-growers paying to protect pollinator habitat and farming communities paying neighbouring communities to protect critical sources of drinking water (Landell-Mills and

Porras, 2002). This approach seems likely to grow significantly for large-scale commercial producers, especially those who seek to export commodities to ecosensitive markets in Europe and elsewhere. Predicted shortages of water for surface and groundwater irrigation may lead smallholder farmer organizations, especially those producing higher-value, water-intensive crops, to establish contracts to secure hydrological services.

Future developments affecting potential growth of PES programmes in developing countries

Finally, this section touches on some of the main issues that may affect future demand and willingness to pay for environmental services from developing countries. There is little doubt that concern over, and awareness of, the costs of environmental degradation will continue to grow, but it is less clear to what extent this will result in increased funds to pay for environmental services, particularly in developing countries. The actual flow of funds to developing countries for environmental services is currently very small and primarily derived from public-sector funding in a handful of countries. Furthermore, payments for environmental services are only small relative to the income that can be obtained from alternative uses of the resources (CTS Nair, FAO Forestry Department, personal communication, 2007). Is there likely to be an increase in external funds to developing countries for payments for environmental services? Are developing countries themselves likely to use more public-sector funds to support PES programmes in their countries? These are the questions addressed in this section.

The private sector is an important source of potential increases in external funding for PES programmes in developing countries. One indicator is the increasing weight given to sound environmental management as a core business strategy for companies. Insurance companies and investors are increasingly noticing links between environmental management and returns on investment. The insurer Swiss Re, for example, calculates that natural disasters cost approximately US$230 billion in 2005, of which the insurance industry bore one-third (Vigar, 2006). Insurance industry concerns are likely to translate into higher premiums, and therefore greater operating costs. In response to these issues, some insurers are offering incentives for climate-aware actions. According to a CERES (2006) report, AIG and Marsh – the world's largest insurer and insurance broker, respectively – have launched carbon emissions credit guarantees and other new renewable energy-related insurance products, in an attempt to engage more companies in carbon offset projects and carbon emissions trading markets (FAO/Forest Trends, 2007). These new insurance products, in turn, are creating incentives for private companies to enter carbon markets.

Environmental-based challenges to companies' "licence to operate", for example in the areas of mining, water bottling and tuna fishing, also reinforce their motivation to pay for environmental services. Consumers are showing stronger interest in the environmental performance of companies, as illustrated by the growth in demand for certified products. Finally, regulators – particularly in Europe – are exploring more innovative approaches to environmental regulation for carbon offsets, as well as other environmental services.

The two global environmental service markets – carbon emission reductions and biodiversity conservation – appear to have the greatest potential for bringing new streams of finance into the agriculture sector (including forestry) in developing countries. The need to offset carbon emissions is clearly generating the greatest expectations. Interest among potential suppliers and buyers in developing countries is also high owing to the lower cost of service provision, although at present sales of carbon offsets are unevenly distributed – with Africa far behind Latin America and Asia (World Bank, 2007).

The potential growth of this market in developing countries depends on three main factors: the extent to which the overall market size expands (which in turn depends on the fate of international agreements to reduce emissions); the types of activities allowed as emission offsets; and the comparative attractiveness of carbon credits from agriculture *vis-à-vis* other sources, such as energy conservation projects.

For example, an agreement on payments for voluntary reduction in emissions from deforestation would significantly increase carbon payment flows to the agriculture sector in developing countries.

Developments in the voluntary carbon market are equally, if not more, important. Even though the voluntary market is smaller, the share of emission offsets from land-use change is much higher. At the same time, less stringent requirements are likely to mean lower transaction costs and easier access to this market for small farmers (A. Ruhweza, personal communication, 2007).

The volume of compliant carbon transactions tripled over the last year, and the voluntary offset segment is also "building in size and dynamism" (Point Carbon, 2007). Some sources project the voluntary market to become as important, by 2010, as the CDM is today, with a volume of 400 million tonnes a year compared with only 20 million tonnes in 2006 (ICF International, 2006, cited in World Bank, 2007). Reaching a generally acceptable standard for this market segment is the next major hurdle to overcome (World Bank, 2007). A determining factor for the fate of voluntary markets is how well offsets from the agriculture sector in non-regulated markets are perceived to be performing in mitigating emissions. At present, concerns over the validity of these offsets are emerging, which could seriously impair the growth of these markets (World Bank, 2007).

Even with rapid growth in the regulated and voluntary markets, the potential for developing countries to benefit depends on their taking steps to provide the necessary institutional structures to engage in such projects. The Nairobi Framework,[9] a United Nations-led partnership linking government action to the private sector, is one example of an initiative to spur the development of capacity to access carbon markets in developing countries, particularly Africa.

Unlike carbon emission reductions, no international regulatory framework currently underpins payments for biodiversity conservation. Nevertheless, several sources of demand for biodiversity services have emerged. National regulations governing the biodiversity impacts of planned economic development projects are stimulating growth in demand from corporate developers for biodiversity offsets.

Even in the absence of any regulations, corporations might seek to enhance their corporate image by offsetting the biodiversity impacts of their activities. Large-scale development projects by private and public actors – road building, mining, oil and gas extraction, and urban development – could bring significant funding and high visibility to this market. Appropriate standards could encourage projects with high social co-benefits.

Second, philanthropic buyers, especially large conservation NGOs, are likely to increase the use of conservation payments and conservation easements in developing countries because the establishment of new nature reserves has become more contentious in many regions, in part because of their impacts on rural livelihoods.

Individual consumers are driving the development of markets for agricultural products certified against environmental standards and represent another important potential source of growth in demand for biodiversity conservation services. This market is small but shows some promise of significant growth with increased consumer awareness and demand for improved environmental management. The expansion in the market for organic agricultural products can provide some insights into how consumer demands for environmentally friendly products are changing. World retail sales of such products were estimated at US$35 billion in 2006. Sales trebled in the period 1997–2005 and, according to industry sources, are expected to double between 2006 and 2012. The extent to which changing consumer preferences will translate into increased demand for products associated with environmental services – particularly biodiversity – is yet to be seen.

The global market for biodiversity conservation will be influenced by the extent to which it can be linked with economically significant problems such as the transmission of diseases or the incidence and severity of natural disasters. Both problems generate high social costs. To the extent that maintaining various forms of biodiversity can be found to reduce these costs, the value and demand for services will increase.

[9] For further information, see http://cdm.unfccc.int/Nairobi_Framework/index.html.

An important constraint that developing countries face in building their markets for ecolabelled products is the lack of local certification systems or, when these exist, their lack of recognition by buyers in international markets. This situation implies that foreign certification bodies must be called in to carry out the inspection and certification work for export products, which tends to raise costs, especially when inspectors must be flown in from abroad. The extent to which developing countries will be able to benefit from the growth of the market for environmentally friendly products will be determined by their capacity to develop local certification bodies and have them fully recognized in importing countries.

A final question to be considered is the degree to which payment programmes will expand for environmental services with primarily local benefits, particularly watershed services. A key issue here is the degree to which users of the water services are willing and able to pay for such services; imposing fees on low-income urban populations for drinking water is not likely to be politically or economically feasible. However, in situations where water users are already bearing heavy costs associated with the degradation of watershed services – be it in the form of payments for water treatment, desiltation or new water-supply development – the demand and willingness to pay for watershed services may be quite substantial.

Conclusions

While there has been significant growth in PES programmes in recent years, the overall size of the markets remains small, and they are mostly confined to developed countries. The public sector has been the major source of payment programmes so far in both developed and developing countries. The international public sector has played an important role in financing PES schemes in developing countries through the GEF, as well as through development loans.

Future effective demand is likely to grow, driven by increased demand for environmental offsets (carbon emissions and biodiversity) that developing countries can supply at relatively low prices. Interest in developing countries as suppliers is high for two reasons: in the case of carbon offsets, because of the lower cost of service provision found in developing countries; for biodiversity, because much of the world's biodiversity is located in developing countries.

The carbon market has seen rapid growth in recent years, but the segment relevant to carbon emission reductions from land-use change is still small. There are two main sources of carbon payments: the regulated market under the CDM and a variety of voluntary and public-sector sources of payments. Voluntary and public sources allow a wider range of land-use changes to generate carbon emission offsets. The potential for growth in carbon markets is promising, although the extent to which this will increase demand for emission offsets from land use depends on future negotiations regarding the activities that will be permissible. A potentially important source of demand currently being discussed is payments for reducing emissions from deforestation.

Environmental services related to biodiversity are purchased by the public sector and NGOs through a variety of mechanisms, by consumers expressing demands for improved environmental management via purchase of ecolabelled products and by private-sector buyers interested in improving their corporate image. Biodiversity offset programmes represent a further potential source of demand, but are not yet well developed. There is also potential for growth in public-sector-funded PES programmes in developing countries where environmental services meet critical policy objectives such as clean water availability and prevention of natural disasters.

Growth in demand and willingness to pay for environmental services from developing countries must be supported by a set of policy and programmatic efforts. These include strengthening the international environmental regulatory framework governing climate change and biodiversity conservation, which are both important sources of demand for offset services, and allowing activities that facilitate the participation of agricultural producers in developing countries. This latter approach

could include the reduction of emissions from deforestation in climate change mitigation. Improving coordination among various forms of ecolabelling schemes and clarifying the environmental benefits that can be obtained from certified products are important for future growth in this form of payments for environmental services.

Building institutions and capacity for managing environmental service payments in developing countries is equally important. The potential of developing countries to benefit from PES programmes will be greatly diminished in the absence of such policy and institutional efforts undertaken at the local, national and international levels.

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

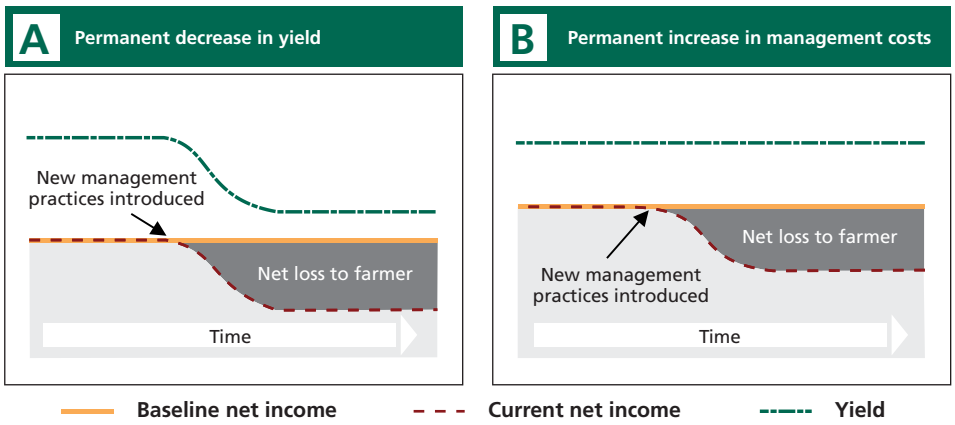
Why don't farmers, fishers and foresters manage natural resources in ways that increase the provision of environmental services? The answer to this is complex and varies according to the influence of a range of social, economic, political and technical factors. In some cases, practices that generate 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).

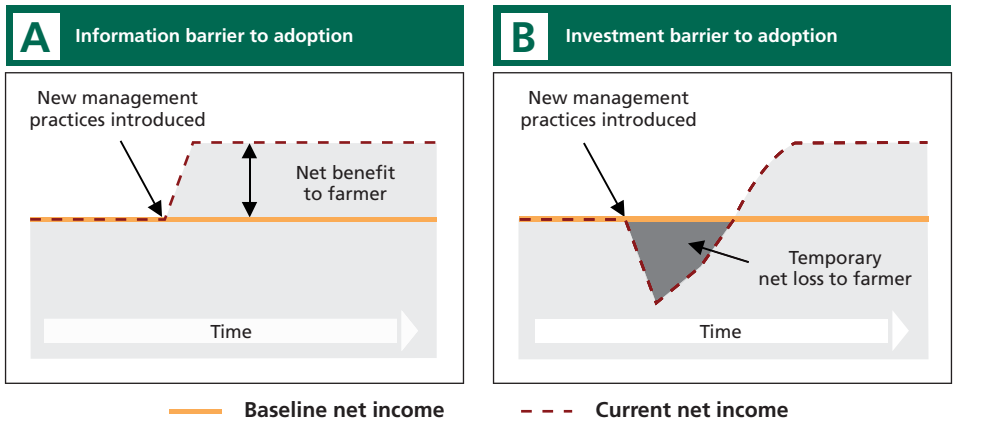
Beyond the decision of the individual farmer, a further consideration in this scenario is the potential impact on local or regional food security if large areas of agricultural land were to be taken out of food production completely to provide other ecosystem services (e.g. a switch from crops to forest 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

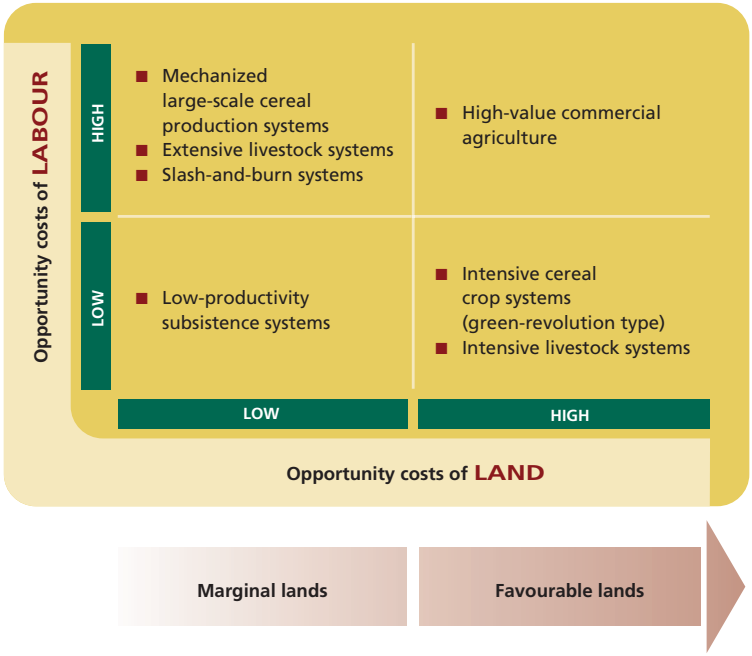
The opportunity cost involved in changing production systems is a function of the change in the use of inputs, including land and labour, and the resulting outputs, such as agricultural products or ecosystem services, as well as the prices of both. Costs vary significantly by agro-ecological conditions, 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).

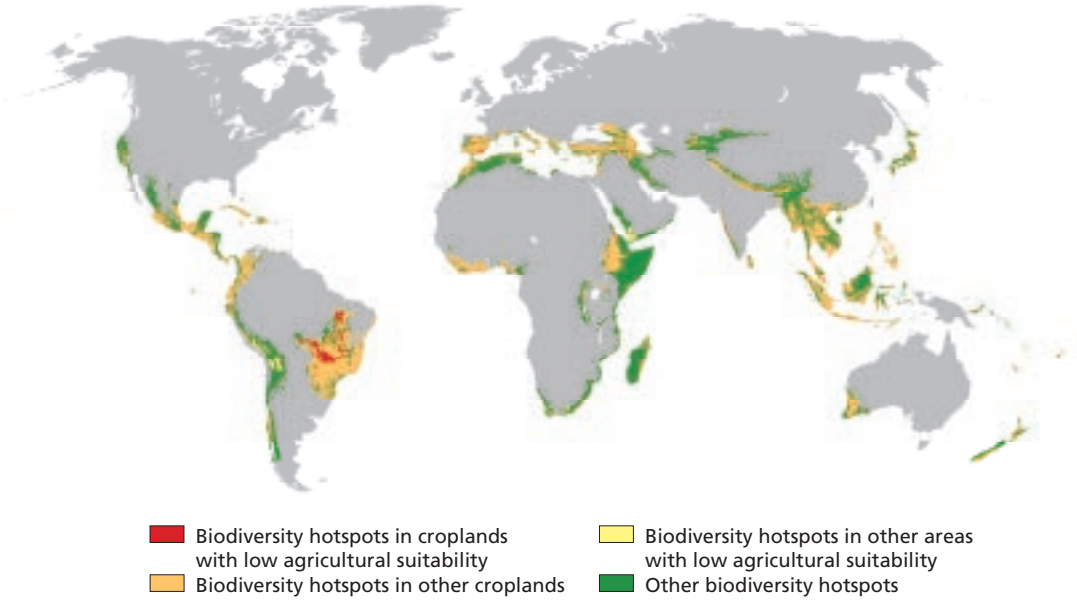
Land-diversion programmes would be most relevant where the opportunity costs of land are low in agriculture. In land-abundant areas, including areas where rising off-farm employment opportunities have drawn populations out of rural areas, the potential for setting aside land for non-agricultural uses 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



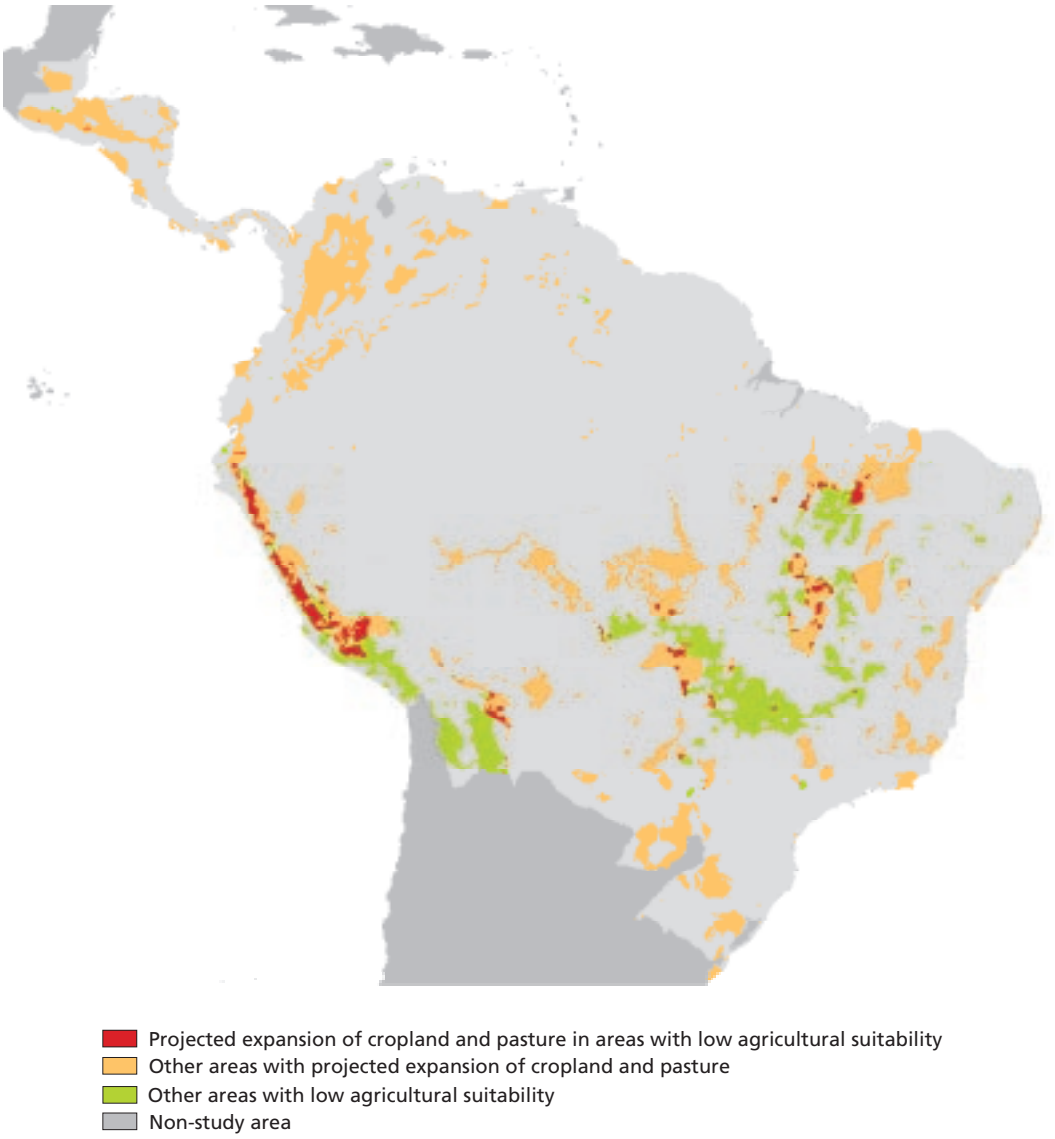
Note: available at http://www.fao.org/geonetwork/srv/en/google.kml?id=31155&layers=biodiversity_hotspots
Source: FAO.

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

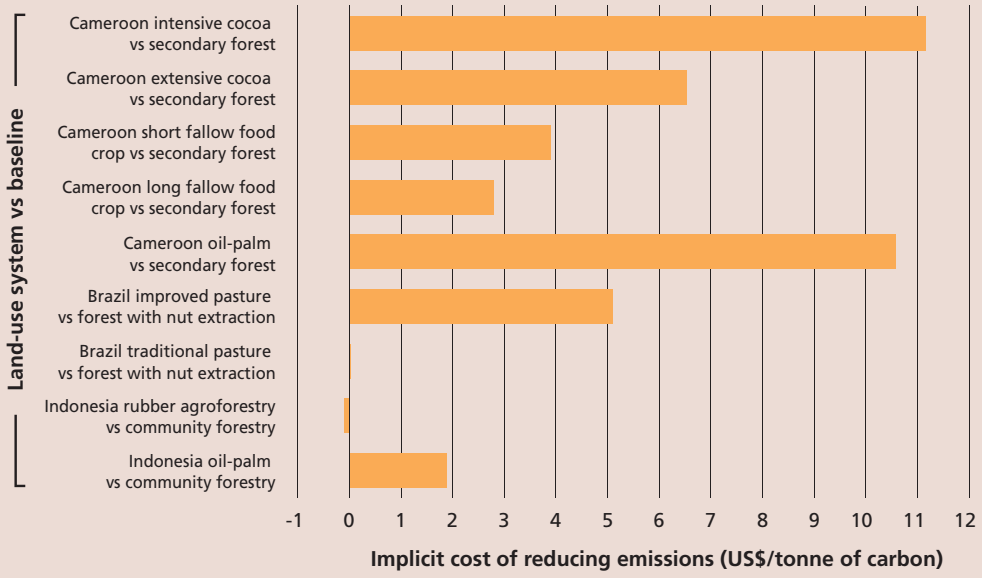


Note: available at
http://www.fao.org/geonetwork/srv/en/google.kml?id=31161&layers=cropland_pasture_expansion_low_def
Source: FAO.

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

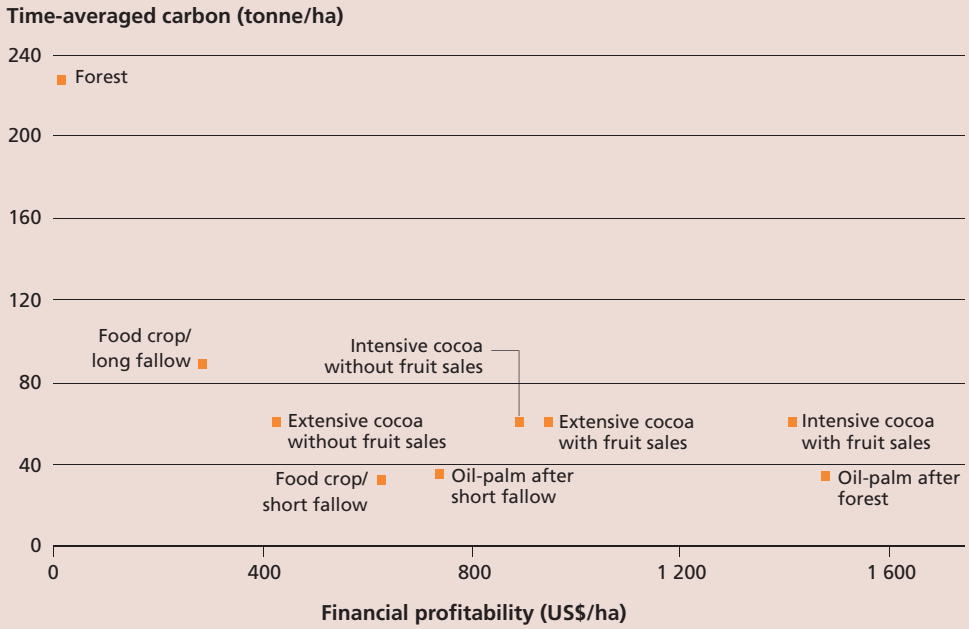
Several studies have examined the level of payments needed to induce farmers to adopt cropping systems that increase the supply of environmental services. Most have focused on carbon sequestration (or in some cases avoided emissions) in response to varying payment levels. Generally, they indicate that 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.

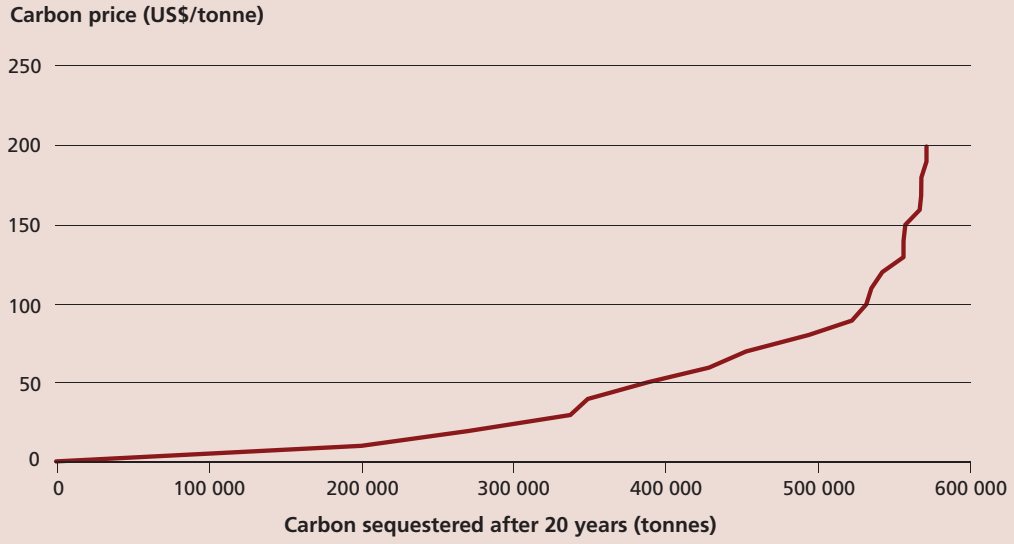
crop/short fallow to intensive cocoa (with or without fruit sales) increases yields in both carbon sequestration and agricultural profitability.

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.

5. Designing effective payments for environmental services

The effectiveness of PES programmes depends on their design and implementation. These factors must be addressed within the specific political, socio-economic and environmental context of the programme. Cost-effectiveness is a key criterion for programme design and constitutes the point of departure for this chapter. The focus is on issues involved in designing PES programmes for cost-effectiveness in meeting environmental objectives. Chapter 6 will broaden the discussion to include design issues as they relate to impacts on the poor and the possibilities for participation of the poor in PES programmes.

The preceding chapters discuss demand for environmental services and the opportunity costs associated with their provision. In addition to these factors, transaction costs associated with making an exchange between buyers and sellers need to be taken into account when designing cost-effective programmes. Transaction costs include the cost of attracting potential buyers or finding potential providers of environmental services, of working with project partners (e.g. negotiations with project participants and capacity-building) and of ensuring that parties fulfil their obligations (e.g. contract development and enforcement, legal and insurance costs, and monitoring of environmental services). These costs are partly determined by the institutions and rules that govern environmental service exchanges, whether they are publicly funded programmes or private exchanges of offsets.

The considerable uncertainties and complexities involved in measuring, monitoring and exchanging services mean that transaction costs can be significant. Moreover, the relevant institutions and rules are still being established. Indeed, transaction costs can easily exceed the cost of actually providing the environmental service. For example, one preliminary assessment suggests that transaction costs in forest carbon projects absorb more than 50 percent (and in some cases more than 90 percent) of the value of total payments made, while the forest producer receives only the residual (Niles *et al*., 2002).

Several studies have examined programme design issues and tools in the context of payments for environmental services. For example, Weinberg and Claassen (2005) and Claassen *et al.* (2001) discuss issues of effective conservation programme design in the context of United States public environmental service payment programmes, and van Noordwijk *et al*. (2007) present a conceptual framework for characterizing various types of compensation or reward mechanisms for environmental services in terms of their effectiveness, efficiency, sustainability and equity. The Rewarding Upland Poor for Environmental Services (RUPES) project in Southeast Asia has explicitly focused on the development of simplified methodologies for cost-effective measurement of the potential for payments for biodiversity and watershed services.[16]

In this chapter, the main design issues discussed are: what should payments be made for, who should be paid, how much should they be paid and in what form? It then briefly considers several issues involved in reducing transaction costs and, finally, the importance of creating an enabling environment, in the form of supporting institutions, within which PES programmes can operate.

[16] For further information, see www.worldagroforestry.org/sea/networks/rupes.

BOX 13
Payments for restoring riparian areas in São Paulo, Brazil

Paolo Toledo and Helena Carrascosa[1]

In the state of São Paulo, Brazil, there are a million hectares of riparian areas in need of rehabilitation. Restoring vegetation along margins of water bodies traps sediments and pollutants before they reach the waterways, plays an important role in flood protection and can provide habitat for wildlife and carbon sequestration. Although today these areas are protected from conversion by state law, there are no incentives for the restoration of previously degraded sections. Yet the cost of degradation in riparian zones is mounting.

For example, when the water utility serving the city of Piracicaba had to switch its main water intake from the Piracicaba River to its tributary Corumbataí because of escalating water treatment costs, great concern arose. As a consequence, in 1999 the intermunicipal consortium of the Piracicaba–Capivari–Jundiaí watersheds initiated a programme whereby R$0.01 per cubic metre was allocated to support restoration of the rivers' riparian strips. Participation of consortium members is voluntary.

The São Paulo State Riparian Forest Restoration Project (PRMC) is supporting this effort by working with farmers currently engaged in subsistence farming and low-productivity pasture management to identify alternative land uses and restore and protect riparian strips. The PRMC is sponsored by the State Environment Secretariat, with the support of the Global Environment Facility, the Nature Conservancy and the National Water Agency, in conjunction with the ongoing State Programme for Sustainable Microwatershed Management.

The management committee of the Piracicaba–Capivari–Jundiaí watersheds has approved US$280 000 per year to support a project for extending and experimenting with payments for riparian restoration. Part of these funds will be used to make payments to farmers who adopt land-use changes that restore the riparian zones and provide watershed services to downstream users. The next big step will be to secure a regular contribution from the water utility serving the city of São Paulo, a city of over 20 million people. The project is also exploring the potential for attracting buyers of carbon emission offsets and purchasers of biodiversity conservation services to support the rehabilitation programme.

In this context, the State Environment Secretariat, together with various partners, is initiating a state-level PES fund to secure a long-term, consistent, statewide restoration programme.

[1] *São Paulo State Riparian Forest Restoration Project.*

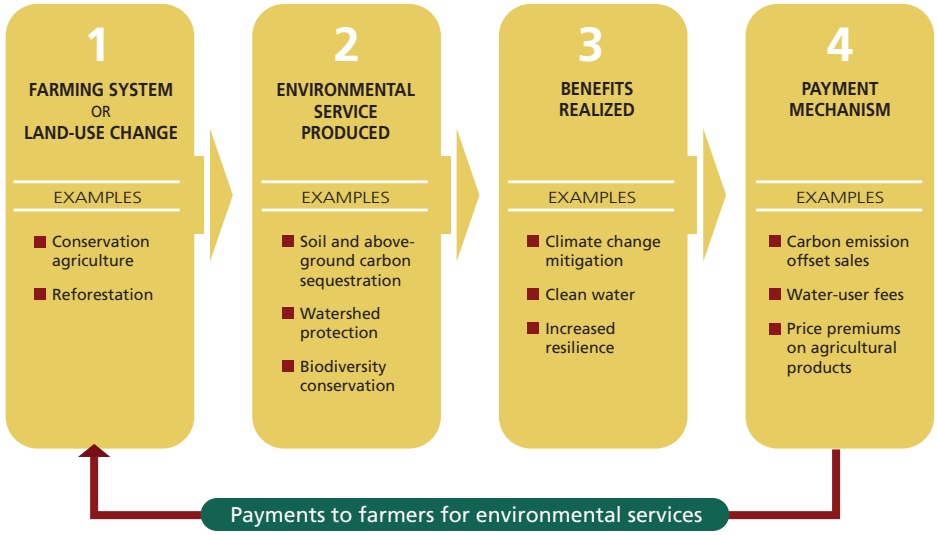
What should payments be made for?

Careful identification of the service of interest is a critical first step in designing an effective PES scheme. This requires an assessment of the potential for environmental service payments to contribute to environmental, social and economic objectives. This assessment, in turn, must be based on an understanding of the underlying biophysical science and the economic motivations of suppliers as well as an assessment of demand (Figure 13). In practice, assessing demand and supply potential are iterative processes. Box 13 gives an example of how these processes are occurring in São Paulo, Brazil.

Payments for actual services or for proxies?

Whether to pay for the service itself or for some proxy is an important design consideration. If the environmental service can be measured easily and the cause-

FIGURE 13
Key elements in PES programme design



Source: FAO.

and-effect linkages are straightforward, payments will be most effective if made directly for performance in increasing the output of the environmental service delivered. Payments for carbon sequestration are relatively simple in this regard. Payments for watershed services, on the other hand, are complicated, because the complex hydrological relationships make it difficult to establish the links between cause and effect in service provision. In these cases, payments are more easily linked to observable land-use changes that are associated with changes in the provision of the desired environmental service. For example, FAO (2002b) describes how perceptions of the linkages between land use and water resources determined the terms of a contract between the La Esperanza Hydropower Project and the Monteverde Conservation League in Costa Rica. The hydropower facility pays the upstream landowners (represented by the Monteverde Conservation League) for conserving and protecting existing forests in the expectation that this will lead to a more stable stream flow over the year and lower sedimentation, both of which reduce the costs of the hydropower operation. In the New York City example described in Box 4 (see p. 34), payments were made for changes in land use and management and not directly for water quality improvements.

When it is difficult to measure the service inexpensively or to monitor compliance, payments for quantifiable changes in agricultural practices that are likely to result in enhanced service provision can be more cost-effective. In the vast majority of PES transactions to date, payments have been associated with land-use changes rather than with service provision directly, and the buyers have borne the risk of inadequate service provision. So long as the farmers manage their property in accordance with the terms of the contract, they are paid whether the service is provided or not.

Whether payments are made for the actual service or linked to a proxy has implications for who bears the risk of an unforeseeable or uncontrollable factor affecting supply. For the seller, a contract for a specific land-management change, such as planting and maintaining a riparian buffer, involves much less risk than a contract based on payments for water purification services, which might be affected not only by land-management changes but also by a drought or a major rainfall that could wash nutrients and soil into watercourses. Insurance against variability in service supply is an important transaction cost in PES exchanges. Self-insurance, where

sellers produce more services than they have contracted (e.g. by planning extra area for carbon offsets) or buyers contract for more services than they need, is one approach. In Guatemala, for example, markets for watershed services offered payments on three times the estimated area needed to ensure delivery of contracted services to the investor. In some cases, NGOs or governments assume responsibility for absorbing the risks of both buyers and sellers (FAO, 2007c).

The use of indices

In an effort to ensure that changes in land-management practices generate the intended service, indices of environmental service provision have been developed. The challenge in selecting indicators is that of establishing an appropriate balance between accuracy and cost. One example is the scoring system used as part of the Silvopastoral Project implemented in Colombia, Costa Rica and Nicaragua described in Box 14.

BOX 14

The Regional Integrated Silvopastoral Ecosystem Management Project in Colombia, Costa Rica and Nicaragua

Muhammed Ibrahim[1]

Tropical deforestation in the Latin America and the Caribbean region is continuing at a high rate with serious consequences for the environment. In Central America, more than 9 million hectares of primary forest have been deforested for pasture expansion, and more than half of this area is degraded. Traditional pasture systems are based on clearing the land of trees, which has negative impacts on biodiversity and carbon sequestration. Furthermore, once established, such systems cause soil fertility and water resource issues, leading to diminishing grass cover and lower productivity. Lower income for producers results in continuing poverty and in pressure to clear additional areas. One alternative to traditional systems is silvopastoral systems, which combine trees with pasture. These systems can be grouped in four major categories (Murgueitio,1999):

- systems in which high densities of trees and shrubs are planted in pastures, providing shade and diet supplements while protecting the soil from packing and erosion;
- cut-and-carry systems, which replace grazing in open pasturelands with stables in which livestock are fed with the foliage of different trees and shrubs specifically planted in areas formerly used for other agricultural practices;
- systems that use fast-growing trees and shrubs for fencing and wind screens. These systems provide an inexpensive alternative to fencing and supplement livestock diets;
- systems where livestock graze in forest plantations. In these systems, grazing is used to control the invasion of native and exotic grasses, thus reducing the management costs of the plantations.

Adopting improved silvopastoral practices in degraded pasture areas is thought to provide valuable local and global environmental benefits, including carbon sequestration and biodiversity conservation. However, producers face barriers to adopting these practices, as they involve high initial costs.

Over the past five years, a project experimenting with the use of payments for environmental services as an incentive mechanism for the adoption of silvopastoral practices has been implemented in Colombia, Costa Rica and Nicaragua. The Regional Integrated Silvopastoral Ecosystem Management Project is funded by the Global Environment Facility and the multi-institutional FAO Livestock, Environment and Development initiative and implemented by the Tropical Agricultural Research and Higher Education Center in Costa Rica with the collaboration of the research and development institute Nitlapán in Nicaragua and the Colombian NGO Centro para la Investigación en

The scoring system attempts to capture the relationships among various types of land use and multiple environmental services (Pagiola *et al*., 2004). Table 11 (p. 78) shows the index value for a variety of agricultural systems. The index for carbon sequestration assigns 0.1 points per tonne of carbon sequestered, while that for biodiversity conservation ranks land uses from most unfriendly to biodiversity (degraded monoculture pasture, 0.0 points) to most friendly (primary forest, 1.0 points). For both carbon sequestration and biodiversity, specific point values were assigned by a panel of experts based on available data. The two indices were combined to create a single environmental services index. Biodiversity and carbon sequestration were monitored in all land-use types in the three pilot areas to verify that the land uses promoted under the project were actually generating the expected environmental benefits. For biodiversity,

Impact of payments on land-use change (total project area for the three countries)

Land use	2003	2006	Difference
	(ha)		*(Percentage)*
Degraded pasture	2 258.28	802.04	–64.48
Natural pasture without trees	1 122.53	368.85	–67.14
Pasture with low tree density	2 232.92	2 582.10	+15.64
Pasture with high tree density	1 074.15	2 488.60	+131.68
Fodder bank	106.30	378.85	+256.40
Forest	3 054.12	3 109.82	+1.82
TOTAL AREA	**9 848.30**	**9 730.26**	

Sistemas Sostenibles de Producción Agropecuaria.

The project seeks to monitor and evaluate environmental services generated by silvopastoral systems so as to develop a methodology for payments for environmental services in agricultural landscapes dominated by cattle production. An ecological index was developed as a tool for such payments, which incorporates the value of different land uses for carbon sequestration and conservation of biodiversity. From 2003 to 2006, cattle farmers participating in the project received between US$2 000 and US$2 400 per farm, representing 10 to 15 percent of net income. The area of degraded pastures was reduced by more than 60 percent in the three countries, and the area of silvopastoral land use (e.g. improved pastures with high density trees, fodder banks and live fences) increased significantly.

The environmental benefits associated with the project include a 71 percent increase in carbon sequestered (from 27.7 million tonnes of CO_2 equivalent in 2003 to 47.6 million tonnes in 2006), increases in bird, bat and butterfly species (see Chapter 2, Figure 5) and a moderate increase in forested area. Milk production and farm income also increased, by more than 10 and 115 percent respectively. Herbicide use dropped by 60 percent, and the practice of using fire to manage pasture is now less frequent.

[1] *Tropical Agricultural Research and Higher Education Center.*

TABLE 11

Environmental service indices in the Silvopastoral Project in Colombia, Costa Rica and Nicaragua (points per hectare, unless otherwise specified)

LAND USE	Biodiversity index	Carbon sequestration index	Environmental service index
Annual crops (annual, grains, and tubers)	0.0	0.0	0.0
Degraded pasture	0.0	0.0	0.0
Natural pasture without trees	0.1	0.1	0.2
Improved pasture without trees	0.4	0.1	0.5
Semi-permanent crops (plantain, sun coffee)	0.3	0.2	0.5
Natural pasture with low tree density (< 30/ha)	0.3	0.3	0.6
Natural pasture with recently planted trees (> 200/ha)	0.3	0.3	0.6
Improved pasture with recently planted trees (> 200/ha)	0.3	0.4	0.7
Monoculture fruit crops	0.3	0.4	0.7
Fodder bank	0.3	0.5	0.8
Improved pasture with low tree density (< 30/ha)	0.3	0.6	0.9
Fodder bank with woody species	0.4	0.5	0.9
Natural pasture with high tree density (> 30/ha)	0.5	0.5	1.0
Diversified fruit crops	0.6	0.5	1.1
Diversified fodder bank	0.6	0.6	1.2
Monoculture timber plantation	0.4	0.8	1.2
Shade-grown coffee	0.6	0.7	1.3
Improved pasture with high tree density (> 30/ha)	0.6	0.7	1.3
Bamboo (*guadua*) forest	0.5	0.8	1.3
Diversified timber plantation	0.7	0.7	1.4
Scrub habitats (*tacotales*)	0.6	0.8	1.4
Riparian forest	0.8	0.7	1.5
Intensive silvopastoral system (> 5 000 trees/ha)	0.6	1.0	1.6
Disturbed secondary forest (> 10 m^2 basal area)	0.8	0.9	1.7
Secondary forest (> 10 m^2 basal area)	0.9	1.0	1.9
Primary forest	1.0	1.0	2.0
New live fence or established live fence with frequent pruning (per km)	0.3	0.3	0.6
Windbreaks (per km)	0.6	0.5	1.1

Note: The environmental service index attempts to assess the level of environmental services generated by different types of land use. It combines two indices: an index for biodiversity and an index for carbon sequestration.
The biodiversity index assigns a number from 0.0 to 1.0 from most unfriendly to biodiversity to most friendly.
The carbon sequestration index assigns 0.1 points per tonne of carbon sequestered. The two indices are added to arrive at a single environmental services index.

Source: Pagiola *et al.,* 2004.

BOX 15
Payments for environmental services and the World Trade Organization Green Box provisions

Support measures that are "decoupled" from output quantities and prices and therefore only minimally distort trade, fall under the Green Box and are exempt from reduction commitments under the current Agreement on Agriculture. In order to fall under the Green Box, support measures must be provided through a publicly funded government programme and the support in question should not have the effect of providing price support to producers. Examples for Green Box subsidies are compensation for income loss for producers located in disadvantaged regions, or for producers implementing environmental programmes. Agri-environmental programmes can be categorized into three different types: programmes focusing on the retirement of land from agricultural uses for conservation purposes; programmes focusing on improving the environmental performance and production practices on current agricultural land; and programmes focusing on maintaining specific performances or agricultural practices.

Source: excerpt from ICTSD, 2006, pp. 2–3.

counts of bird species were the main indicator used, complemented by studies of butterflies, ants and molluscs. Factors such as endemicity and rarity in the species observed were also taken into consideration.

Another example emerged from the Australian BushTender programme (see Box 19, p. 86), which used a field staff scoring system for establishing environmental service indicators. Agency officials visited farms and "scored" how land-use changes would change biodiversity service provision. The score was then divided by the bid price in order to determine "biodiversity per dollar".

Certification

In payment programmes involving certification, the payment is linked to a characteristic of the product or its production process that is associated with the supply of an environmental service. The number of ecolabel and certification programmes has risen markedly in recent years.[17] By the mid-2000s, nearly 30 national and international bodies were certifying natural resource-based products (Searle, Colby and Milway, 2004). The standards and procedures involved in obtaining certification vary considerably, although efforts are being made to consolidate and standardize certification standards (ISEAL, 2006).

International trade rules

Finally, international or regional trade agreements may affect what can be paid for and how PES programmes can be designed. In particular, World Trade Organization (WTO) rules restrict public payment programmes that directly affect production of marketed commodities. The most significant WTO provisions of relevance for payments for environmental services from agriculture are found in the Agreement on Agriculture. According to the Agreement, payments to enhance environmental services would be permitted under the Green Box provisions (Annex 2 of the Agreement) provided that they are decoupled from agricultural production, from post-base period prices and from factors of production (see Box 15). Direct payments under "environmental programmes" are specifically permitted under paragraph 12 of the Green Box, provided payments are limited to extra costs or loss of income involved in complying with the programme. In the current trade round, Green Box criteria may be reviewed

[17] For example, a United States Web site (http://www.eco-labels.org/labelIndex.cfm), lists 146 ecolabels, each differing in the products they certify, the type of environmental benefit associated with the product, and the standards they use.

and clarified with a view to ensuring that Green Box measures have no, or at most minimal, trade-distorting effects. Concerns have been raised that some current Green Box measures may not meet this criterion and that some payments under Green Box measures may indeed be trade-distorting. (UNCTAD, 2007; FAO, 2004d).

Other provisions of the Agreement on Agriculture could also be potentially relevant for PES programmes, including provisions covering structural adjustment assistance, where land could be removed from agricultural production, for example on environmental grounds, or payments under regional assistance programmes, where payments could be made to producers in "disadvantaged regions".

Other multilateral trade agreements could also be relevant for environmental service payments in agriculture, for example the Agreement on Subsidies and Countervailing Measures and the WTO General Agreement on Trade in Services. For environmentally based product certification or labelling schemes, some provisions of the WTO Agreements on the Application of Sanitary and Phytosanitary Measures (SPS) and on Technical Barriers to Trade (TBT) could also be of relevance.

Who should be paid?

The answer to the question of who should be paid to supply environmental services is highly dependent on the overall programme objectives. Perhaps the most controversial issue is whether environmental service payments should be directed to those who currently provide services or to those whose land parcels have the greatest potential for increased service provision.

To frame this dilemma more starkly, we can imagine two adjacent farmers, A and B, who raise cows for a dairy operation on gently rolling land beside a stream that flows into a reservoir. Five years ago, Farmer A constructed fencing alongside her streams, creating a 3-metre riparian buffer on either side of the bank. This change in land management significantly reduced the amount of nutrients and soil washing off her land and the eutrophication and turbidity downstream. On the other hand, Farmer B has continued to manage her land in such a way that nutrient and soil runoff after large storm events affect water quality in the downstream reservoir. Should a downstream water consumer make payments to Farmer A, Farmer B, or both? Although Farmer A provides the greatest level of current service provision, the most efficient use of payments to enhance services is likely to be to Farmer B.

"Additionality" is a key concept in PES programmes designed for efficiency. To meet an additionality requirement, payments should be for a service that would not have been supplied otherwise. Farmer A was already providing the service and thus would not qualify under an additionality standard.

Paying only for additional services can potentially present risks arising from what is known as "moral hazard". For example, some farmers might knowingly use a polluting production practice because they expect, sometime in the future, to receive payments to stop doing so. In practice, however, there are checks that limit the potential seriousness of problems resulting from moral hazard. Increasing one's attractiveness for potential service payments can carry a significant cost in terms of long-term farm productivity. Such a strategy also carries a significant risk to the farmer if payments are granted on a competitive basis, as some farmers may end up receiving no funds. Both the Australian BushTender (see Box 19 on p. 86) and the Costa Rican (see Box 16) programmes, for example, were oversubscribed. In the context of payments, risks associated with moral hazard should not present serious cause for concern unless the expected private benefits of poor land management exceed the costs dramatically.

The hypothetical example above nevertheless points to a more general problem: should farmers be paid for services that are already being provided? Given social and political realities, it may be very difficult to implement programmes based on strict efficiency and additionality criteria, especially publicly funded programmes. Programmes based on additionality may be perceived as "not fair" and as "rewarding the bad guys" (Dobbs and Pretty, 2004). As critics of the United States CRP have made clear, responsible land managers can

BOX 16
The Payments for Environmental Services programme of Costa Rica: setting the baseline

The Costa Rica PSA (Pago de Servicios Ambientales – Payments for Environmental Services) programme, one of the oldest and best known examples of a national payments for environmental services scheme in a developing country, demonstrates the need for setting a good baseline.

In 1997, the country pioneered payments for environmental services programmes based on a national forestry law that explicitly recognized four environmental services provided by forest ecosystems: climate change mitigation, biodiversity conservation, watershed protection and landscape beauty. The government contracts with landowners to maintain forest area in order to provide these services.

By the end of 2005, about 10 percent of the country's forest area was enrolled (Pagiola, 2006). The programme was initially untargeted, with participation on a "first-come, first-served" basis. This resulted in inclusion of land that was at low risk of deforestation.

As Pfaff, Robalino and Sanchez-Azofeifa (2006) describe in their evaluation of its first five years, the programme annually inhibited deforestation on only a small portion of the enrolled forest. "…[O]ver 99 percent of the PSA funds allocated did not change land use." In a separate study, Tattenbach, Obando and Rodríguez (2006) found that an area equal to about half the contracted area would have been deforested in the absence of the PSA programme. Differences in methodology, study area and study period make it hard to compare these results directly, and a consensus on the impacts of the programme has not been reached, but it is clear that only a part of the enrolled area represents actual land-use change. A more detailed discussion of the debate is given in Walker (2007).

The relatively low apparent additionality of the PSA programme should be seen in the context of an overall trend of falling livestock prices, which had made the conversion of forest to pastures much less profitable and had reversed deforestation trends even before the introduction of the PSA programme in 1997. The PSA programme has also been accompanied by the introduction of new legal restrictions on clearing land; compliance with these restrictions would likely have been much less forthcoming had they not been accompanied by payments. It also bears mention that Costa Rica's PSA programme has no additionality requirement. In principle, if the budget were sufficient, the programme would pay every land user with forest for the services that that forest is providing (Pagiola, 2006). With support from the World Bank and the Global Environment Facility, the PSA programme has been evolving towards a more targeted approach that seeks to improve its efficiency.

become dispirited if those who employ less responsible land-management practices are effectively rewarded for doing so (see Box 4). On the other hand, international markets such as the CDM require additionality. If a country wishes to access international payments for environmental services, especially for carbon credits, meeting an additionality criterion will be necessary.

Costa Rica's PSA (Pago de Servicios Ambientales – Payments for Environmental Services) programme is explicitly non-additional. In principle, given a sufficient budget, the PSA programme would pay every forest owner for the services that the forest provides (Pagiola, 2006). Of course, budgets are generally limited and thus some choices need to be made. One way of making that choice is to identify sites that present credible threats to the loss of environmental services. Wünscher, Engel and Wunder (2006) analysed the potential efficiency gains from improved targeting

for the Costa Rica programme. They show that, given a fixed budget, selecting sites according to their service delivery potential increases the amount of contracted services supplied. Even greater efficiency is gained where opportunity costs and payment levels are differentiated. Wunder (2006) compared the potential efficiency of payments in Amazonian states in Brazil having low development pressures and government support for conservation policies to areas experiencing high rates of land conversion to agriculture. He noted that payments in low-development areas are non-additional, while in areas of high conversion rates they may not be sufficient to achieve desired objectives. An important strategy for targeting suppliers of environmental services, therefore, is the identification of areas where threats are projected to emerge, and where payments for environmental services are likely to be effective in changing land use and farming practices.

Setting baselines

Identifying what would have happened under a "business as usual" (no payments) scenario is necessary to assess the effectiveness of a programme and is linked to the question of additionality. The establishment of a baseline requires consideration not just of the level of services when payments start, but also of potential changes in external factors during the period when the environmental service payments are being made.[18] For example, deforestation and reforestation rates change in response to many economic and social pressures, and an increase in forest cover may not be attributable to the payment at all, but rather to other forces, as the Costa Rica example illustrates (see Box 16).

Targeting and self-targeting

For environmental service purchasers concerned solely with the efficient supply of environmental services, the ideal programme would identify and target payments to the lowest-cost suppliers. The key information needed for effective targeting to the lowest-cost suppliers relates to the spatial distribution of land ownership and productivity. The distribution of land is a factor in determining not only who could benefit most from a PES scheme, but also what kind of PES scheme (e.g. land-use vs farming system change) is most likely to be attractive to producers (FAO, 2006e).

In recent decades, considerable field experience has been gained in targeting development projects that is relevant also for the potential targeting of PES programmes. The optimal level of targeting depends on the trade-offs between the cost and the tolerable degree of errors of exclusion and inclusion (the reduction of which is the benefit of targeting) and is constrained by administrative capacity. There are different levels and degrees of targeting. Area-based targeting criteria, for example identifying marginal regions or communities, are generally relatively inexpensive. Targeting becomes more data-intensive, and therefore expensive, when moving to a household or individual level. In general, a trade-off exists between the complexity of targeting strategy and its cost.

Applying targeting criteria is particularly challenging in developing countries with poor data availability and low institutional capacity, as is the case in a number of African countries. Self-targeting, where programmes offer benefits that appeal only to a selected group, has been used by some project designers to try and attract the participants with the desired characteristics. This approach can be problematic, however, as it may exclude the most vulnerable and is only appropriate in certain circumstances. A recent global study on poverty targeting methods (Coady, Grosh and Hoddinott, 2004) found that more-developed countries tend to use means-testing while less-developed countries use self-selection or characteristics-targeting, which are often easier to implement. However, given the wide variation in results across countries and programmes, the study concludes that the most important determinant of targeting success, regardless of the methodology, is the implementation capacity specific to a given programme.

As environmental service supply is inherently linked to location, the use of geographical criteria represents a low-cost means of targeting programmes. For

[18] See, for example, UNEP (2005) for a discussion of baseline methodologies for the CDM.

BOX 17
China's Grain for Green programme

Pushed into action by a series of devastating floods in 1998, the Government of China launched the Grain for Green programme in 1999. One of the largest conservation set-aside programmes in the world, its main objective is to increase forest cover on sloped cropland in the upper reaches of the Yangtze and Yellow River Basins to prevent soil erosion. When possible in their community, households set aside all or parts of certain types of land and plant seedlings to grow trees. In return, the government compensated the participants with grain, cash payments and free seedlings. By the end of 2002, officials had expanded the programme to some 15 million farmers in more than 2 000 counties in 25 provinces and municipalities in China (Xu *et al.*, 2004). If the programme meets its original goals, by 2010 nearly 15 million hectares of cropland will have been set aside, affecting the land of more than 50 million households.

Source: Uchida, Rozelle and Xu, 2007.

example, because the main objective of the China Grain for Green programme (Box 17) is to prevent soil erosion, steepness of slope is one of the main criteria by which plots are selected (Uchida, Rozelle and Xu, 2007). The programme targets lands with slopes of 25 degrees or higher in southwest China and 15 degrees in the northwest. As slope is easy to measure, this is a relatively low-cost targeting tool (Uchida, Rozelle and Xu, 2007), although several studies have found the programme's targeting to have been less than optimal in certain regions, where, indeed, a number of productive and low-sloped plots were retired when less productive and high-sloped plots were still available (Xu *et al*., 2004; Uchida, Xu and Rozelle, 2005).

Mapping locations with high potential environmental service benefits and low opportunity costs of supply (see, for example, Maps 5 and 6) is a further means of geographic targeting, and is becoming progressively less expensive as increasing amounts of geographically referenced information become available.

One approach to self-selected targeting is the use of a reverse auction system as described in the Australian BushTender programme (see Box 19). In this system, landholders provide sealed bids for the amount they are willing to accept for changes in land-use management. Funding is provided in the order of the bidders providing the greatest service provision at the lowest cost, and the process continues until the funds run out. This approach has two major benefits compared with direct grants. First, communication is more efficient: under a reverse auction, farmers weigh the costs and benefits of their own land-use changes and inform the government of their willingness to accept in order to institute these changes. The government, for its part, decides which of the proposed land-use changes will be most effective for meeting its overall service provision goal. Reverse auctions are also well suited to situations in which there is only one buyer and many sellers. This is often the case with water quality services, for example, when a utility seeks to change the behaviour of many landowners.

Targeting is complicated by the potential for "holdouts" – individuals who try to exploit their location or choose not to participate in a programme but capture the benefits of actions of others. The effectiveness of holdouts depends on the degree to which environmental service provision requires coordination among suppliers. This is most easily illustrated in the context of biodiversity conservation. The functional value of a reserve design or wildlife corridor usually depends on contiguous land parcels. If successful, the benefits from the sum of the connected parcels managed for biodiversity conservation are greater than those of its parts. Success can be frustrated by the actions

of a very small number of landholders of key parcels who hold out for prices well above market rates. Without their participation, it may be impossible to create effective habitats.

Equity and efficiency

Decisions on how to set and implement targeting criteria are, of course, strongly related to the overall programme objectives. Alix-Garcia, de Janvry and Sadoulet (forthcoming) compared two hypothetical PES schemes – one with a flat payment and a cap on the amount of land that could be enrolled by any one participant and another that took deforestation risk and land productivity into account. In their simulations, targeted payments were far more efficient in terms of generating environmental services, but the flat payment scheme was more egalitarian. Their results indicate the importance of considering trade-offs between efficiency and equity. These issues are revisited in Chapter 6.

Setting programme objectives and targeting strategies in order to balance equity and efficiency goals is inherently a political process, and the balance may change over the course of programme design and implementation (see Box 18).

How much should be paid?

The amount of an environmental service provided will depend on the level of payments. In general, how much should be paid depends on the options available to buyers and sellers of environmental services, along with other factors that determine their supply and demand. For a transaction to take place, the maximum amount the buyer would be willing to pay for the services must be at least as much as the minimum that the seller would be willing to accept to provide them. The amount the buyer is willing to pay is affected by factors such as the cost of alternatives to the services in question and the financial resources available. The amount the seller is willing to accept depends on the cost of adopting new practices to provide the services.

Historically, some public programmes have set a flat payment rate per hectare for a land-management practice. These programmes did not distinguish between varying service supply potentials and often set prices significantly above what farmers would have been willing to accept,[19] either because of inadequate analysis of supply–demand dynamics because the programmes had income-support objectives in addition to environmental objectives, or because it was administratively too costly to determine farmer-specific payment rates (or politically infeasible to implement them).

In some cases, pressure to maintain flat payments arise out of equity concerns. For example, in the case of the Nairobi National Park Ecosystem Wildlife Conservation Lease programme, the Maasai community, who were the intended recipients of the payments, objected (at least initially) to differentiated payments on social grounds, even though environmental service values and opportunity costs did vary by location.

In most programmes to date, prices for environmental services have been set close to the minimum amount that farmers would accept, although the reasons for this outcome differ by service (Pagiola and Platais, 2007). In carbon markets, the supply of potentially salable carbon credits from land-use change and forestry projects exceeds current demand, thus giving buyers the upper hand in setting prices (Bayon, Hawn and Hamilton, 2007). In markets for watershed and biodiversity services, potential sellers are rarely able to exclude any of the potential buyers from benefiting from the resources, which gives them little leverage in setting prices (Landell-Mills and Porras, 2002).

Publicly funded payment systems face pressure to maximize programme cost-effectiveness. This can be achieved by setting payment levels close to the amount farmers would accept or through a reverse auction system.

Reverse auction approaches, while a potentially useful means of improving the efficiency of supply, can be expensive and difficult to implement, especially with the limited institutional capacity in many developing countries and where producers have low levels of information and formal education. The Silvopastoral Project in Costa

[19] An example was Costa Rica's PSA programme, see Ferraro, 2001.

BOX 18

The political economy of targeting: the Payment for Hydrological Services Programme in Mexico

The design of payments for environmental services programmes, including the areas they target and their recipients, can be strongly influenced by ongoing political debates and institutional arrangements. A payments for environmental services programme in Mexico to conserve water services is an example of how political realities shape programme outcomes.

At its inception in 2003, the programme had both environmental and anti-poverty goals. Because of water scarcity in many areas with high population density, and because the potential seemed highest for developing local markets for the service, it developed into a programme focused on hydrological services.

The programme faced challenges in obtaining funding and management changes. Instead of a 2.5 percent levy on municipal water fees, a fixed amount per year was applied. Initially, the programme was implemented only in priority watersheds, but final implementation was nationwide. The focus on poor communities was abandoned. The scheme was classified as a subsidy and not as a payment, which created a host of additional problems. The rules had to be publicly debated, and the money could not be targeted in a decentralized manner.

Changes in targeting rules from the first proposal to the final scheme can be seen in the table. Other important changes included the removal of the originally planned pilot programme, the elimination of the focus on marginalized communities, the inclusion of commercial forests and private properties and the decision to give payments based on percentage of forest rather than on forest density.

An evaluation (FAO, 2005b) of the first two years of the programme showed that most of the payments had gone to protect forests outside of critical watersheds and were too fragmented in their distribution to provide a measurable improvement in water services. In addition, payments were made mainly for forests that were not at risk of being lost.

Changes in targeting rules for Mexico's PES scheme to protect water services

Original targeting rules (SEMARNAT/INE)	Final targeting rules (SEMARNAT/CONAFOR)
■ Pilot programme with an experimental design	■ Nationwide programme: – Rules of operation – Establishment of a Trust Fund
■ Beneficiaries', *ejidos*[1] and indigenous communities located in priority watersheds: – Overexploited – Serving large populations	■ Beneficiaries augmented to include private owners
■ Other selection criteria: – Forest cover – Clear property rights – Ecosystem type – Marginalization	■ Added selection criteria: – Priority mountains – Availability of satellite image – Protected areas
■ Priority given to forest with high deforestation	■ Subtracted selection criteria: – Marginalization – Deforestation risk

Notes:
SEMARNAT = Secretaría de Medio Ambiente y Recursos Naturales (Secretariat for the Environment, Natural Resources); INE = Instituto Nacional de Ecología (National Ecology Institute); CONAFOR = Comisión Nacional Forestal (National Forestry Commission).
[1] *Ejidos* are a special form of land tenure in Mexico resulting from the land reform process that started after the Mexican revolution in 1910. *Ejidos* are composed of two different kinds of property rights over land: individual parcels and common lands

Source: FAO, 2005b.

BOX 19

Measurement and targeting issues: the BushTender programme of Australia

In Australia, the State of Victoria's Department of Natural Resources and Environment (NRE) has developed a pilot programme to conserve native vegetation remnants on private property. In exchange for payments from the state government, landholders commit to fencing off and managing an agreed amount of native vegetation for a set period. The first BushTender trial was completed in 2002 in the north central and northeast regions of the state. The programme is based on the Conservation Reserve Program in the United States of America. The innovation of the BushTender programme is its reliance on a robust assessment methodology and reverse auction mechanism to set the price of the contracts.

With the assistance of farmers' associations, NRE publicized that it might be willing to pay farmers to conserve native vegetation. Interested landholders contacted NRE, which sent out field staff to inspect the sites, explaining to landholders which of their native vegetation was most significant and the most effective conservation activities.

The field staff assessed the value of each site's native vegetation on two scales of value. One was called the Biodiversity Significance Score, which rated the site's conservation value according to scarcity of remnant types. The other was the Habitat Services Score, which assessed the contribution of the proposed management action, such as fencing or weeding, to biodiversity improvement. Landholders were informed of the Habitat Services Score but, not of the Biodiversity Significance Score. Interested landholders could then choose to submit bids, detailing in a management plan developed with the field officer which remnant vegetation (and how much) they would be willing to conserve, as well as the management regime for the remnants. The proposed management actions ranged from excluding livestock, retaining large trees and controlling rabbits to controlling weeds and

Rica, Colombia and Nicaragua (Box 14, p. 76), for example, opted to offer fixed payments for eligible land uses because the reverse auction approach was deemed too complex for the setting.

The potential of auctions in a developing country context is being explored in the Sumberjaya subdistrict in Sumatra for the purchase of erosion abatement services from coffee farmers. Researchers have found that extending the auction approach to a developing country setting required several adaptations in their design and implementation, including the use of a uniform price rule to minimize risks of social conflict created by discriminatory pricing in small communities. The prices achieved at the auction allowed the purchase of 30–70 percent more conservation services than would have been the case at the estimated labour cost for contract implementation, and bidding behaviour across rounds indicated that farmers adjusted their bids in response to previous outcomes in ways that indicated an understanding of the mechanism (Leimona, 2007).

Direct negotiation between service users and providers – another approach for price-setting – results in individually crafted agreements that reflect the different levels of service that different landholders can provide and the specific conditions faced by each landholder. This was the approach adopted by Vittel in France and in the New York City case (Box 4, p. 34). This approach can result in highly optimized contracts, but can also incur high transaction costs. A variant of this approach is used in the Silvopastoral Project in Costa Rica, Colombia and Nicaragua. Recognizing that different land uses can provide different levels of the desired services, payments are based on the increase in services generated by the specific mix of land uses adopted by each landholder, measured using an index (see Table 11, p. 78). While this approach has lower

revegetation. In the end, 98 landholders submitted 148 bids for 186 sites.

Since NRE had an estimate of potential biodiversity importance for each of these sites, they were able to calculate the best value for money (i.e. by identifying those bids that offered greatest biodiversity value for least cost per hectare). Given a limited funding budget, only the most cost-effective bids were funded. In the end, NRE accepted 97 bids, with landholders committing to conserve and manage roughly 3 200 hectares of native vegetation under three-year BushTender Management Agreements for a total cost of approximately $A400 000. Compliance monitoring occurs through random site inspections.

Beyond the fact that the scheme was well received and oversubscribed, the environmental benefits seem significant. NRE field staff concluded that most of the successful bids contained sites of high or very high conservation significance, including 24 new populations of rare or threatened plant species. Perhaps the most unexpected finding was that many of the bids were for less money than the NRE would have been willing to pay, had they negotiated directly with landholders. It is not clear whether the lower price was a result of market pressures of competitive bidding, the NRE underestimating landholders' willingness to accept, or the fact that once landholders understood the non-market value of their native vegetation they were willing to internalize some of the perceived costs of conservation. It is an open question whether persuasion instruments, such as brochures or educational visits from conservation staff, would have achieved the same result. At first glance, this seems unlikely because the landholders would not have been forced to consider the true value of their willingness to accept land changes.

Source: FAO, 2007d.

negotiation costs, it still has relatively high monitoring costs (Pagiola *et al.*, 2004).

How should payments be made?

Three main issues must be addressed in determining the form payments should take:

1. Should payments be in cash or in another form?
2. How should payments be timed?
3. What payment mechanism should be used?

Cash versus in-kind payments

Other types of payments than cash can be envisaged. Wunder (2005) describes the perceived advantages and disadvantages of cash versus the use of beehives as payment for watershed services in Bolivia. The in-kind payment involved providing farmers with beehives and technical assistance in bee-keeping. This form of payment was perceived as creating a lasting benefit, while cash would more likely have been spent right away. One way to address this concern is by targeting payments towards women, which has been shown to be particularly effective in increasing spending on education, health and nutrition (Davis, 2003; Haddad, Hoddinott and Alderman, 1997). One objection to in-kind payments is that they allow less flexibility for meeting fluctuating labour and skill requirements. Moreover, they can also be seen as paternalistic – i.e. it is an outsider who determines what is best for suppliers, rather than allowing them to choose how to invest or dispose of their cash payments. Offering a variety of payment modes, if the administrative costs of doing so are not too high, could be one way to overcome these objections (Wunder, 2005).

Timing and duration

The timing and duration of payments are critical issues from both a buyer's and seller's

point of view. In many cases, environmental services are only generated years after the supplier actually makes the required land-use changes (and bears the costs). Obtaining investment credit is often difficult and expensive for developing country farmers, further strengthening the need for payments in the short term. Whether payments should be made in a single instalment or periodically also needs to be considered.

Referring back to Figures 7 and 8 in Chapter 4 (pp. 52–3), we can see that different arrangements for the timing of payments may be required when considering a farmer in scenario B in Figure 8, who faces an investment barrier to adoption and thus a temporary decline in income, versus those in scenarios A and B in Figure 7, who face a permanent decrease in income from the land by adopting the land-use system that generates environmental services. In the former case, payments can allow the farmer to overcome the investment barrier through short-term funds to facilitate the transfer to new production systems that will be more profitable in the long run, even without the payment.

This is the strategy used in the Silvopastoral Project in Colombia, Costa Rica and Nicaragua (Box 14), where payments are explicitly short-term. Indeed, despite their long-term benefits, silvopastoral practices tend to be unattractive to farmers primarily because of the substantial initial investment and the time lag between the investment and returns. The project assumed that, given this situation, relatively small payments provided in the early stages could "tip the balance" between current and silvopastoral practices by increasing the net present value of investments in silvopastoral practices and by reducing the initial period in which these practices impose net costs on farmers. The payments also alleviate the liquidity problems faced by many farmers and help them finance the required investments (Pagiola *et al.*, 2004).

When the land-use change needed to generate environmental services results in a permanent decrease in income, payments for the environmental service must be maintained indefinitely to preserve the incentive to supply it. Farmers continue to receive payments every season for the agricultural products they generate from their lands; receiving a continuing payment for the environmental services they generate is analogous to receiving continuous payments for the crops they produce each year.

Payment forms

Three main types of mechanism for environmental service payments can be identified:

- direct payments (public and private);
- offsets (both voluntary and mandatory);
- agricultural product certification programmes (ecolabels).

Each involves different sets of stakeholders among the buyers and sellers, as well as intermediaries involved in making the transaction. In the following paragraphs, we summarize the main features of each of these mechanisms and identify key actors in the transaction chain.

Direct payments. This category includes direct payments from public programmes, such as the China Grain for Green programme, as well as public programmes in Australia (Box 19), Costa Rica (Box 16), Mexico (Box 18) and the United States of America (Box 12). Private payments may also fall into this category, including cases of hydropower companies paying for watershed services (FAO, 2002a) and payments made by NGOs for biodiversity conservation services. Currently, this mechanism accounts for the largest share of payments.

Sources of funds in this category range from general tax revenues to specific taxes or charges on beneficiaries. International funds (e.g. the GEF) are a further source, and in some cases public and private funding sources are combined. In Costa Rica, in the Rio Segundo watershed, for example, payments to landholders are financed in part with payments from a private bottler, Florida Ice & Farm, and in part by the local town's public service utility ESPH (Empresa de Servicios Publicos de Heredia) (Pagiola, 2006). An important distinction in these cases is the extent to which funds come directly from service users or through intermediaries. When payments are made directly by service users, a good case can be made that payments are likely to be efficient and sustainable, as the financing source has both a direct incentive to pay and the

power to insist on an efficient use of their monies; where payments are made through intermediaries, such as government agencies, as in the case of the United States CRP, Mexico's Payment for Hydrological Services Programme (PSAH) and Costa Rica's PSA, it can be argued that this efficiency is muted (Pagiola and Platais, 2007).

Mandatory and voluntary offsets. Mandatory offsets are the medium of exchange in regulated cap-and-trade markets, such as the Kyoto flexible trading mechanisms and United States wetlands mitigation banking (see Box 12 on p. 62). Private- or public-sector entities wanting to meet regulatory compliance through offsets are the ultimate purchasers in this exchange, although there are usually one or more intermediaries involved. These include NGOs as well as private-sector firms specializing in carbon market exchanges. (See Box 20 for a more detailed description of the process of certification under the CDM.) There also exists a significant and growing sector concerned with voluntary carbon offset payments. The certification standards and procedures vary between voluntary and mandatory offset schemes. Several actors are present in the transaction chain between buyer and sellers for both.

Agricultural product certification programmes. When consumers buy certified products, they are paying not just for the product itself, but also for the manner in which it was produced and brought to the market. The source of funds is from within the private sector and the payment mechanism is via price premiums and/or market access. These programmes establish a set of standards for particular categories of goods or services and, for a payment, certify whether the producer has met these requirements. If so, they may use an identifying label on their product and in their advertising to distinguish their products from others in the marketplace and, presumably, benefit from increased prices or market share by serving the "green" consumer niche.

Certified products involve three sets of buyers along the supply chain. The most obvious is the point-of-sale buyer – the green consumer. Moving up the supply chain, the second is the retailer – Home Depot, Carrefour or other companies buying wholesale before selling to the consumer. The third buyer is, ironically, the supplier of the green product, who must pay the certification organization for use of the label and sometimes separate certifiers. The transaction costs associated with the certification process and the need to streamline marketing value chains to provide producers with sufficient incentives to participate in the certification schemes can prove to be a formidable barrier, especially for small and low-income producers (Searle, Colby and Milway, 2004). Some efforts have been made to facilitate the participation of such groups through the introduction of simplified procedures or promotion of group certification schemes.

There is also a trade-off in terms of market growth between setting highly stringent and more flexible standards. Highly stringent standards can result in fairly small "luxury good" market niches that may be inaccessible to most producers, whereas more flexible standards could involve a much broader market segment but may not deliver any real environmental benefits. A hybrid solution that involves a dynamic process of standard setting to promote continuous improvement is an option being used by the Marine Stewardship Council (see Box 21).

Payments for any one service may fall into any one of these three categories of mechanisms. This is illustrated in Table 12, which presents a variety of specific payment mechanisms for biodiversity conservation services. There is also potential to combine payment mechanisms. One strategy being implemented is the use of public payment programmes to initiate PES programmes, with the eventual intention of transitioning to private-sector and/or offsets payments. PES programmes with funding from the GEF typify this strategy. Here, public funds are being used to establish capacity and mechanisms and to illustrate the potential for these types of mechanisms, in the expectation that private-sector purchasers of services will participate once they have been convinced of the benefits they could reap. Establishing strong public–private partnerships in the implementation of PES programmes is a key part of a new strategy

BOX 20

Rules and modalities for afforestation and reforestation payments under the Clean Development Mechanism of the Kyoto Protocol

Under the Clean Development Mechanism (CDM) of the Kyoto Protocol, industrialized countries can meet a part of their greenhouse gas reduction obligations through offset projects in developing countries. CDM projects must also promote sustainable development in host countries. Emission offsets can be generated either by reducing emissions or by removing carbon from the atmosphere (sequestration). Afforestation and reforestation (A&R) projects are the only type of carbon sequestration projects currently allowed under the CDM. Emission offsets are measured in metric tonnes of carbon dioxide equivalents and are traded as certified emission reductions (CERs).

Rules and modalities

Baseline. Baselines for A&R projects are calculated based on the changes in carbon stocks in above- and below-ground biomass that would have reasonably occurred without the project. Baselines are calculated using an approved CDM methodology, or a new methodology may be proposed for approval along with the project.

Additionality. A strict additionality criterion is applied for projects. A project may be additional if it overcomes barriers related to investment or technology constraints.

Leakage. Any increase in greenhouse gas emissions that occurs outside the project area and is measurable and attributable to the project must be minimized, monitored and subtracted from project carbon sequestration credits.

Credits. Two types of credits have been developed for A&R projects, based on the possibility that forests can eventually release carbon (i.e. sequestration may not be permanent):

- temporary credits that expire at the end of the commitment period for which they were issued and must be replaced by the buyer to ensure continuing carbon storage. This type of credit commands a low price, but the producer faces no risk if the carbon sequestration is lost as a result of calamity (e.g. fire) or harvesting.
- long-term credits that expire at the end of the project's crediting period, a time span of up to 60 years.

proposed by the GEF. The partnerships are intended to encourage the development and scaling up of voluntary PES payments, and reduce the transaction costs of such instruments (GEF, 2007b).

Reducing transaction costs

The need to reduce transaction costs, subject to achieving a defined level of service provision, is an overarching issue in all the exchange mechanisms discussed above. In the early stage of PES programme development, when institutions and participants are inexperienced and projects are small, transaction costs per unit of service tend to be relatively high, but they can be expected to decline over time. However, unless institutions exist to manage and coordinate transactions among large numbers of smallholders and unless economies of scale in monitoring and payment systems can be found, such costs can render PES initiatives unworkable. Three main approaches to reducing transaction costs in developing country PES schemes can be identified:

- **Simplify the rules**. A rule of thumb is to use the simplest rules possible and the simplest compliance mechanisms that will satisfy the buyers and beneficiaries in the contract. For example, for determining baselines and monitoring carbon outcomes, standardized measures can be developed and scientifically evaluated to serve as proxies for detailed measures. Independent bodies would determine the reference rates, and

The project cycle

The first step of the CDM project cycle is the preparation of a Project Design Document. In the document, the project developer must:

- identify a suitable region with areas not covered by forests since at least 1990;
- gather land-use, social and economic information about the project area to develop the baseline;
- identify suitable forms of A&R and estimate their carbon sequestration potential;
- contact and establish relationships with the local people;
- negotiate the terms of the project and the schedule of payments for carbon sequestration services; and
- analyse possible environmental and social impacts.

After the document is prepared, it must be approved by the Designated National Authority of the host country, validated by a Designated Operational Entity accredited by the CDM Executive Board and registered with the Executive Board. Once the CDM Executive Board issues the appropriate number of CERs for a project, the project developer becomes a seller in the international carbon market.

Once the project is approved and under way, the next part of the CDM cycle is monitoring the carbon dioxide abatement actually achieved by the project, including certification and verification by the Designated Operational Entity. Monitoring costs are incurred every time a new batch of carbon is submitted for CER credits.

Project management costs include the establishment of a local project office and the training of staff, the cost of keeping records of project participants and administration of payments to sellers, as well as salaries and transportation costs of project employees. Enforcement and insurance costs arise from the risk of project failure or underperformance, which might be caused by fire, slow tree growth or leakage.

Source: FAO Forest Resource Division Fact Sheet (FAO, n.d.).

verification would only involve a third party confirming that the activities had been undertaken (Sandor, 2000, cited in Landell-Mills and Porras, 2002).

- **Facilitate buyer–seller linkages**. Most PES programmes involve buyers and sellers who are geographically and socially distant from one another. To reduce search costs, some countries have established "one-stop shops" for potential buyers of carbon emission offsets, where they can find out all the relevant rules, identify pre-screened sellers and learn about locally knowledgeable market intermediaries.

- **Exploit economies of scale**. Costs such as project design, management and certification are characterized by economies of scale; consequently, project size has an important effect on unit costs. Transaction costs can be greatly reduced by developing projects in communities where active local organizations and participatory development programmes are already in place, with representatives already selected and authorized to negotiate with outsiders. For example, organized indigenous communities in El Salvador have undertaken their own diagnostic studies of local needs and priorities and are actively marketing specific ecosystem services from specific areas that would contribute to meeting those priorities (Rosa *et al.*, 2003). Because carbon can be sequestered in almost

BOX 21
Ecolabelling in fisheries

William Emerson[1]

With trade in fishery products at an all-time high and concern over the status of wild marine stocks growing, ecolabelling offers a way to promote responsible fish trade while preserving natural resources for future generations. In 2005, the FAO Committee on Fisheries adopted a set of voluntary guidelines for the ecolabelling of marine capture fisheries products. They provide guidance to governments and organizations that already maintain, or are considering establishing, labelling schemes to certify and promote fish and fishery products from well-managed marine capture fisheries. The guidelines outline general principles that should govern ecolabelling schemes, including the need for reliable, independent auditing, transparency of standards-setting and accountability, and the need for standards to be based on good science. They also lay down minimum requirements and criteria for assessing whether a fishery should be certified and whether an ecolabel should be awarded.

The FAO guidelines acknowledge the hurdles that developing countries face in responsibly managing their fisheries. These result from a lack of financial and technical resources, as well as the particular challenges posed by the small-scale fisheries common in many developing nations. The guidelines, therefore, call for financial and technical support for developing countries to help them implement and benefit from ecolabelling schemes.

Over the past 15 years, a number of countries and private organizations have put ecolabelling programmes into place for a wide range of products. The proliferation of ecolabels has created a number of challenges, as well as confusion among producers and consumers. There have also been concerns that ecolabelling schemes could result in unfair competition. The purpose of the FAO guidelines is to create a framework for the development of responsible and trustworthy ecolabelling schemes.

The main fishery certification and ecolabelling programme is currently run by the Marine Stewardship Council (MSC), an independent non-profit organization that promotes responsible fishing practices. A number of major seafood retailers carry MSC-certified products. For example, Wal-Mart, a retail chain in the United States of America, has committed itself to sourcing all its fresh and frozen fish products from MSC-certified fisheries within three to five years. There are currently more than 50 fisheries that are certified by the MSC or under assessment. Only three MSC-certified fisheries are, however, from developing countries (South African hake, Mexican Baja California spiny lobster and Patagonian scallop fisheries).

[1] *FAO Fisheries and Aquaculture Department.*

any site (unlike the more site-specific biodiversity and watershed services), area-based projects can be designed in which an entire jurisdiction commits to a defined increase in forest cover or area of forest protected. This increases land-use flexibility and is especially useful for heterogeneous landscapes (Smith and Scherr, 2002).

Establishing an enabling environment

No transactions – ranging from the informal to the highly regulated – take place in the absence of supporting institutions. Even the simplest contracts between buyers and sellers rely on legal institutions to protect property

TABLE 12
Types of payments for biodiversity protection

PURCHASE OF HIGH-VALUE HABITAT
■ Private land acquisition (purchase by private buyers or NGOs explicitly for biodiversity conservation)
■ Public land acquisition (purchase by a government agency explicitly for biodiversity conservation)
PAYMENT FOR ACCESS TO SPECIES OR HABITAT
■ Bioprospecting rights (rights to collect, test and use genetic material from a designated area)
■ Research permits (rights to collect specimens, take measurements in an area)
■ Hunting, fishing or gathering permits for wild species
■ Ecotourism use (rights to enter an area, observe wildlife, camp or hike)
PAYMENT FOR BIODIVERSITY-CONSERVING MANAGEMENT
■ Conservation easements (owner paid to use and manage a defined piece of land only for conservation purposes; restrictions are usually in perpetuity and transferable upon sale of the land)
■ Conservation land lease (owner paid to use and manage a defined piece of land for conservation purposes, for defined period of time)
■ Conservation concession (public forest agency is paid to maintain a defined area under conservation uses only – comparable to a forest logging concession)
■ Community concession in public protected areas (individuals or communities are allocated use rights to a defined area of forest or grassland, in return for commitment to protect the area from practices that harm biodiversity)
■ Management contracts for habitat or species conservation on private farms, forests, grazing lands (contract that details biodiversity management activities, and payments linked to the achievement of specified objectives)
TRADABLE RIGHTS UNDER CAP-AND-TRADE REGULATIONS
■ Tradable wetland mitigation credits (credits from wetland conservation or restoration that can be used to offset obligations of developers to maintain a minimum area of natural wetlands in a defined region)
■ Tradable development rights (rights allocated to develop only a limited total area of natural habitat within a defined region)
■ Tradable biodiversity credits (credits representing areas of biodiversity protection or enhancement that can be purchased by developers to ensure they meet a minimum standard of biodiversity protection)
SUPPORT TO BIODIVERSITY-CONSERVING BUSINESSES AND PRODUCTION PROCESSES
■ Business shares in enterprises that manage for biodiversity conservation
■ Biodiversity-friendly products (ecolabelling)
■ Niche market development for products with valuable agricultural biodiversity

Source: Scherr, White and Khare, 2004.

rights and adjudicate disputes, when they arise, and on law enforcement to ensure the legal judgments are carried out. Property rights, institutions to support collective management of resources, capacity-building needs and coherence of the overall policy framework are key aspects of establishing an enabling environment.

Effective ownership of resources is often a prerequisite for entering into PES programmes (Landell-Mills and Porras, 2002; Grieg-Gran, Porras and Wunder, 2005), but ownership need not be on an individual private basis. There are already a number of PES programmes that target community groups (Muñoz-Piña *et al*., 2005; Scherr, White and Kaimowitz, 2002; Swallow, Meinzen-Dick and van Noordwijk, 2005; van Noordwijk, Chandler and Tomich, 2004).

Property rights to land- and water-based resources in many developing countries are often complex, incorporating multiple layers of claims for access, use, exclusion and management rights among both well- and poorly defined groups. If individuals, a community or its members cannot document their ownership, structuring a PES transaction will be difficult.

Several countries, including Brazil and Ghana, have proposed or implemented laws to facilitate PES programmes. To facilitate exchange of carbon sequestration credits, the Australian state of New South Wales has statutorily created an alienable property right in sequestered carbon. Thus, a forest landowner can sell credits for carbon stored in his or her trees, and this can then be resold by third parties. A number of countries have created the equivalent of a national carbon office that keeps track of carbon emission reduction and carbon sequestration projects, and private certification organizations now ensure that carbon sequestration projects report accurately on their activities.

It is often necessary to coordinate actions within a group in order to achieve effective supply of the environmental service. Examples include managing watersheds, communal lands and fisheries. A supporting institutional environment is needed here also. For example, consider a payment scheme to rehabilitate upstream areas to reduce soil erosion and improve water quality and flow downstream. If the land is held in common and the environmental service buyer is concerned that all claimants are adequately compensated, the buyer needs to establish certainty over the primary, secondary and tertiary claims to various resources – a potentially difficult task. Both public and private groups can serve as intermediaries or brokers to overcome collective action problems. For example, The Nature Conservancy has played a central role in brokering forest carbon projects in Belize, Bolivia and Brazil (Wunder, The and Ibarra, 2005), and small farmers in the Macquarie River Valley in Australia have relied on their local organization (Macquarie River Fruit and Fibre) to negotiate with upper watershed ranchers.

Devising enforcement schemes and penalty mechanisms poses additional difficulties in common property regimes. Should the entire group be punished for one individual's infraction, following the group-credit rationale? Unlike credit groups, where members choose to work together, communities have members with existing rights to resources. Thus, membership is likely to be more heterogeneous and power relations are far more important. It remains an open question whether and how PES mechanisms would increase self-monitoring and enforcement rather than engender conflicts and hasten a breakdown in collective management.

Empirical work by Alix-Garcia, de Janvry and Sadoulet (2005, forthcoming) in Mexico provides insights for the design of payment mechanisms in areas where many resources are held communally. They find that, in order to generate appropriate incentives, PES programmes should be based on an understanding of the traditional rules and institutions that govern land use. They argue that payment schemes should be based on variables that cannot be manipulated by the recipient. They also stress the importance of identifying both environmental outcomes and distributional outcomes.

Participation in some types of environmental service exchanges can require a fairly high level of production, marketing or information management skills. Smallholders who are potential environmental service suppliers need business skills to negotiate private deals effectively. To facilitate an equal participation of smallholders in PES schemes, there is a clear need for stronger investment in building human and institutional capacity among these groups (FAO, 2007c).

Thus far, however, PES capacity-building efforts in developing countries have remained fragmentary, with little practical guidance for implementation and with most resources being absorbed by agency staff costs. The limited experience available internationally suggests that existing farmer organizations and technical assistance programmes already effectively serving smallholders are best placed to build PES capacity among smallholders. In addition, interesting success stories have resulted from "learning by doing", where secondary community-based organizations developed

internal capacity in conjunction with pilot projects (Waage, 2005).[20] The Katoomba Group began, in 2006, to develop resource materials for community capacity-building, but these have not yet addressed issues specific to farmers.[21] Experience has indicated that local communities play a critical role in the process of setting and adapting the "rules of the game", at both policy and programme levels. For example, through civil society engagement in the International Tropical Timber Organization, community-based forestry organizations have contributed to policy dialogue on payments for environmental services. Resources are required, however, to enable community groups to organize themselves, prepare for meetings and attend them. Organizations of smallholder farmers could play a similar role in local, national and international policy dialogues on payments for environmental services (FAO, 2007c; van Noordwijk *et al*., 2007).

In addition to establishing policies and institutions directly related to PES programmes, coherence in the overall policy structure that may have indirect impacts on programme effectiveness is critical. For example, programmes to encourage farmers to reduce water pollution from agricultural chemical runoff will be less effective in the presence of a policy providing pesticide subsidies. Cross-sectoral policy coherence is an important issue requiring coordination between agricultural, environmental, financial, trade and other policy sectors.

Conclusions

The process of designing an effective payment programme involves four important and challenging steps: identifying what should be paid for; who should be paid; how much should be paid; and what payments mechanisms should be used.

Cost-effectiveness is an important overall criterion for programme design because public budgets are generally constrained. Minimizing the transaction costs associated with making payments for services, while ensuring at least a minimal level of service provision, is a key element of cost-effectiveness. Transaction costs include the cost of attracting potential buyers, identifying potential sellers of services, working with project partners, ensuring compliance and monitoring of service provision. They are affected by the availability of information and the institutional capacity for managing exchanges, both of which vary by country as well as by environmental service. There is often a direct relationship between the transaction costs associated with a programme design and its effectiveness in achieving the desired environmental outcomes. Thus, choosing the most cost-effective payment design may not be straightforward.

Payments schemes will be easier to develop for some services, countries and locations than for others because better information is available. Indeed, understanding the underlying biological science as well as the economic motivation of farmers is critical. The success of a PES scheme hinges on the accuracy and cost of such assessments and, by extension, on the creation of cost-effective assessment methodologies for use in the field.

A variety of payment mechanisms are currently in use. Where environmental services are easily measured, payments should be linked directly to the service itself. However, more frequently payments are linked to some proxy associated with changes in the provision of services, as this may minimize transaction and measurement costs. The most common payments are made for changes in land use (e.g. from agriculture to forestry), but payments are also common for changes in farmers' practices on land that remains in agricultural production.

If changes in production practices are to be adopted, payments to providers must exceed the opportunity costs they face in making the change. To maximize cost-effectiveness, payments must be targeted to locations where the biggest gain can be

[20] Examples include ACICAFOC (Asociación Coordinadora Indígena y Campesina de Agroforestería Comunitaria de Centroamérica) in Central America, the Sierra Gorda Biosphere Reserve in Mexico and EcoTrust-Uganda.
[21] For further information, see the Katoomba Group Web site at www.katoombagroup.org.

obtained per unit of payment. Targeting also involves costs, however, and the ideal strategy must be based on the best trade-offs between these costs and the added efficiency achieved. Because environmental service provision is linked to location, strategies aimed at areas with relatively low costs of provision offer a promising solution. Some payment programmes may address multiple objectives (for example environmental service provision and poverty reduction); this will generally involve some degree of trade-off between the objectives or an increase in the cost of providing the environmental service.

Transaction costs can swamp effective payments if a programme is ill-designed. Although reducing transaction costs is an overarching concern for effective programme design, some specific additional measures can be taken with a view to minimizing them: simplifying the rules, where possible, facilitating buyer–seller linkages and looking for ways to capture economies of scale.

An enabling environment is critical for payment programmes. Indeed, no transactions can take place in the absence of supporting institutions, which can range from informal to highly regulated in nature. Capacity building, in particular, is an essential component of efforts to broaden the use of the PES approach in developing countries. Working with local communities can play a key role in developing PES programmes. A final, but crucial, issue is the need for coherence between the objectives of PES programmes, the overall national policy framework and multilateral commitments.

6. Implications for poverty

There are considerable expectations that PES programmes can contribute to poverty reduction as well as to improved environmental management. These expectations are largely based on actual or perceived links between poverty and environmental management. If poverty – which may be defined as lack of income or assets, vulnerability or powerlessness – is a major cause of environmental degradation, then paying poor producers to adopt more environmentally friendly systems of production would appear likely to generate a "win–win" outcome resulting in both poverty reduction and environmental benefits. There are, indeed, many situations in which this is likely to be the case.

However, reducing poverty and increasing the supply of environmental services are two distinct policy objectives. Using one policy instrument, for example payments for environmental services, to reach both objectives can reduce its effectiveness in achieving either. This is clearly undesirable from the standpoint of either poverty reduction or environmental services. Blanket assumptions that PES programmes will or should also benefit the poor are thus problematic. This is particularly true for PES programmes that are strongly market-oriented. However, the reality may be quite different for public-sector funded projects; indeed, almost all public investments have multiple objectives. Public investments need to pass ethical standards of fairness and justice as well as environmental impact assessments and thus some combination of policy objectives and instruments is inevitable. The Working for Water programme in South Africa is a good example of a programme that combines poverty reduction and environmental service provision (see Box 22).

PES programmes can affect the poor, either positively or negatively, and this is undoubtedly a major consideration when assessing the role of payment programmes in developing countries. Much of the discussion on the links between PES programmes and poverty reduction focuses on the role of the poor as potential suppliers of environmental services; yet the indirect impacts on non-suppliers may be as, if not more, important. Iftikhar *et al*. (2007) suggest three levels of criteria should be considered in assessing the impact of PES programmes

BOX 22
The Working for Water Programme in South Africa

The Working for Water Programme is a public-sector-funded programme that supports rural employment programmes that involve the removal of alien invasive species from riparian zones, as well as mountainous areas, in South Africa. The programme is based on the premise that alien vegetation uses higher quantities of water than indigenous vegetation; this phenomenon is even more pronounced where alien vegetation falls within upper catchment areas and along riparian zones (Herling and King, 2005). The programme has 350 sites covering approximately 1.2 million hectares of riparian areas and 11 million hectares of mountain areas. The programme employs over 25 000 people who were previously unemployed. The main focus of the programme is employment generation; however, the programme combines the provision of improved watershed services with its main social objectives (Turpie and Blignaut, 2005).

TABLE 13
People living on fragile land

REGION	Population on fragile land *(Millions)*	Share of total population *(Percentage)*
East Asia and the Pacific	469	25
Latin America and the Caribbean	68	13
Middle East and North Africa	110	38
South Asia	330	24
Sub-Saharan Africa	258	39

Note: Fragile lands are defined as lands with limited ability to sustain growing populations and include arid lands, significantly sloped land, lands with poor soils, and forest lands. See World Bank, 2003a, Table 4.1.
Source: adapted from World Bank, 2003a, Table 4.2.

on the poor. Programmes should: (i) leave the poor at least as well off as they were before; (ii) explicitly involve the poor in the streams of benefits; and (iii) ensure that the poor gain disproportionate benefits. The first two criteria can usually be met with minimal loss of efficiency, while the third can be met only in certain circumstances.

This chapter takes a closer look at the potential implications of PES programmes for poverty, starting with an analysis of the potential for the poor to benefit as suppliers in PES programmes. It then expands the discussion to consider the possible indirect impacts of PES programmes on the poor and the role of the poor as consumers of environmental services. Finally, some conclusions are drawn on how PES programmes can be designed so as to facilitate participation of poor producers.

The poor as suppliers of environmental services

Three main dimensions govern the ability of poor agricultural producers to participate in, and benefit from, PES programmes: their location, their access to the productive assets needed to generate environmental services, and the characteristics of their livelihood systems. Each is considered in turn. The discussion also focuses on the significance of transaction costs for participation of the poor and summarizes the conditions under which the poor are most likely to benefit.

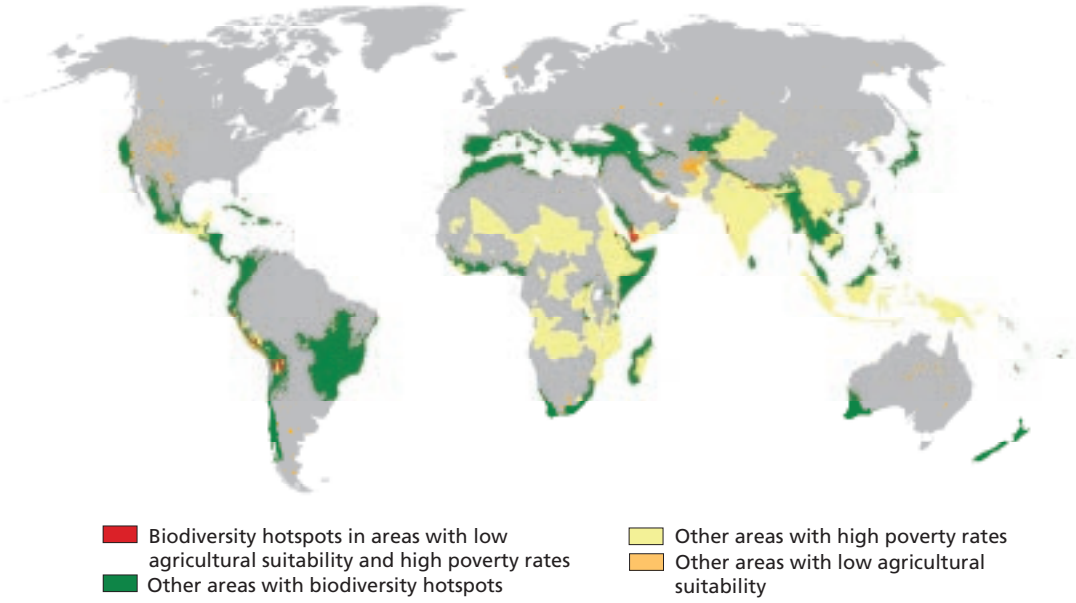
Where are the poor located?

As we have seen, location is a key factor affecting the potential returns to the provision of an environmental service as well as the cost in terms of foregone agricultural production, which agricultural producers face when participating in PES programmes.

The rural poor tend to live and work in ecologically fragile, economically marginal and environmentally degraded areas. The World Bank estimates that more than one billion people in developing countries live in fragile ecosystems covering more than 70 percent of the Earth's land surface (Table 13). Half a billion of these people reside in fragile arid regions; 400 million occupy land with soils unsuitable for agriculture; 200 million have their homes in slope-dominated regions; and more than 130 million live in fragile forest ecosystems (World Bank, 2003a). Poverty maps reveal that the poor tend to reside in areas with one or more environmentally problematic feature, such as degraded land, naturally low soil fertility, air and water pollution, and limited access to water (UNDP, 2005). These areas generally have low agricultural productivity, which is one of the most important constraints against improving incomes among the poor.

When looking at where the poor are located, it is important to distinguish between poverty rates and poverty density (Chomitz, 2007). The former is a measure of the proportion of inhabitants who are poor, while the latter is a measure of the number of poor people per unit of land area. The two measures can show strikingly different results: for example, the Brazilian Amazon has high poverty rates but low poverty densities, because overall population densities are low (Chomitz, 2007). Using poverty rate measures to locate the poor can yield an indication of the extent to which

MAP 7
Biodiversity hotspots in areas poorly suited to rainfed agriculture and with high poverty rates



Note: available at http://www.fao.org/geonetwork/srv/en/google.kml?id=31156&layers=biodiversity_hotspots_high_poverty_rates
Source: FAO.

people living in an area that could supply environmental services are poor; however, it gives no indication of the number of people involved or the extent to which environmental service supply could be a major means of reducing poverty in a given country or region (see Box 23).

Map 7 builds on Map 5 (see p. 65), which shows biodiversity hotspots with low suitability for rainfed agricultural production, by adding a poverty dimension. The map shows areas where the prevalence[22] of stunting among children under the age of five exceeds 40 percent. The stunting indicator is based on an estimate of the distribution of chronic undernutrition at national and subnational levels using stunting in growth among children under five years of age.[23] This indicator reflects the long-term cumulative effects of inadequate food intake and poor health conditions resulting from lack of hygiene and recurrent illness in poor and unhealthy environments. This prevalence measure is used here as an indicator of regions where the poor are likely to be affected by land-use changes, noting that in many cases these are areas with low population densities where the number of people involved may be small.

As can be seen in the map (shown in red), relatively few areas of high poverty prevalence overlap with biodiversity hotspots with poor agricultural suitability. Clearly, the scale of the map is insufficient to arrive at any definitive assessments of the spatial intersection of poverty, low agricultural

[22] The 40 percent prevalence criterion is based on the World Health Organization (WHO) classification for very high prevalence of malnutrition (for further information, see http://www.who.int/nutgrowthdb/about/introduction/en/index5.html).

[23] Stunting is defined as height-for-age below –2 standard deviations from the National Center for Health Statistics/WHO International Growth Reference Standard. New standards have been issued based on regional averages; however, actual data based on these are not yet available. The analyses in this report are therefore based on the old standards.

BOX 23

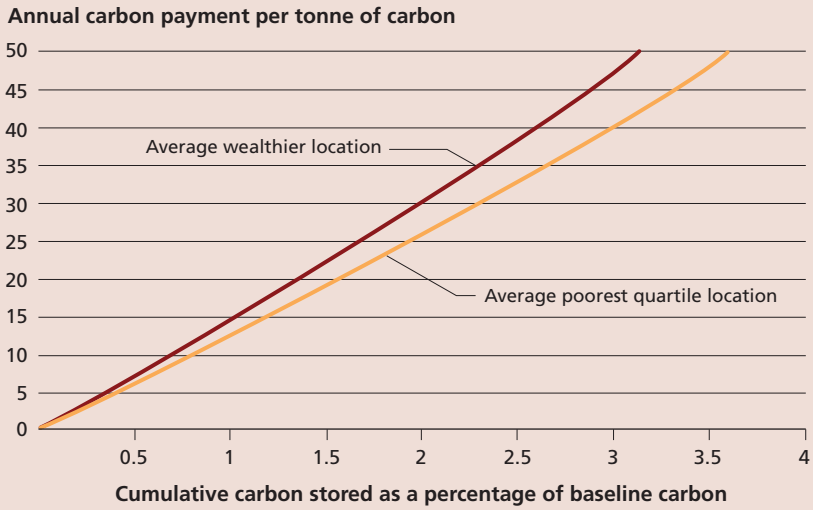
Will the poor respond to payments for avoided carbon emissions? Evidence from Costa Rica

Will the poor respond to payments for reducing deforestation (and thus carbon emissions)? If so, more or less than others? These were the questions posed in a study of the potential supply response of the poor to carbon payments in Costa Rica. The study used district-level data on poverty, as well as returns to crop and livestock production and agro-ecological indicators, to predict the rates of deforestation for each of various possible levels of carbon payments.

The results indicated that landowners would respond to payments by reducing deforestation and thus emissions but also that there were no significant differences in response between poorer and less poor districts. However, as the poorer areas have more forest, payments could help both forests and the poor. As the figure indicates, those areas could receive a larger share of carbon payments. The results suggested neither gains nor losses in efficiency from having poor land users in carbon payments programmes. Because this study used district-level estimates of poverty incidence, caution is needed in interpreting the results. It may be that, in poor areas, though a large fraction of people are poor, those who own the land are not. If services and payments were proportional to landholdings, payments to poor areas would not necessarily go to poor people.

Source: Pfaff *et al.*, 2007.

Carbon supply in 2020 for poorest and less poor districts

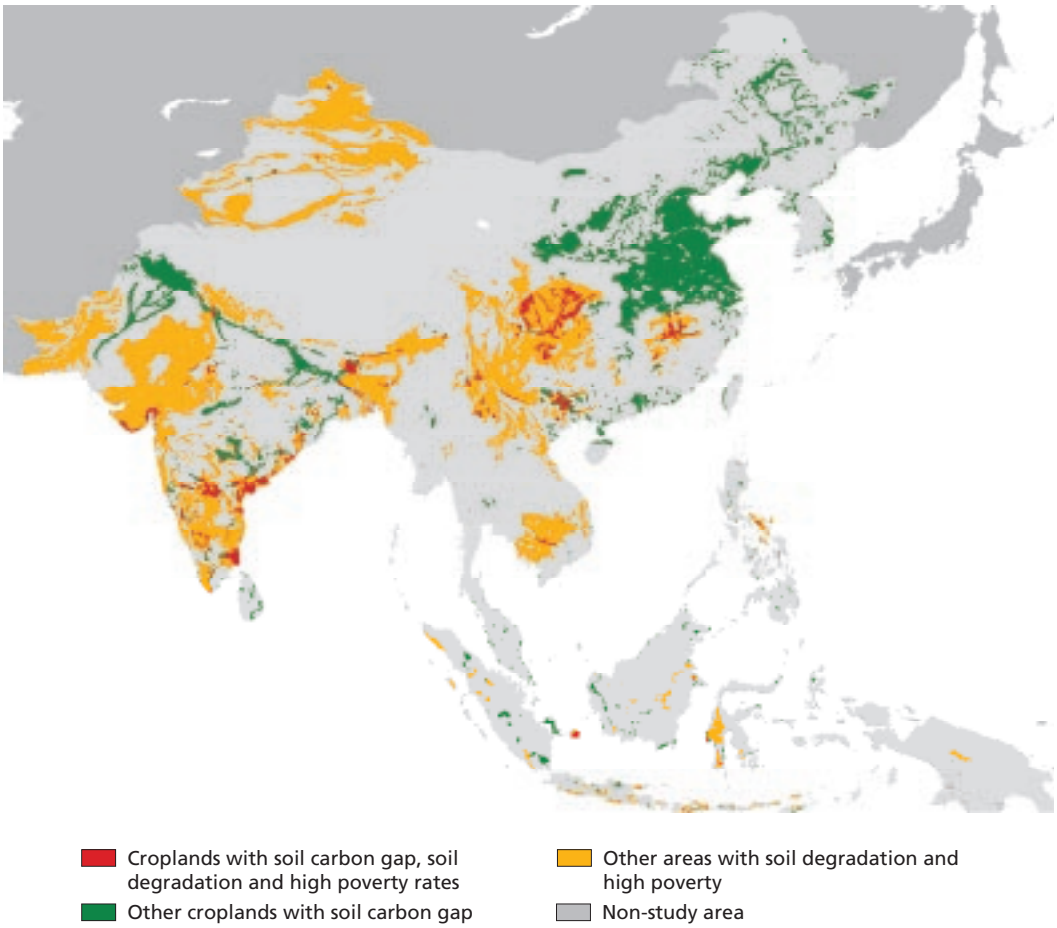


Source: Pfaff, Robalino and Sanchez-Azofeifa, 2006 and Kerr *et al.*, 2004.

suitability and biodiversity conservation; however, it suggests that the overlap between the three may be smaller than is often assumed. Lowering the cut-off point for prevalence of stunting in children below five years of age to 20 percent results in only a very modest increase in the overlap.

Map 8 uses the Soil Degradation in South and Southeast Asia (ASSOD) database (ISRIC, 2007) to investigate the potential synergies between soil carbon sequestration, improvements in soil fertility and poverty reduction. The map identifies locations in agricultural production that are highly

MAP 8
Highly degraded croplands with soil carbon sequestration potential and high poverty rates



Note: available at http://www.fao.org/geonetwork/srv/en/google.kml?id=31159&layers=highly_degraded_croplands
Source: FAO.

degraded as well highly degraded areas that also have medium-to-high soil carbon sequestration potential. In the latter areas, adoption of soil carbon sequestration may generate both an agricultural and an environmental benefit in the form of improved soil quality and carbon sequestration. These areas are overlaid with areas that have a high percentage of stunted children under the age of five. The red areas indicate where supplying soil carbon sequestration might generate a further benefit in the form of poverty reduction. The map suggests that areas in central and western China and central and eastern India are potentially good sites for programmes that combine environmental service and poverty reduction objectives. However, analysis with data at a higher degree of resolution and more detailed information about farming systems and access of the poor to the land will be needed to verify this potential.

Poverty and access to productive resources

Poverty, by its very nature, is associated with a lack of access to, and control over, productive resources – including land, water, investment capital and human capital. This lack of access is a major barrier also for participation of the poor in PES programmes.

Moreover, a gender bias is often found to exist, and rural women, who constitute a significant share of the rural poor, encounter particular difficulties in accessing resources (FAO, 2006g).

Many of the obstacles impeding participation of the poor in PES programmes are the same ones that inhibit their adoption of more productive and sustainable management practices and prevent them from rising out of poverty. Chapter 4 identifies several constraints to the adoption of farming and forestry production systems that would benefit the producers themselves in addition to generating higher levels of environmental services. Lack of information, property rights and financing, as well as risk, were all identified as barriers that can inhibit desirable changes in production systems.

Even when the poor do have access to land and other productive resources, the control and rights they have over the resource are often weak and poorly defined. This can also be an important barrier to participation in PES programmes as well as to undertaking any type of investment for sustainable management (Lipper, 2001; Dasgupta, 1996). Moreover, there is a risk that the poor may lose out from PES programmes by being excluded from lands to which they have only tenuous rights by wealthier or more politically powerful groups, as land values increase with such payments (Pagiola, Arcenas and Platais, 2005).

In practice, "ownership" of resources is often a prerequisite for entering into contracts for the provision of environmental services (Grieg-Gran, Porras and Wunder, 2005). In Costa Rica, both Thacher, Lee and Schelhas (1996) and Zbinden and Lee (2005) found tenure-related variables to be highly significant in explaining participation in the country's current and preceding PES programmes. In some cases, the barrier of tenure insecurity has been overcome by allowing holders of non-formal kinds of tenure to enter into contracts. In Costa Rica, for example, participants were initially required to have land titles; this requirement has since been eliminated but while in force it served to exclude poorer land users (Pagiola, Arcenas and Platais, 2005).

Where the poor do hold rights over resources, they often take the form of common property rights, with resultant implications for their ability to respond to PES programmes. Changes in natural resource management of commonly held resources, such as pastures or waterways, require group coordination, which is costly to the producers and in many cases difficult to achieve. The experience of the Mexican PSAH (see Box 18), which was implemented targeting indigenous communities and *ejidos* (both communally held land and individually controlled plots), serves as an enlightening example. For the *ejidos*, payments were made to the entire community, which could then either distribute them among individuals or make investments for the benefit of the community. The effectiveness of this type of communal payment scheme in providing incentives for changing land use is under review (Muñoz-Piña *et al.*, 2005). The distribution of costs and benefits of programme participation among participants has also been raised as a concern (Alix-Garcia, de Janvry and Sadoulet, forthcoming).

Lack of access to financial resources can be another major barrier to participation of the poor in PES programmes (see Chapter 4). Frequently, the land-use changes needed to generate environmental services require an up-front investment, with returns occurring only later in the future. In many parts of the developing world, rural financial markets function poorly, resulting in lack of access to external finance. The poor may be unable to finance the changes from their own assets, unlike wealthier PES programme participants. For example, the owner of a 20-hectare farm in Nicaragua wishing to introduce a variety of silvopastoral practices to receive payments under the Silvopastoral Project might have to invest, in the first year, about US$500 (equivalent to about 70 percent of net income under current practices), in addition to forgoing part of the farm's normal income in that year. These are heavy costs for poor households. Savings, remittances or off-farm income may help some households make the necessary investments, but poorer households will tend to have fewer such alternatives – and a greater likelihood of needing such supplements for subsistence requirements. Front-loading payments or credit may be necessary in such cases (Pagiola, Rios and Arcenas, forthcoming).

TABLE 14
Who are the poor?

CATEGORY	REGION				
	West and Central Africa	East and southern Africa	Asia and the Pacific	Latin America and the Caribbean	Near East and North Africa
Rainfed farmers				■	■
Smallholder farmers	■	■	■	■	
Pastoralists			■	■	■
Artisanal fishers		■	■	■	■
Wage labourers/landless		■	■	■	■
Indigenous people; scheduled castes/tribes			■	■	■
Female-headed households			■	■	■
Displaced people			■	■	■

Source: IFAD, 2001.

Where a PES project entails adopting new practices that are complex, difficult or unfamiliar, households may need technical assistance from extension services. However, poor households are less likely to have access to extension than better-off households, and this factor, too, may prohibit their participation in the programme.

Livelihood systems of the poor

Even if the poor are located in areas that are likely to be economically viable sources of environmental service supply and have access to the productive resources needed for participation, their ability to participate in, and benefit from, PES programmes will depend on how well the changes required by the PES programme fit into their overall livelihood strategy. A key consideration is the overall rural nature of poverty. Of the world's 1.1 billion extremely poor people, 75 percent live in rural areas and depend on agriculture, forestry, fisheries and related activities for survival. Increasing the return to natural resource management, be it through agricultural production or environmental service supply, is thus a critical means of reducing poverty (FAO, 2007e).

As discussed in Chapter 2, there are many ways in which agricultural producers may shift land-management systems towards producing environmental services, ranging from a complete change of land use to minor modifications in a current system.

Table 14 gives some insight into the primary production activities of the rural poor by region. Smallholder farmers constitute a major segment of the rural poor in several regions, including Asia and the Pacific, East and southern Africa, West and Central Africa and Latin America and the Caribbean. In addition, the rural poor in Latin America and the Caribbean and in the Near East and North Africa are often rainfed farmers or pastoralists (IFAD, 2001).

A clearer understanding of the potential of environmental services to fit into these strategies can be obtained by closer examination of the types of changes to farming systems required within the framework of the decision-making process of poor farmers. The nature of the change is of particular importance for poor farmers, who are more likely to face market failures for food, credit, insurance and labour. Consequently, food-security and food-access concerns, including through their own production, are more likely to be determining factors in their decisions regarding participation in PES programmes. Naturally, if a PES programme restricts or bars traditional land uses, such as unsustainable grazing

TABLE 15
Relative importance of different poverty reduction strategies by resource potential

STRATEGY	Agricultural resource potential	
	High[1]	Low[1]
Intensification	1.9	0. 9
Diversification	3.1	1.4
Increased farm size	1.2	0.9
Increased off-farm income	2.5	2.4
Exit from agriculture	1.2	4.4

Note: This table is from an FAO study prepared as a contribution to the World Bank Rural Development Strategy, *Reaching the rural poor* (World Bank, 2003b). Over 20 case studies were prepared to support the analyses, which investigated innovative approaches to small farm or pastoral development. The material in the World Bank publication draws upon this study as well as on expertise from years of specialized work on the topic at FAO and the World Bank.

[1] Scores add to 10.

Source: Dixon and Gulliver with Gibbon, 2001.

and cropping, it must provide acceptable alternatives; otherwise it is unlikely that the poor will be able to participate. Use-restriction rules count among the main conditions that discourage or exclude smallholder participation. In contrast, PES programmes allowing mix-use activities that provide diversified sources of income (e.g. agroforestry and silvopastoral systems) play a positive role in facilitating participation of the poor (WRI in collaboration with UNDP, UNEP and World Bank, 2005; Grieg-Gran, Porras and Wunder, 2005).

Risk, too, is a critical dimension for poor farmers. When PES programmes promote a change in resource management and perhaps input use (e.g. switching from pesticides to an integrated pest management strategy, or from conventional tillage to reduced or no tillage), adopters may face increased risks while they are learning about these new practices. Because the poor are generally more risk-averse than the well-off and have fewer options for managing risk, their supply response to risk-increasing activities is likely to be lower. Thus, poor farmers may be less inclined to participate in a PES programme if an enhanced supply of environmental services is accompanied by reduced food production, especially if food markets are functioning poorly. However, PES programmes can also contribute to *reducing* risk when the payments represent a stable source of reliable income.

A 2001 FAO/World Bank study on farming systems and poverty gives some insights into the types of changes in livelihood strategies in general and farming system management specifically, that may benefit the poor (Dixon and Gulliver with Gibbon, 2001). Table 15 shows the degree of relevance of different strategies for poor farmers to exit from poverty for areas of high and low agricultural-resource potential, respectively. In the high-potential areas, the most important strategies are diversification of production activities and increased off-farm income; in the areas of low agricultural potential, the highest benefits are obtained by exiting from agriculture and increasing off-farm income.

PES programmes could contribute to such poverty reduction strategies to the extent that they can support diversification of agricultural production in high-potential areas or facilitate exiting agriculture in low-potential areas. Indeed, farmers could conceivably diversify the output from their agro-ecosystems to include environmental services along with agricultural products. Payment schemes could also represent a de facto means of exiting from agriculture, at least at a specific site, in cases where environmental service provision involves changing land use away from agriculture. The study found increased off-farm income and exiting from agriculture to be important poverty reduction strategies, given that improving agricultural productivity in the agro-ecosystems managed by the poor is costly and in some cases impossible. However, increasing the returns to such ecosystems by

switching to environmental service provision may offer a viable alternative.

Transaction costs and participation of the poor in PES programmes

Transaction costs may constitute the biggest impediment to participation of poor households in PES programmes (FAO, 2003c; Zilberman, Lipper and McCarthy, forthcoming; Antle and Valdivia, 2006; Landell-Mills and Porras, 2002; Pagiola, Arcenas and Platais, 2005; Wunder, 2005). As discussed in Chapter 4, transaction costs can be a determining factor for the feasibility of PES exchanges in general. When the potential suppliers of the service are poor farmers, the issue of transaction costs becomes more critical. Fixed costs, such as developing a project proposal, setting a baseline and identifying a buyer, account for a large share of the transaction costs. In the case of a very small transaction – say for carbon sequestration at a site of less than 1 hectare in size – transaction costs per hectare will be prohibitively high. The larger the transaction costs, the more attractive it will be for PES programmes to focus on large land holdings. As farm size tends to be highly correlated with income, in practice this means focusing on better-off households.

FAO (2006f) found that one of the most important ways of improving the feasibility of smallholder carbon sequestration projects is to reduce the *ex-ante* fixed transaction costs faced by the buyers. They identify three broad strategies to this effect:

1. increasing project size by fostering/building upon collective action among suppliers;
2. reducing contracting costs by utilizing existing management structures;
3. reducing information costs through public provision of data, templates and guidelines.

The three strategies are not mutually exclusive and, in many cases, can be complementary.

Examples of the first strategy, with projects involving smallholder coordination in the supply of carbon services, have been documented by FAO (2003c), Smith and Scherr (2002) and Orlando *et al.* (2002). In these projects, the costs to buyers of identifying, contracting and enforcing viable carbon sequestration opportunities among smallholders are reduced through the presence of an intermediary representing the suppliers. This intermediary can be an NGO, a community group or a government agency. However, such group schemes may lead to the participating sellers facing greater transaction costs; these costs, however, must not exceed the benefits they derive from participation. Several of the carbon smallholder projects were built upon pre-existing community projects, such as ongoing community-based natural resource management projects (particularly community forestry projects) or farmers' groups.

The second way of reducing transaction costs in projects involving small- and low-income suppliers is to utilize management structures and lessons from existing projects. For example, important lessons on how to design and administer PES schemes for poor producers can be obtained from the experience with conditional cash transfers (see Box 24).

Making information available on situations where the poor could potentially become significant providers of environmental services – via the use of maps such as those presented in this chapter – together with more detailed analysis of the type of programme design needed to facilitate the participation of the poor is the third strategy to reduce transaction costs facing low-income suppliers. This strategy is being pursued by a wide range of international and national public agencies, and NGOs.

Finally, the possibility of marketing environmental services that are explicitly linked to poverty reduction merits consideration. If buyers of environmental services are willing to pay a premium for environmental services provided by the poor, higher levels of transaction costs could be supported (FAO, 2006f). Is there any evidence of this type of market demand? Several examples of carbon buyers specifically interested in livelihoods and poverty reduction benefits are given in Box 25. The projects referred to in the box indicate some development of a poverty-focused market niche for carbon offsets in the voluntary market. Even in regulatory markets such as the CDM, sustainable development is a mandatory aspect of certifying the eligibility of offsets. The definition of sustainability is left to the implementing countries, and

BOX 24

Reaching the poor with cash? Lessons from conditional cash transfers

Benjamin Davis[1]

Cash payments are often considered the most flexible, and thus the preferable, mode to pay for environmental services. However, there are concerns about both the capacity to reach poor producers with cash payments and the effectiveness of these payments. Important insights into this debate can be obtained from the experience of conditional cash transfers.

Conditional cash transfers (CCTs) are a form of social assistance that has come to dominate the social protection sector in the Latin America and the Caribbean region over the past decade and is increasingly being considered for use in other parts of the world, including Africa. CCTs are linked directly to human capital development by making receipt of the transfer conditional on school attendance and a variety of health- and nutrition-related activities. In most cases, CCTs are provided directly to mothers on the assumption, substantiated in the literature, that they are more likely to use the resources for the benefit of their children.

The experience of CCTs in Latin America has shown this type of cash transfer to be very effective in obtaining its objectives. The conditional aspect of CCTs is one of the most attractive (and controversial) features of the programme, and also one of the most complicated to execute. The administrative burden of monitoring conditionality, particularly in countries with weaker institutional structures, leads to the question of whether conditionality is feasible or necessary and, if so, the type of monitoring mechanism that is most appropriate.

Despite this concern, countries from Mexico to Nicaragua, at opposite ends of the spectrum of wealth, development and administrative capacity in the region, have successfully implemented CCT conditionality.

One important dimension of the CCT experience is that of the professionalization of administrative practices. Beginning particularly with the Oportunidades (formerly the Education, Health, and Nutrition Program of Mexico [PROGRESA]) programme of the Government of Mexico, and improving over time in other programmes in the region, CCTs have modernized the public administration of social assistance. CCTs have established modern information and management systems for beneficiary selection, registration and payment, as well as the monitoring of conditionality, assuring more transparency and efficiency in implementation (de la Brière and Rawlings, 2006).

Despite the complex nature of these programmes, they have been shown to be relatively cost efficient (Caldés, Coady and Maluccio, 2006). While many challenges remain, including how to institutionalize and formalize effective community participation, as well as the coordination of the provision of services, the administrative setups of CCTs have done much to promote transparency and counter problems in the application of social spending. A core element in this professionalization has been the concerted effort to conduct independent evaluations of CCT programmes.

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thus a wide range of definitions have been proposed, some of which include a poverty reduction dimension. Nevertheless, only limited evidence is available, to date, on the willingness to pay a premium for environmental services that explicitly include a poverty benefit.

When are the poor likely to benefit from PES programmes?

Summarizing the discussion in the above sections, the spatial distribution of poverty, property rights to land, and the productivity of the land for the provision of agriculture and environmental services are key

BOX 25
A market for carbon offsets from the poor? Evidence from the Plan Vivo System

Plan Vivo has established standards for carbon emission offsets with explicit poverty reduction aspects. The Plan Vivo System is managed by BioClimate Research and Development (BR&D), which is a non-profit organization. BR&D is responsible for development and maintenance of the Plan Vivo System and "contracts" the Edinburgh Centre for Carbon Management (ECCM) to provide the systems maintenance resources needed for the continued development of Plan Vivo.

Plan Vivo has three operational projects that are producing carbon for the sale of Plan Vivo carbon offsets: the Scolel Té project in Chiapas, Mexico, the Trees for Global Benefit project in Uganda and and the N'hambita Community Carbon Project in Mozambique.

At present, purchasers of the carbon offsets generated by the Scolel Té project include the FIA Foundation, to offset carbon emissions from Formula 1 and World Rally championships, The CarbonNeutral Company, on behalf of a number of companies, the World Bank International Bank for Reconstruction and Development and the United Kingdom Department for International Development.

Source: Plan Vivo, 2007.

determinants of where and when the poor could benefit from supplying environmental services, as well as the type of change required to generate the service.

The poor are most likely to benefit from participation in PES programmes where land distribution is relatively equitable and where the poor are found on lands of poor quality for agricultural production but high quality for environmental service supply. They are most likely to benefit from programmes involving a change of farming system, rather than land use, because the small size of the land holdings, combined with food security concerns, will limit their ability and inclination to take land totally out of agricultural production.

Indirect impacts of PES programmes on the poor

Separate from the issue of the poor as potential participants in the programmes, PES programmes may also have indirect impacts on the poor via land price, wage and food price effects (Zilberman, Lipper and McCarthy, forthcoming). It is useful to consider three different groups which may be affected by PES programmes: consumers of food products, wage labourers and consumers of environmental services. For example, payment programmes that lead to a significant reduction in food production could have impacts on food prices. If food markets are functioning poorly and food supplies are largely locally procured, even a small reduction in local food production could have significant negative impacts on poor food consumers. Impacts on rural consumers are likely to be more or less localized, depending on the degree of integration of rural areas with urban markets.

Changes in farming systems or land use may also involve changes in labour use. For example, converting land from agricultural production to forestry will release labour, while moving to silvopastoral production systems from conventional systems is likely to absorb labour. This, in turn, will affect local wage rates, either upwards or downwards, depending on how the PES programme affects labour demand. Effects on wage rates could have a significant impact, for better or worse, on the poor, who are generally highly dependent on wage labour for their income (Zilberman, Lipper and McCarthy forthcoming). As with food markets, the overall effect of a PES programme depends not only on the magnitude and direction of the changes in labour use, but also the degree to which labour markets are isolated or integrated into national or international markets. Uchida, Rozelle and Xu (2007) find

that one of the most important benefits for the poor of China's Grain for Green programme has been an increase in off-farm income. The programme provides cash funds that allow participants to overcome a liquidity constraint against entering the labour market.

Finally, PES programmes could provide benefits to the poor as consumers of an environmental service. A prominent example would be services related to water quality and quantity, where studies have shown that even poor consumers are willing to pay for good water quality. In any of the watershed protection programmes where water quality or quantity has been improved, poor consumers have benefited also, even though many of them do not pay for water. There may also be a significant gender dimension to benefits from environmental services. Rural women are often the household members in charge of collecting water, fuelwood and other natural resources needed for household consumption and could therefore be major beneficiaries. Other environmental services for which there may be demand from the poor include access to crop genetic resources or pollinator services. Of course, the question remains whether the poor will be willing and able to pay for these services.

Payments for environmental services and poverty reduction: where are the synergies?

As noted in Chapter 4, a wide range of land-use and farming system changes that, in the long run, will be more profitable for farmers are not adopted owing to problems such as lack of credit, property rights and technical information. Poor farmers face these types of barriers disproportionately. Where a privately profitable practice is not adopted for these reasons, the solution should aim at removing the barrier concerned. However, in many cases, addressing these barriers is fraught with difficulty. Assuming that the main objective of PES programmes is to increase the provision of environmental services, would it be reasonable to use such programmes to help farmers overcome the barriers to change?

First, it is important to note that for location-specific services, such as watershed management and biodiversity conservation, the poor may be located in exactly the areas identified as having high potential for environmental service provision, making their participation necessary in order to meet the environmental objective. But location alone is not enough. Pagiola, Arcenas and Platais (2005) noted that the requirement of formal title for participation in the Costa Rica PES programme reduced the efficiency of the programme by excluding poor landowners. Addressing barriers preventing the poor from participating is essential when the poor are in key locations for environmental service supply. Evidence to date does indicate that those who do participate as suppliers in PES programmes are likely to become better off (Pagiola, Rios and Arcenas, forthcoming).

The maps presented in this chapter show several locations where a combination of high poverty rates, low agricultural productivity and high potential for environmental service supply suggest a potential for poor producers to benefit from PES programmes. This type of mapping can be helpful as an indication of where PES programmes could result in both environmental service supply and poverty reduction. However, such maps can only be indicative, and careful investigation into land tenure, farming systems and land-use patterns is needed in order to confirm the real potential.

Innovative PES programme designs may be needed to ensure the participation of the poor. For example, providing up-front or early payments (e.g. large payments within the first year of a project, rather than spreading the total amount over several years) may be desirable in PES projects requiring initial investments in areas with many poor households. Also, while full title or private ownership of land or resources may be preferable in some PES programmes, it does not have to be a prerequisite. There are other ways to increase security of tenure for the poor, including legally sanctioned use of key resources, the right to exclude and the right to manage the resource for optimum benefit. In conservancies in Namibia, for example, the devolution of wildlife rights on communal lands was sufficient to allow local communities to

BOX 26

Can the poor benefit from payments for environmental services programmes? Evidence from the Silvopastoral Project in Nicaragua

Can poorer households participate in PES programmes? A recent study of the experience of the Regional Integrated Silvopastoral Ecosystem Management Project (see Box 14) in Matiguás-Río Blanco indicates that they can. Not only did poorer households participate quite extensively, but by some measures they participated to a greater extent than better-off households. Extremely poor households do appear to have had somewhat greater difficulty in participating, but even in their case the difference is solely a relative one. Extremely poor households not only were not shut out, but participated at high rates in the project. Their participation was not limited only to the simpler and cheaper practices, but included the full spectrum of land uses.

These results are particularly strong in that the Silvopastoral Project imposes much greater burdens on participants than most PES programmes. Nevertheless, one should not jump to the conclusion that all poor farm households everywhere will always be able to participate in such programmes. Both the programmes and local conditions differ from case to case, and there may well be cases where otherwise eligible poor households may find it difficult or impossible to participate. Indeed, the results show that extremely poor households do appear to have had greater difficulty in participating as intensively as other households.

The study helps identify several factors that tend to affect participation. Lack of credit may be an important constraint for poorer households. This constraint will not always be critical in PES programmes, for example in programmes that maintain an existing land use. However, financing constraints are likely to be important when land-use changes are required for participation, as in Costa Rica's reforestation or agroforestry contracts. Providing some initial financing (such as the baseline payment made by the Silvopastoral Project) may be desirable for PES programmes that involve initial investments in areas with many poor households. The importance of technical assistance emerges far less clearly from the study results. The practices being promoted by the project were relatively complex, but were also relatively well known in the area.

The availability of multiple options in the Silvopastoral Project may well have contributed to high participation by the poor, as they were able to choose the options that worked best for them in the light of their particular requirements. When a given service can be provided in different ways (or at different levels), it makes sense to offer multiple ways in which households can participate, as long as transaction costs do not increase unduly. It is worth noting, however, that at Matiguás-Río Blanco the poorer households did not predominantly choose the cheaper and easier land uses – in fact, the better-off households were more likely to do so.

Source: Pagiola, Rios and Arcenas, forthcoming.

earn income from managing the wildlife even though they could not exclude others from using the land (FAO, 2007f). Another option is to distribute payments to larger community associations, which can then attempt to identify and implement an appropriate solution. Box 26 describes the participation of the poor in one innovative programme in Nicaragua.

Conclusions

Reducing poverty and increasing the supply of environmental services are two separate and distinct policy objectives that would normally need to be addressed by separate policy instruments. Blanket assumptions that PES programmes will, or should, also benefit

the poor are thus problematic. However, public-sector-funded projects and many voluntary sources of payments are interested in both environmental and socio-economic objectives, thus leading to multi-objective PES programmes. PES programmes can affect the poor – either positively or negatively. The poor may be affected directly, as potential suppliers or consumers of environmental services, but there may also be an indirect impact on non-participants through effects on local wages, food prices or land values. PES programmes could hurt the poor, particularly the landless, by driving down wages or increasing food prices. Likewise, they may result in pressures to exclude the poor from lands to which they have only informal rights if the value of the land increases.

The discussion above has identified situations where there may be strong potential for poor farmers to supply environmental services. For location-specific services, such as watershed management and biodiversity conservation, the presence of the poor in areas of importance for environmental service provision makes their participation necessary. In these situations, addressing the barriers preventing the poor from participating is indispensable.

Environmentally beneficial land-use and farming-system changes that will be more profitable for the farmer in the long run are not always adopted owing to problems such as lack of credit, property rights or technical information. Often, it is the poor producers who face these types of barriers, in which case PES programmes may offer some opportunities.

The maps in this chapter suggest that the poor could benefit from PES programmes, particularly in areas characterized by a combination of high poverty rates, low agricultural productivity and high potential for environmental service supply. However, such maps are only indicative. Further research on land tenure, farming systems and land-use patterns is needed to identify the actual potential. Evidence from PES programmes to date has shown that the poor can participate and benefit from PES programmes.

A critical problem is that of the transaction costs of PES programmes, which may be prohibitive in the case of poor producers, unless strategies are adopted to minimize them as far as possible.

Innovative PES programme designs are needed to ensure the ability of the poor to participate as suppliers of environmental services. Two important examples are the timing of the payment to help address credit and investment constraints farmers may have, and making provisions to work with producers who have only informal title to lands.

7. Conclusions

This issue of *The State of Food and Agriculture* has examined the role of agriculture in the provision of ecosystem services. These include all outputs from agricultural activities, ranging from food production to climate regulation. Many of these services are provided only as externalities; that is, they are unintended consequences of the production of food or fibre. These services, which we refer to as environmental services, are normally not compensated for. Therefore farmers lack incentives to supply them in the desired quantity.

In exploring the potential of agriculture to provide enhanced levels of environmental services and how these can be achieved, the discussion has focused on one relatively novel approach that aims to provide positive incentives to farmers for their provision: payments for environmental services. The three types of environmental services that have seen the most significant growth in PES programmes have been emphasized: climate change mitigation, improved water supply and quality, and biodiversity conservation. Five main messages emerge from the report.

Demand for environmental services from agriculture will increase.

Two forces are generating a growing demand for environmental services: greater awareness of their value and their increasing scarcity, arising from mounting pressures on the Earth's ecosystems. The growing demand for these services has led to a significant increase in the number of PES programmes in recent years. The overall magnitude of these programmes is still small, however, and they remain mostly, but not exclusively, confined to developed countries. The public sector has been the major source of payment programmes so far, in both developed and developing countries, but privately funded programmes are also emerging.

Future demand for environmental services is likely to increase, driven by population and income growth, and globalization. The demand may come from disparate sources, such as local water users, international offset programmes for carbon sequestration and biodiversity, and private-sector purchasers interested in meeting consumer demand for improved environmental management (certified, for example, via ecolabels) or in improving their corporate image. There is also potential for additional growth in national public-sector programmes, even in low-income developing countries where environmental services can meet critical policy objectives, such as the availability of clean water and prevention of natural disasters.

Although this report has focused on the three environmental services that have seen the most significant expansion in PES programmes to date, demand for other services – for example, disaster prevention, pollination and disease control – is likely to rise in the future. In addition, bioenergy has recently become one of the most dynamic and rapidly changing sectors in the global energy economy. While significant impacts on agriculture and environmental services are possible, their nature and magnitude remain uncertain. Bioenergy will be examined in greater detail in next year's *State of Food and Agriculture* report.

Agriculture can provide a better mix of ecosystem services to meet society's changing needs.

Farmers both depend on and generate a wide range of ecosystem services, and their actions can enhance or degrade ecosystems. As population and income growth puts increased pressure on farmers and the ecosystems they manage to provide ever greater volumes of conventional agricultural outputs, threats to other services – such as the three referred to above – are intensifying. There are very significant costs involved in the inadequate provision of these services, and these costs are receiving

increased attention from the media and policy-makers as well as the private sector. Through changes in land use and production systems, agricultural producers can provide a better mix of ecosystem services, expanding the share of those characterized as externalities, to meet society's changing needs.

The way in which environmental services can be generated varies by service, type of production system and agro-ecological context. The changes needed range from shifts in land or water use (e.g. away from crops or livestock production to grasslands or forest) to modifications within a given production system (e.g. adopting farming practices that provide higher levels of environmental services alongside conventional agricultural outputs).

Often there are synergies in the provision of different ecosystem services. Production practices adopted to enhance one type of service may enhance others at the same time. For example, enhancing 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, in many cases there are trade-offs among the provision of different ecosystem services. Although agriculture has the technical potential to supply enhanced levels of environmental services, the costs and, hence, the economic feasibility of the changes required, are central to understanding whether they can be achieved and what level of payments would be required to realize them.

If farmers are to provide a better mix of ecosystem services, better incentives will be required. Payments for environmental services can help.

For a variety of reasons, the full value of all ecosystem services is not normally reflected in the incentives faced by the service providers. As a consequence, many environmental services are underprovided, because adopting the necessary changes in land use or management practices would result in lower benefits to the producers. In addition, many farmers, particularly in developing countries, face barriers to the adoption of new practices, such as constraints on access to information, appropriate technologies and financing, as well as non-existent or insecure property rights and legal or regulatory constraints. The effect of these barriers is often compounded by poorly functioning markets and infrastructure, risk and difficulties in collective management of commonly held resources.

There are several options for policy-makers to change farmers' incentives. In the past, non-market instruments, such as regulations or taxes, were most common, but today flexible, decentralized market-based approaches are receiving increasing attention. Payments for environmental services are among these options.

Farmers may be compensated either to enhance the provision of certain environmental services that may be degraded or undersupplied as a result of current agricultural practices or to offset pollution generated in other sectors. In the first case, a critical decision is whether farmers should be paid to reduce the negative externalities they generate rather than requiring them to bear the cost themselves. Who holds the initial rights to the environmental services: the producers or society? The answer to this question is complex and may differ according to service and context. In the second case, the appropriateness of payments to farmers hinges on the more technical consideration of the efficiency of the offset in meeting the intended objective.

Cost-effective PES programmes require careful design based on the characteristics of the service and the biophysical and socio-economic context.

Different types of PES programmes are appropriate to different socio-economic and agro-ecological contexts. The process of designing an effective payment programme involves four important and challenging steps: identifying what should be paid for; who should be paid; how much should be paid; and what payment mechanism(s) should be used. Ideally, payments should be linked directly to the level of service provided. More frequently, however, they are linked to some proxy associated with

changes in the provision of environmental services, as this may reduce transaction and measurement costs. The most common payments are those made for changes in land use, but farmers are also frequently paid to change their management practices on agricultural land.

To maximize cost-effectiveness, payments must be targeted to farmers and locations where the largest gain in environmental service provision can be obtained for a given level of payment, or where a given increase in environmental service can be achieved for the lowest cost. Some PES programmes address multiple objectives (e.g. environmental service provision and poverty reduction); in many cases this will lead to some degree of trade-off between the objectives or to an increase in the cost of providing the environmental service.

The level of payments required to motivate farmers depends on the opportunity costs, or foregone benefits, they face in making a change in land use or management. These vary according to agro-ecological conditions, technology employed, level of economic development and policy environment. Land diversion programmes (away from agriculture) are most likely to be effective where the returns to land in agriculture are low. In land-scarce environments, changes that generate environmental services within agricultural production systems are more likely to be favoured. The opportunity cost of labour also plays a role in determining the feasibility of changes. Where labour is scarce, production changes that reduce labour use are more likely to be adopted.

Minimizing the transaction costs involved in programme implementation, including monitoring and enforcement, can play a pivotal role in designing programmes that will be cost-effective. These costs are influenced by the availability of information and the institutional capacity for managing exchanges, both of which vary by country as well as by environmental service. Choices may need to be made between programme designs that may be effective in service provision but entail high transaction costs and others with lower levels of both effectiveness and transaction costs.

An enabling environment is critical for PES programmes. No transactions can take place in the absence of supporting institutions, which can range from informal to highly regulated in nature. Capacity building will therefore be an essential component of efforts to support the use of the PES approach in developing countries.

- ***Payments for environmental services are not primarily a poverty reduction tool, but the poor are likely to be affected, and implications for the poor must be considered.***

Reducing poverty and increasing the supply of environmental services are two distinct policy objectives. Using one policy instrument to achieve both may reduce its effectiveness in reaching either. However, most public-sector-funded payment programmes require that socio-economic impacts be taken into account, and even some private-sector-funded schemes include poverty reduction criteria. PES programmes can affect the poor, either positively or negatively. The poor may be affected directly, as potential suppliers of environmental services, or indirectly, through effects on wages, food prices or land values, particularly in large-scale programmes or in areas with limited links to external food and labour markets. If appropriate measures are not incorporated into the programme design, PES programmes could hurt the poor, especially the landless, by driving down wages or increasing food prices. They could also result in the poor being excluded from lands to which they have only informal rights. Given these possibilities, universal assumptions that PES programmes will benefit the poor should be avoided.

Nevertheless, PES programmes have been shown to be potentially accessible and beneficial to the poor. Where poor producers considering adopting improved agricultural practices are faced with barriers such as lack of credit, property rights or technical information, PES programmes can sometimes offer opportunities for overcoming them. For location-specific services such as watershed management and biodiversity conservation, the presence of the poor in specific areas of importance for environmental service provision makes their participation indispensable.

The transaction costs involved in contracting with numerous small-scale

producers, many of whom have limited access to resources, can be a critical constraint on the participation of the poor in PES programmes. These costs may remain prohibitive in the case of poor producers – who are generally small-scale suppliers – unless strategies are adopted to reduce them.

The way forward

Payments for environmental services represent a broad and flexible array of measures aimed at improving farmers' incentives to provide services such as carbon sequestration and water purification that are increasingly valued by society. These measures range from narrowly defined voluntary private transactions to more broadly applied public programmes.

Although payments for environmental services are not a panacea for solving all environmental problems, they nevertheless have significant potential for further application in both developing and developed countries. However, much work remains to be done before they can play their role in full. Three key challenges confront public and private stakeholders at the local, national and international levels.

The rights to environmental services must be clarified

First, the establishment of PES programmes involves inherently difficult and potentially controversial decisions about who should bear the cost of providing the services. Any environmental policy is based on an, at least implicit, assumption about who holds the rights to a service and who should bear the costs of providing it. These rights are related to, but not the same as, rights to the resources that contribute to the provision of environmental services. If society decides that farmers hold the right to use the land, water and other resources at their disposal in ways that may have adverse environmental consequences (as has historically been the case), then those who wish to reduce those adverse consequences will have to compensate farmers for any necessary changes. On the other hand, if changes in production practices or impacts warrant, society may decide that farmers should bear the cost of reducing those impacts. Naturally, the question is open to debate and must be resolved on a case-by-case basis. The answer will vary according to the nature of the threat involved and the specific biophysical and social context it occurs in.

Resolving the question at the practical level requires a political process of negotiation, which may range from the international level for issues such as climate change mitigation and biodiversity conservation, to the local level involving community-based farmer associations and representatives of urban consumers in the case of watershed management. Equity as well as efficiency concerns are important in making these decisions, and in some cases it will be necessary to balance trade-offs between the two criteria. However, growing pressure on the Earth's natural resource base, together with the increasing scarcity of environmental services and their associated costs, calls for serious political commitment to clarify the issue of rights to environmental services to allow the problem of environmental management to be addressed effectively, be it through payments for environmental services or through other instruments.

More information is needed through research in both natural and social sciences

A second area of pressing need is further research in both the natural and social sciences of environmental service provision and use. Better information on the causal links between land-use and farming-system practices and their environmental outcomes is critical not only as an aid to clarifying rights to environmental services, but also for identifying the locations and activities that will generate the highest environmental service benefits and for designing effective PES programmes.

Social science research is equally important in order to identify the socio-economic contexts in which payments will be most effective. More work is also needed on the development of guidelines and frameworks for assessing potential, institutional requirements and ways of meeting them, as well as for designing programmes. Such

research outputs will constitute an important means of reducing the high transaction costs that PES programme participants, both buyers and sellers, currently face. High-quality data on both natural and social science indicators are needed to support the analysis required for effective targeting of priority services, areas and programme participants. Geographic information systems can be used to understand and illustrate the interactions among agriculture, environmental services and poverty. Rich, spatially referenced databases are already being generated and offer strong potential for improvement in this area.

In addition, it should be recognized that agricultural production is just part of a long and complex chain that begins with input supply and continues with post-harvest processing, transportation, marketing, consumption and disposal. Each of these stages has impacts on environmental services, and a more complete understanding of the provision and use of environmental services would require analysis of these processes also.

Institutions and capacity building must be strengthened

A third and final challenge relates to institutional support and capacity building. Improved coordination between the public and private sectors through partnerships can enhance the demand for environmental services as well as the sustainability of funding. The public sector also has an important role to play in establishing frameworks for private-sector PES programmes. For instance, improving the coordination among the various ecolabelling schemes and clarifying the environmental benefits that can be obtained from certified products will help to increase the effectiveness of this form of payments for environmental services.

Designing rules that facilitate the access of developing country suppliers to international PES programmes is a further important aspect of the institutional requirements. Rules for certification are indispensable, but can represent serious barriers to entry into global markets for developing country suppliers of environmental services, and there is a need to work across the public and private sectors to develop strategies to overcome these barriers. A relevant issue in this domain concerns the types of activities allowed under flexible trading mechanisms such as the CDM. Restrictions on the type of land-use activities allowable under this mechanism greatly limit the potential demand for environmental services supplied by farmers.

Institutions and capacity building are also needed at the national level to establish the enabling environment required for effective PES programmes and to facilitate the transfer of internationally sourced payments for environmental services. Aligning national environmental, agricultural and financial regulations to support PES projects is another important area where national governments can provide institutional support. In some cases, national government support in clarifying property rights to the natural resources on which PES programmes are based (particularly land) can be critical for their success. Close cooperation among various national ministries and other bodies is a necessary condition for effective coordinated national efforts.

Finally, local institutions and capacity building are required to facilitate the technical and institutional changes needed for enhanced provision of environmental services. Building upon and strengthening the capacity of existing community groups is essential. Working with local organizations to facilitate the transfer of payments, monitoring and certification also serves to reduce transaction costs, particularly where smallholders are involved. Non-governmental organizations can play a fundamental role as mediators between buyers and sellers, as neutral brokers or by helping to facilitate farmers' collective action.

Current policies and incentives favour the production of conventional agricultural outputs at the expense of non-marketed environmental services such as climate change mitigation, improved water quality and quantity, and biodiversity. The costs to society of degrading environmental services are increasingly being recognized. However, it is also essential to recognize that providing enhanced levels of these services entails costs. Potential providers must be offered appropriate incentives.

Developing mechanisms to provide these incentives is challenging. This is a new area – the science is not always clear, the policy context is complex and budgetary resources are a constraint, especially in poorer countries. Nevertheless, payments for environmental services can trigger creativity in finding innovative solutions to improve the management of agricultural and environmental resources, even in countries that are poor in budgetary resources but rich in potential supply of environmental services. When effectively designed, PES programmes can give both providers and users of environmental services more accurate indications of the consequences of their actions, so that the mix of ecosystem services provided matches more closely the true preferences of society.

Part II

WORLD AND REGIONAL REVIEW

a longer-term perspective

Part II

World and regional review
A longer-term perspective[1]

World agriculture has achieved notable success over the past half century but faces serious challenges now and in the coming decades. The proportion of people suffering from hunger has fallen by half since 1969–71, the earliest period for which estimates are available. In developing countries, where most of the world's undernourished people live, progress is still being made on reducing the proportion of undernourished people, but the absolute number appears to be rising.

Steady growth in agricultural output and a long-term decline in real agricultural commodity prices attest to the success of the global agricultural system in meeting the increase in effective global demand for food and other products. Recent rises in commodity prices have been driven by weather-related production shortfalls and other factors such as the emergence of liquid biofuels as a large source of demand for agricultural commodities. It remains unclear whether this signals a new paradigm for agricultural prices and, if so, what that might mean for agricultural development, poverty reduction and food security.

Agricultural growth contributes directly to food security, but it also supports poverty reduction and acts as an engine of overall economic growth in much of the developing world. The success of the agriculture sector has not been uniform across regions and countries, however, and seems to have waned since the early 1990s. The challenge is to revive it and extend it to those left behind. Many of the least-developed countries, particularly those located in marginal production environments, continue to experience low or stagnant agricultural productivity, increasing food deficits and rising levels of hunger and poverty.

[1] This report is based on Wik, Pingali and Broca, 2007, and several previously published FAO reports cited in the text.

AGRICULTURAL PRODUCTION

The value of total agricultural output (all food and non-food crop and livestock commodities) has almost trebled in real terms since 1961 (Figure 14), representing an average increase of 2.3 percent per year, well ahead of global population growth (1.7 percent per year). Much of this growth has originated in developing countries, but it also reflects the rising share of high-value commodities such as livestock products and horticulture in the total value of production (FAO, 2006i).

Regional differences in performance

Global agricultural value added per capita has grown at an average rate of 0.4 percent per year in real terms since 1961 (World Bank, 2006), but not all regions have followed the same trend (Figure 15). Latin America and the Caribbean and South Asia have had a small increase, while the East Asia and Pacific region has more than doubled agricultural value added per capita over the last four decades. Sub-Saharan Africa is the only region in which per capita agricultural value added has not seen a sustained increase, with an overall declining trend and a considerable variation over time and across countries (Figure 16).

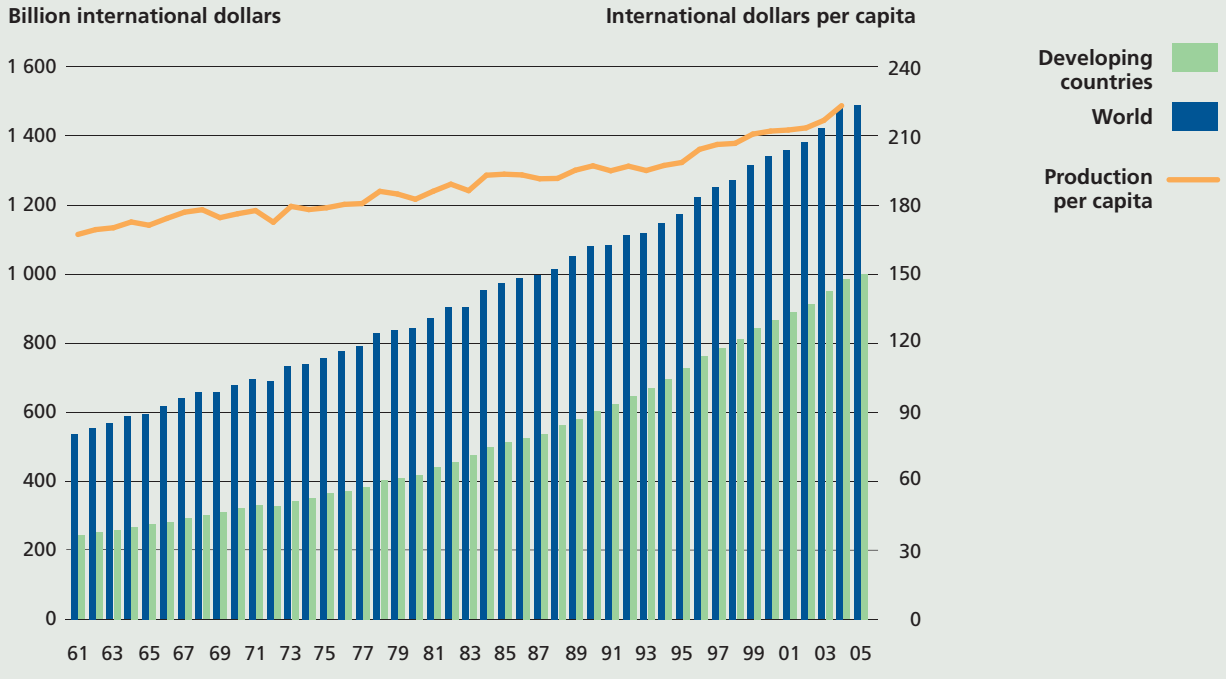
Changing composition of agricultural production

The composition of agricultural production has changed considerably over the last 40 years. The global output of cereals, oil crops, sugar, vegetables, eggs and meat has increased more than population growth rates, while the production of pulses and roots and tubers has declined relative to total population growth (Table 16).

Since 1990, cereal production growth has slowed compared to that of earlier decades. On the other hand, production of oil crops has accelerated, fuelled by growth of demand in developing countries for these crops' feed and food uses (FAO, 2006i).

In developing countries, egg and meat production has grown even more rapidly than that of oil crops. Given the diversification of diets driven by rising

FIGURE 14
Total and per capita agricultural production



Note: International dollars are an international commodity prices unit, average 1999–2001.
For more information on international dollars, see http://faostat.fao.org.

Source: FAO, 2006h.

FIGURE 15
Average growth rate in per capita agricultural value added, by region

Note: Agricultural value added includes fish and forestry products. No data are available for the Near East and North Africa until 1974. Data for sub-Saharan Africa are available from 1967 and for Latin America and the Caribbean from 1965.

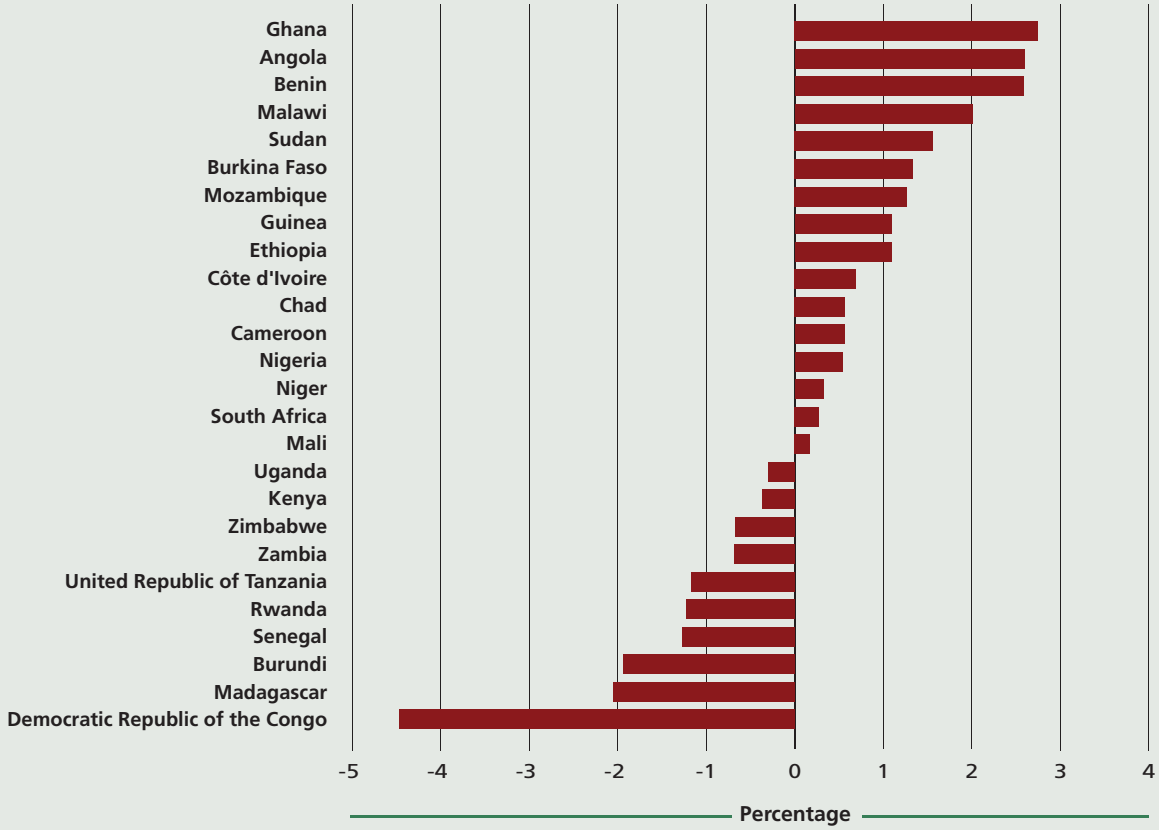
Source: World Bank, 2006.

TABLE 16
Global growth rates for outputs of different agricultural commodities

		1961–76	1977–91	1992–2005	1961–2005
		Annual percentage change			
CEREALS	WORLD	3.5	1.8	1.3	2.2
	Developing countries	3.9	2.8	1.5	2.8
OIL CROPS	WORLD	2.9	4.8	4.2	4.0
	Developing countries	3.1	5.0	4.9	4.4
SUGAR	WORLD	3.4	2.3	0.8	2.2
	Developing countries	3.1	3.5	1.2	2.6
PULSES	WORLD	0.8	1.5	0.9	1.1
	Developing countries	0.5	1.0	1.4	1.0
ROOTS AND TUBERS	WORLD	1.3	0.5	1.5	1.1
	Developing countries	3.0	1.6	2.2	2.3
VEGETABLES	WORLD	1.8	3.2	4.7	3.2
	Developing countries	1.9	4.4	6.1	4.1
EGGS	WORLD	3.0	3.4	3.6	3.4
	Developing countries	4.6	7.0	6.0	5.9
MEAT	WORLD	3.5	3.0	2.6	3.0
	Developing countries	4.3	5.3	4.8	4.8
MILK	WORLD	1.6	1.4	1.2	1.4
	Developing countries	2.7	3.3	3.8	3.2

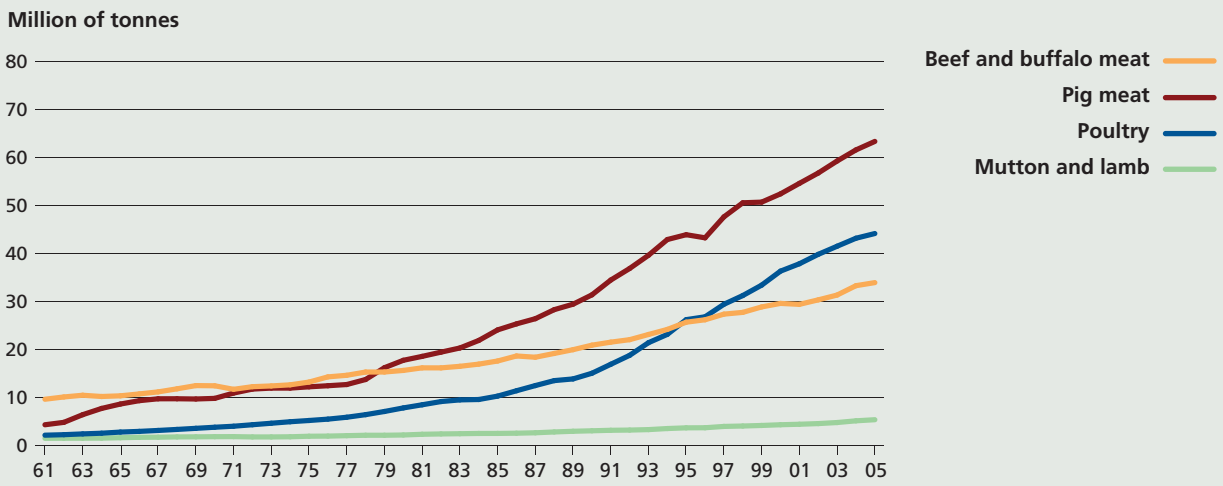
Source: FAO, 2006h.

FIGURE 16
Growth rate in per capita agricultural production in sub-Saharan Africa, 1990–2004



Source: FAO, 2006h.

FIGURE 17
Meat production in developing countries



Source: FAO, 2006h.

incomes and urbanization, it will probably continue to grow at a faster rate than will the population. Growth in the milk sector is expected to accelerate, mainly because of increased demand in developing countries.

Sugar production growth has accelerated recently. It is expected that this sector will see continued growth in the future because of both increased demand from developing countries (including China, which has very low sugar consumption per capita) and the potential for using sugar cane for the production of biofuels (FAO, 2006i).

Spotlight on livestock production

Total meat production in developing countries more than quintupled from 27 million tonnes to 147 million tonnes between 1970 and 2005 (Figure 17). Although the pace of growth is slowing down, global demand for meat is expected to increase by more than 50 percent by 2030 (FAO, 2006i). Satisfying the increasing demand for animal food products, while at the same time sustaining the natural resource base and coping with climate change and vulnerability, is one of the major challenges facing world agriculture today.

Globally, livestock production is the largest user of agricultural land and accounts for almost 40 percent of the total value of agricultural production. In developed countries, this share is more than 50 percent. In developing countries, where livestock production accounts for one-third of the value of agricultural production, its share is rising rapidly as a result of growth in income and changes in lifestyle and dietary habits.

Until recently, a large proportion of livestock in developing countries were not raised for food, but for providing draught power and manure and as capital assets that were only disposed of in times of emergency. Livestock were an integral part of agricultural systems, distributed among many owners and raised close to their feed supplies. This pattern is changing rapidly. Almost all of the growth in livestock production is now occurring in industrial systems, where meat production is no longer tied to a local land base for feed inputs or to supplying animal power or manure for crop production (Naylor *et al.,* 2005).

The world has been getting more meat, milk and eggs per kg of cereals used as feed. A rising share of poultry production in total meat production has contributed to this gain (poultry requires much smaller quantities of cereal feed per kg of meat than beef), but the growing use of high-protein oilmeals in livestock feeding is another important factor. World production of soybean, which is mainly processed into oil for human consumption and oilmeal for animal feed, grew at 5 percent per year in the last decade.

FOOD CONSUMPTION

The world has made significant progress in raising food consumption per capita, from an average of 2 280 kcal/person/day in the early 1960s to 2 800 kcal/person/day (Figure 18). The gains in world average food consumption predominantly reflect those of developing countries, given that developed countries already had fairly high levels of per capita food consumption in the mid-1960s. The overall progress of developing countries has been decisively influenced by the significant gains made in East Asia.

Diversification of food consumption

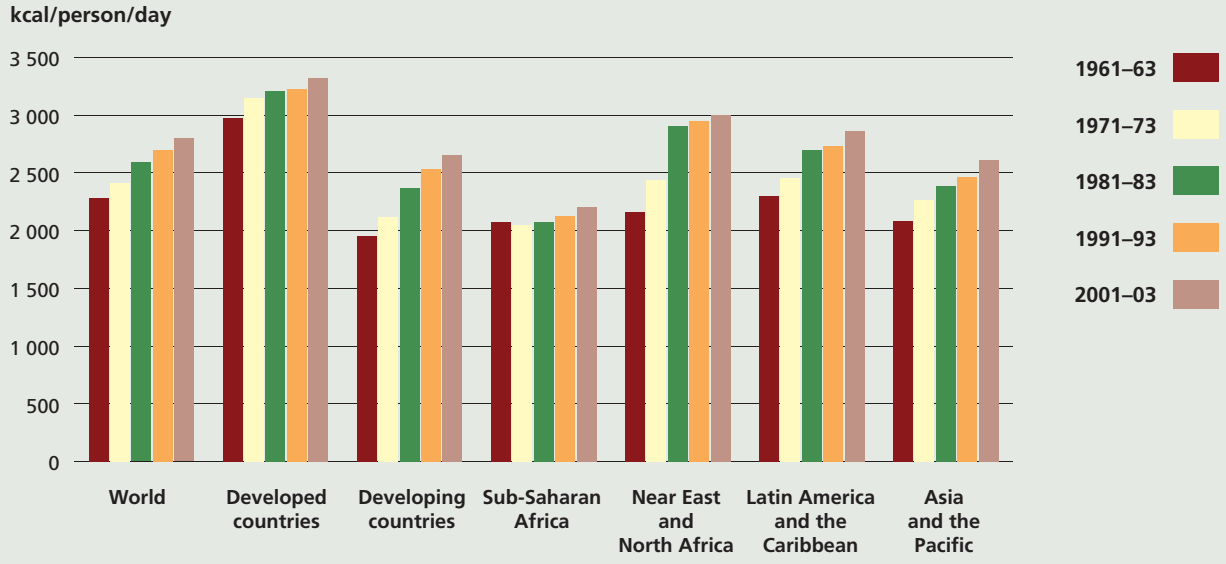
Both reflecting and driving the changes in agricultural production described above, global dietary patterns have changed significantly over the past four decades (Figure 19). Diets have shifted away from staples, such as cereals, roots and tubers and pulses, towards more livestock (meat and dairy) products, vegetable oils and fruits and vegetables.

Income growth, relative price changes and urbanization have altered dietary patterns in both developed and developing countries. When people have more money to spend, they normally add more variety and more expensive and high-value foods to their diets, although responses differ between developing and developed countries. In the latter, most consumers can already afford the foods they prefer. Therefore, when their incomes rise, changes in their diets and food purchases are relatively small.

In developing countries, on the other hand, rising incomes have an immediate and pronounced impact on diets, as people adjust their budgets to include higher-value food items (Figure 20). As wages increase, people are also willing to pay for convenience, freeing up their time for income-earning activities or leisure. They demand more processed foods with shorter preparation times. This is typically the case when more women participate in the labour market (Pingali, 2007). Also, declining real food prices have allowed poor consumers to access improved diets at existing income levels.

Urbanization is another important factor influencing consumers' preferences. Urbanization is taking place at a high pace, and urban dwellers were expected to outnumber rural populations by around 2007 (Millennium Ecosystem Assessment, 2005b). Large urban markets create opportunities for the establishment of large supermarket chains, and they attract foreign investment and advertising from global corporations. Non-traditional foods are also becoming

FIGURE 18
Per capita food consumption



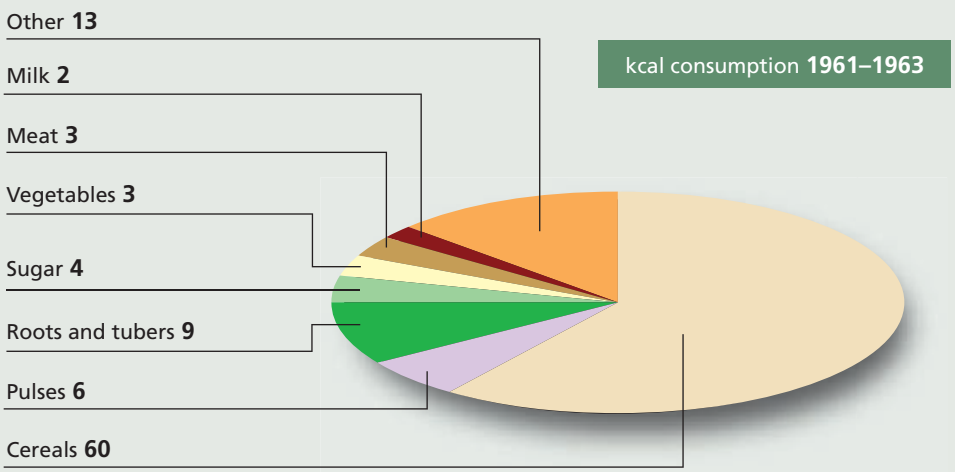
Source: FAO, 2006h.

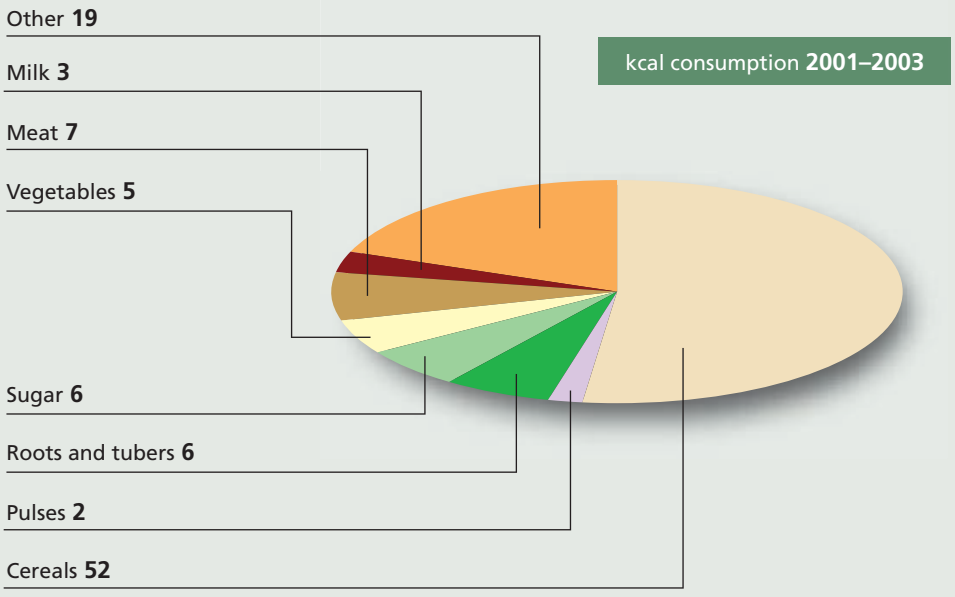
more accessible to urban populations as a result of trade liberalization and declining transportation costs (Pingali, 2007).

Emerging obesity concerns in developing countries

The progress in raising and diversifying per capita food consumption has had positive and negative effects in several developing countries. In raising dietary energy supplies to 3 000 kcal/person/day, the related diet transition often includes a large increase in the consumption of refined carbohydrates and processed fats and oils. In developing countries, this diet transition, combined with a more sedentary lifestyle, generally results in rapidly growing rates of overweight, obesity and a number of diet-related non-communicable diseases such as Type 2 diabetes and heart disease (Boutayeb and

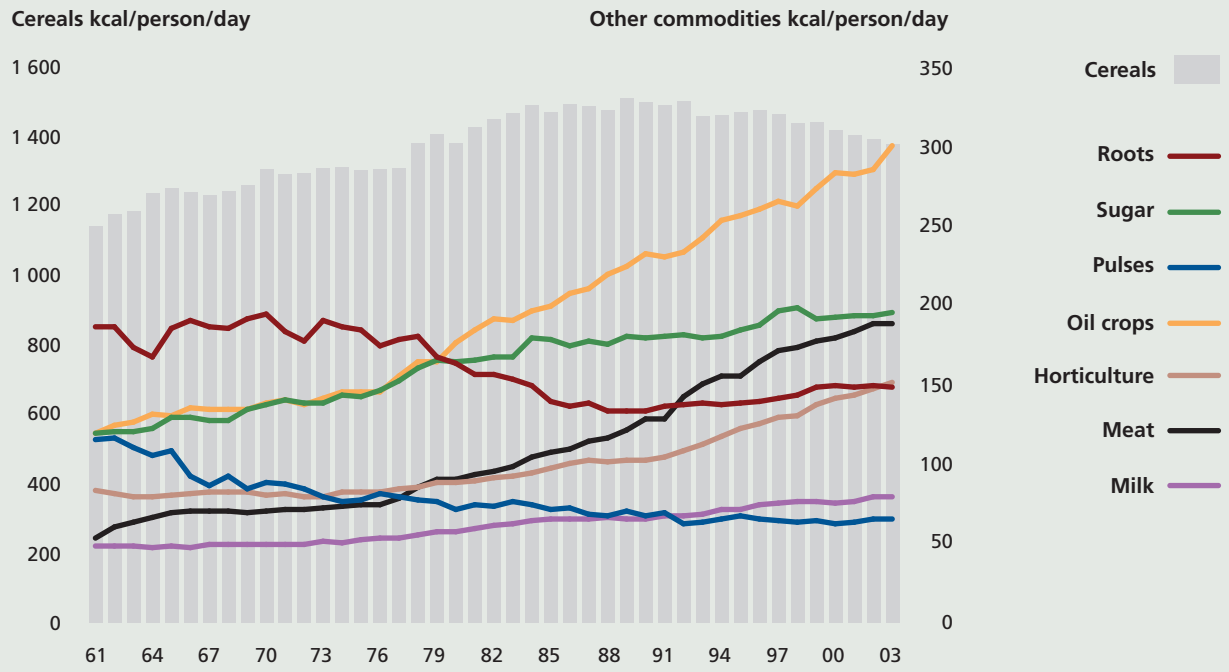
FIGURE 19
Composition of food consumption in developing countries (percentage)





Source: FAO, 2006h.

FIGURE 20
Consumption of different food commodities in developing countries



Source: FAO, 2006h.

Boutayeb, 2005; Popkin, 2004). It is now common to find overweight/obesity and malnutrition side by side in developing countries, even within the same household, with obese parents and malnourished children under the same roof (Doak *et al.*, 2000).

Globally, 1.6 billion adults are overweight, and at least 400 million are obese. Two out of three overweight and obese people now live in low- and middle-income countries, with the vast majority in emerging markets and transition economies (WHO, 2006). Health problems resulting from obesity-related non-communicable diseases tend to appear side by side with health problems related to undernutrition, making these countries confront a "double burden of malnutrition", resulting in novel challenges to, and strains on their health systems.

AGRICULTURAL TRADE[2]

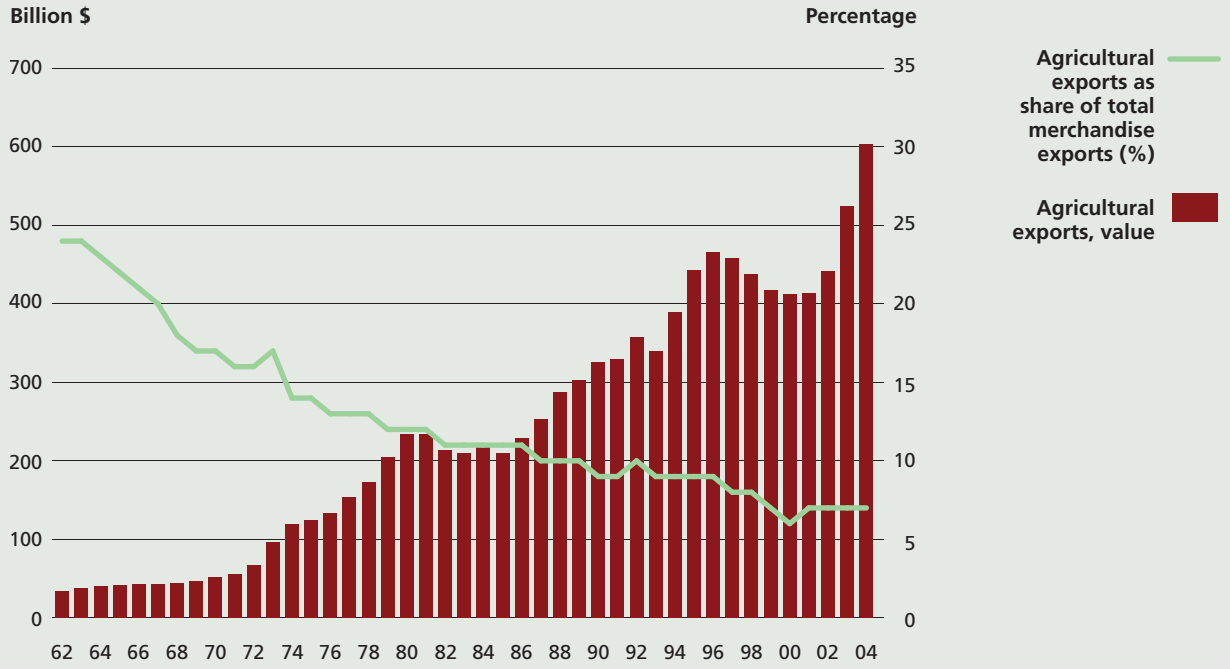
Trade

Since the early 1960s, the nominal value of agricultural exports has increased tenfold, while the share of agricultural trade in total merchandise trade has followed a long-term downward trend, falling from almost 25 percent to less than 10 percent in recent years (Figure 21).

Over this period, the net flow of agricultural commodities between developed and developing countries has reversed direction (Figure 22). In the early 1960s, developing countries had an overall agricultural trade surplus of almost US$7 billion per year. By the end of the 1980s, however, this surplus had disappeared. During most of the 1990s and early 2000s, developing countries were net importers of agricultural products. Without Brazil, the deficit of the rest of the developing world would have been considerably bigger; it

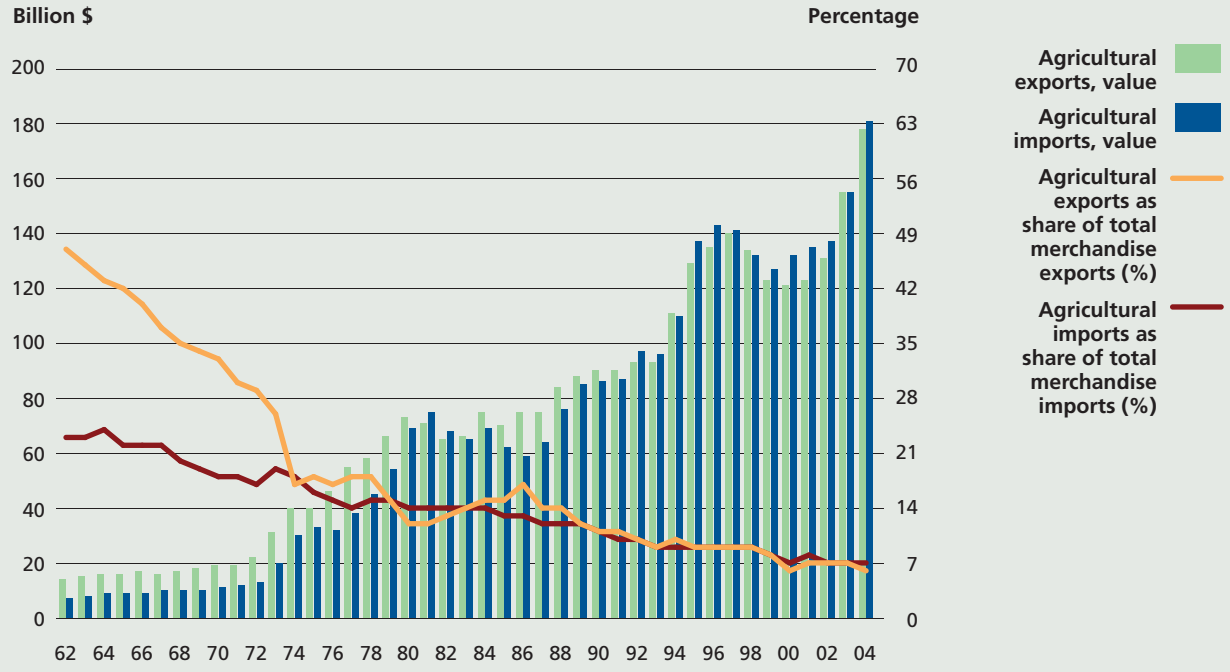
[2] This section is based on FAO, 2004d and FAO, 2006j.

FIGURE 21
Global agricultural exports



Source: FAO, 2006h.

FIGURE 22
Agricultural imports and exports in developing countries



Source: FAO, 2006h.

would have grown from US$20 billion in 2000 to US$27 billion in 2004 (FAO, 2006i).

The change has been even more pronounced for the least-developed countries, which over the same period have changed from being net exporters to significant net importers of agricultural commodities (Figure 23). By the end of the 1990s, imports by these countries were more than double their exports.

Cereal foodstuffs once dominated international agricultural trade. Now, however, the share of cereals in total agricultural imports has fallen below 50 percent in developing countries and below one-third in developed countries. While the share of cereal imports has declined, both developed and developing countries are importing greater quantities of higher-value and processed foods, particularly edible oils, livestock products and fruits and vegetables.

Prices

An analysis of agricultural commodity prices over the past 40 years reveals some striking features (Figure 24):

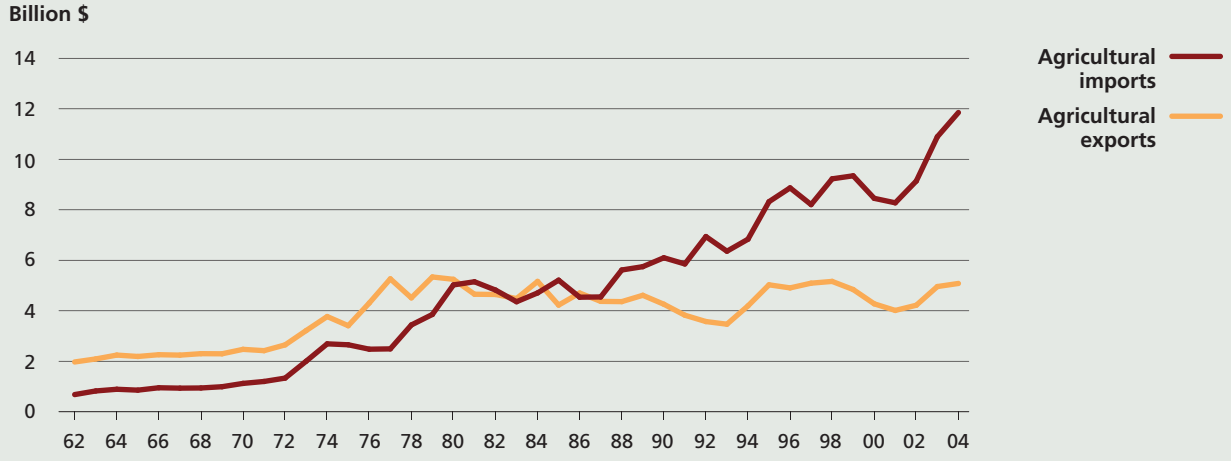
- Real prices of agricultural commodities, that is, prices relative to those of all manufactured goods, have declined significantly – almost 2 percent per year.
- Real prices have fluctuated considerably around the long-term downward trend.
- Both the fluctuations and the long-term decline have been less pronounced since the mid-1980s.
- Cereal and oilseed prices have increased recently, driven partly by rising demand for biofuels and by weather-related production shortfalls.

A number of factors have contributed to these trends. Trade policy reforms and improvements in transportation and logistics have helped to hold down prices of traded goods, including agricultural products. Technological advances have reduced costs and made it possible, at given prices, to expand production at a rate that has outstripped demand growth, despite rising population and income. Trade liberalization has permitted a wider range of countries to participate in world commodity markets, reducing the relative importance of the supply situation in any one country. Technological advances have reduced the vulnerability of some crops to climatic influences.

Production and export subsidies in some developed countries have also contributed to the downward trend of world prices for many agricultural products grown in temperate zones, reducing the export earnings of developing countries that export commodities such as cotton, sugar and rice.

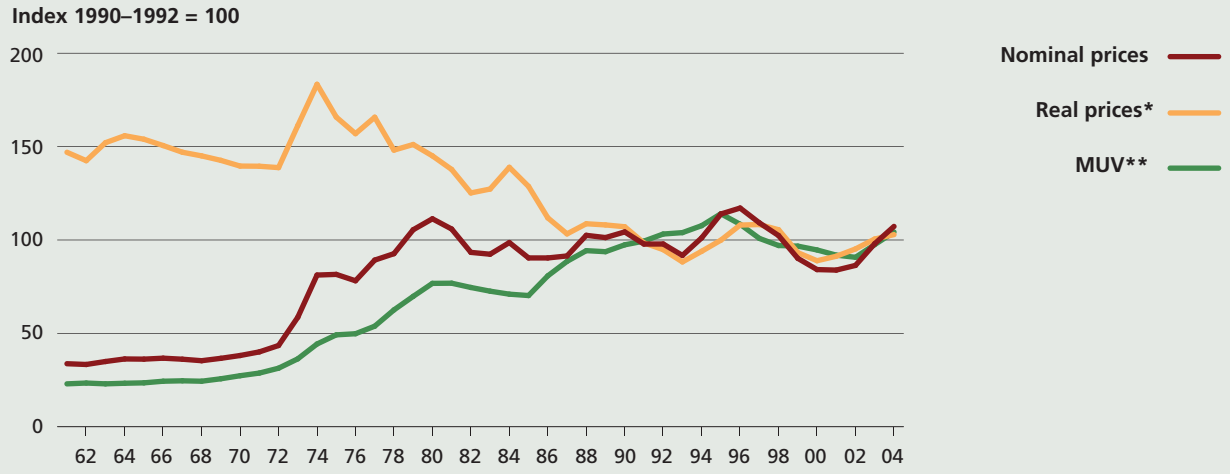
Even though real prices for all agricultural commodities have declined over the past

FIGURE 23
Agricultural trade balance of least-developed countries



Source: FAO, 2006h.

FIGURE 24
Agricultural commodity prices



* Real prices are deflated by export unit values of all merchandise exports.
** MUV is the manufactures export unit value (World Bank).

Source: FAO, 2004d.

40 years, the rate of decline has varied from one commodity to another. Prices of traditional commodities such as raw materials, tropical beverages, oil crops and cereals have experienced the largest variation and the steepest decline.

Trade diversification

Some developing countries have managed to take advantage of changing price and demand trends by shifting production and trade into the non-traditional higher-value sectors. It has mainly been the more advanced and prosperous developing countries that have managed to do this. Developing countries other than the least-developed countries have more than doubled the share of horticultural, meat and dairy products in their agricultural exports, while reducing the share of tropical beverages and raw materials in their agricultural exports from 55 percent in the early 1960s to around 30 percent in 1999–2001.

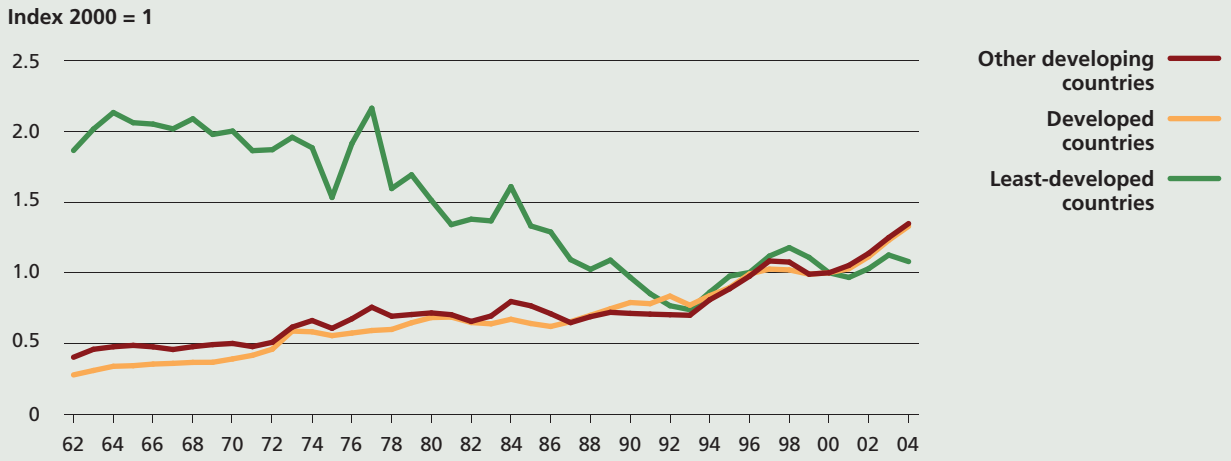
An analysis of FAOSTAT data (FAO, 2004e) found that trade in some non-traditional agricultural exports, including fruits, vegetables and selected speciality and processed products (excluding trade in bananas and citrus) was worth more than US$30 billion annually. Developing countries held a 56 percent share of world trade in non-traditional fruit and vegetables in 2001 and also accounted for two-thirds of trade in selected speciality products, such as chillies, ginger and garlic.

Across a broad range of these products, developing countries have been gaining market share at the expense of developed countries. This is especially the case of trade in vegetables and speciality products, in which developing countries have taken the lion's share of the substantial growth in global trade during the last decade.

The non-traditional agricultural export market is, however, dominated by just a handful of countries. Some of these, such as Argentina, Brazil, Chile, Costa Rica and Mexico are leading exporters of more than one product. Other countries are dominant in the market for only one product – for example, Kenya for green beans, Malaysia for minor tropical fruits, Thailand for minor fresh fruits and Zimbabwe for green peas.

A large number of countries have only a very limited participation in the market for non-traditional products. Least-developed countries account for only 0.5 percent of world fruit trade and 0.8 percent of world vegetable trade. On the other hand, they have increased their dependence on traditional export products such as raw materials and tropical beverages for their agricultural export earnings from 59 percent to 72 percent during the last 40 years.

FIGURE 25
Income terms of trade for agriculture



Source: FAO.

For these countries, export earnings have failed to increase, and rising import prices have further eroded their purchasing power. Real agricultural export earnings of least-developed countries have fallen by more than 30 percent over the last two decades, and by half over the last 40 years (Figure 25).

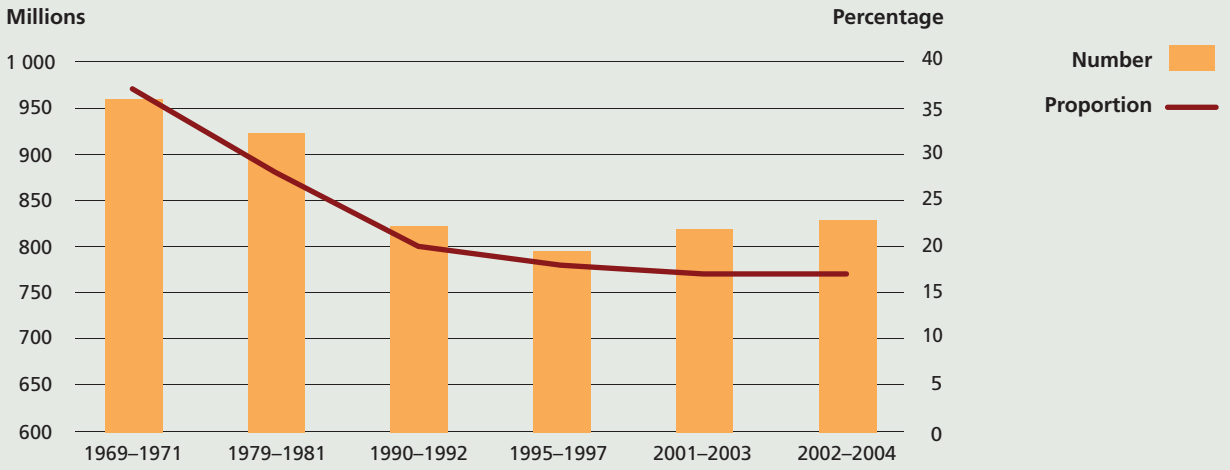
FOOD INSECURITY

The World Food Summit (WFS) established the target of reducing by half the **number** of undernourished people in the world by 2015, from a 1990–92 base period. The Millennium Development Goal target is to reduce by half the **proportion** of people who suffer from hunger, during the same time period (1990–2015).

The historical trend of increased per capita food production and consumption at the global level resulted in a reduction of the **proportion** of undernourished people in developing countries from 37 percent in 1969–71 to 17 percent in 2002–04 (Figure 26) (FAO, 2006k). Most of the reduction occurred in the first two decades of this period; indeed, from the 1990–92 base period, the proportion of undernourished fell by only 3 percentage points. The **number** of undernourished people in the developing world declined from 960 million in 1969–71 to 830 million in 2002–04, but almost all of the decline occurred before 1990–92, and, in fact, the number rose from 1995–97 to 2002–04 (FAO, 2006k).

In the period 1990–92 to 2001–03, the only significant progress towards reducing the number of undernourished people was concentrated in very few, but populous, countries and subregions: China, Southeast Asia and South America (Figure 27). In

FIGURE 26
Undernourishment in developing countries



Source: FAO, 2006h.

India, the prevalence of hunger declined by 5 percentage points, but the progress in terms of reducing the number of undernourished people was small because of population growth. At the same time, the number of undernourished increased in the rest of East Asia (excluding China) and even more in the rest of South Asia (excluding India) (FAO, 2006l).

The Near East, Central America, East Asia (excluding China) and Central Africa subregions experienced an increase in both the *number* and *proportion* of undernourished between 1990–92 and 2001–03 (FAO, 2006l).

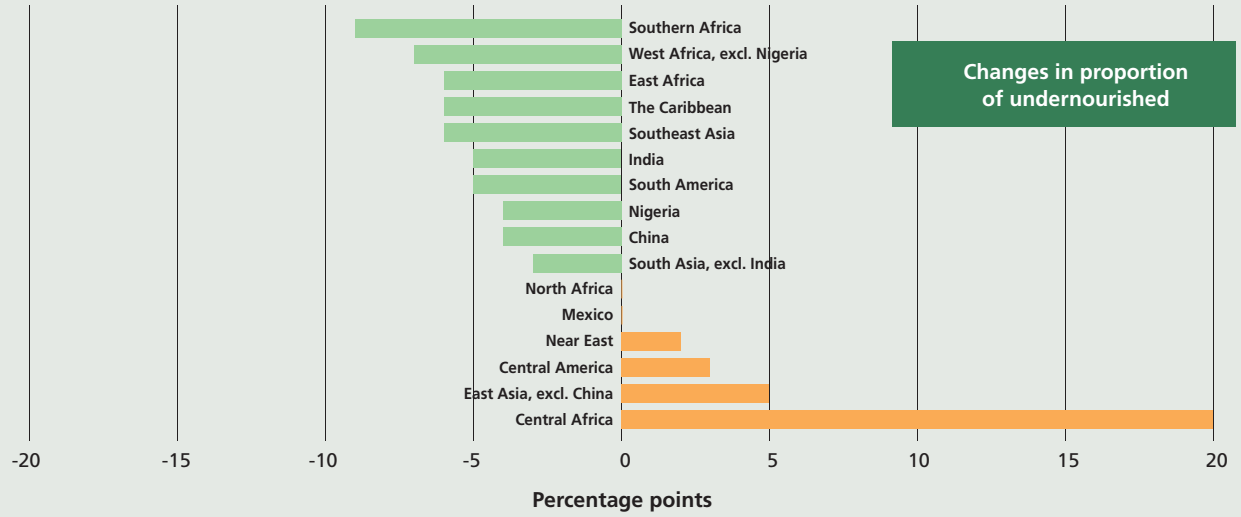
In sub-Saharan Africa, recent progress in reducing the prevalence of undernourishment is noteworthy. For the first time in several decades, the share of undernourished people in the region's population declined significantly – from 35 percent in 1990–92 to 32 percent in 2001–03, after having reached 36 percent in 1995–97. While Central Africa experienced a dramatic increase in both the number and prevalence of undernourishment, Southern Africa, West Africa, East Africa and Nigeria saw a decline in the prevalence of undernourishment (FAO, 2006l).

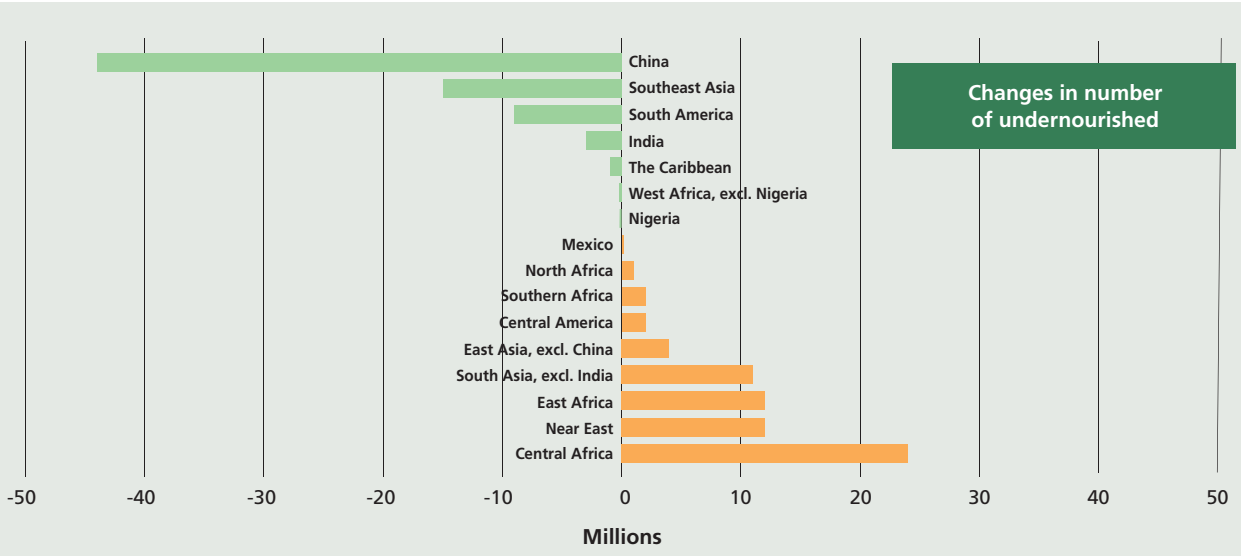
In addition to Ghana, which has already reached the WFS goal of halving the number of undernourished people, Angola, Benin, Chad, the Congo, Ethiopia, Guinea, Lesotho, Malawi, Mauritania, Mozambique and Namibia have also reduced the number of undernourished people. Although the explanations for success have varied among these countries, most seem to have combined good economic growth performances with a significant expansion of per capita agricultural and food production (FAO, 2006l).

The decline in the prevalence of undernourishment in the region is an encouraging development. Still, the task facing sub-Saharan Africa remains daunting. Sub-Saharan Africa accounts for 25 percent of the undernourished people in the developing world, and it has the highest proportion (one-third) of people suffering from chronic hunger. In 14 countries in the region, 35 percent or more of the population were chronically undernourished in 2001–03. The number of undernourished people increased from 169 million to 206 million from 1990–92 to 2001–03, and only 15 of the 39 countries for which data are reported reduced the number of undernourished (FAO, 2006l).

Efforts to reduce hunger in the region have been hampered by natural and human-induced disasters, including conflicts occurring during the 1990s and the spread of HIV/AIDS. Indeed, the increase in the number of undernourished people from the WFS baseline period was driven mainly by five war-torn countries: Burundi, the Democratic Republic of the Congo, Eritrea,

FIGURE 27
Changes in number and proportion of undernourished people in subregions from 1990–1992 to 2001–2003





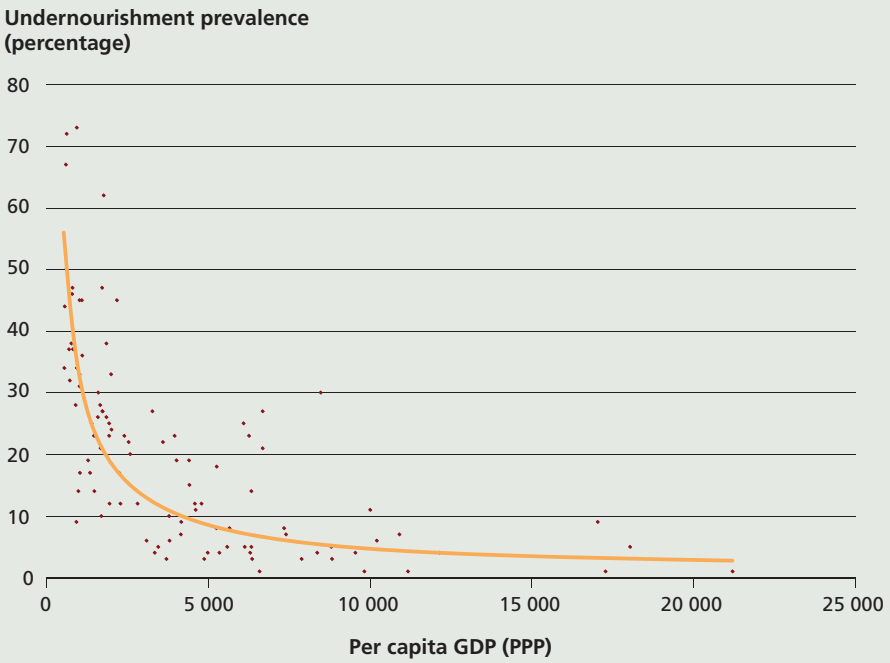
Source: FAO, 2006l.

Liberia and Sierra Leone. Particularly dramatic is the worsening of food insecurity in the Democratic Republic of the Congo, where the number of undernourished people tripled from 12 to 36 million, and the prevalence rose from 31 to 72 percent of the population (FAO, 2006l).

There is a clear negative correlation between countries' income per capita and prevalence of undernourishment in the population (Figure 28). Empirical evidence confirms that sustained economic growth leading to increased productivity and prosperity at the national level results in reduced hunger. But cross-country studies of developing countries suggest that economic growth alone, in the absence of specific measures to combat hunger, may leave large numbers of hungry people behind for a long time, particularly in rural areas (FAO, 2005c).

Numerous studies have provided evidence that the impact of economic growth on reducing hunger and poverty depends as much on the nature and distribution of the growth as on its scale and speed. Some 70 percent of the poor in developing

FIGURE 28
Per capita GDP and undernourishment (average 2001–2003)



Note: PPP is purchasing power parity dollars. Each data point represents a developing country.

Source: FAO; World Bank, 2006.

countries live in rural areas and depend on agriculture for their livelihoods, either directly or indirectly. In the poorest countries, agricultural growth is the driving force of the rural economy. Particularly in the most food-insecure countries, agriculture is crucial for income and employment generation. Agricultural growth is, therefore, a critical factor in hunger reduction.

Future trends for food security[3]

Historical trends towards increased food consumption per capita globally and particularly in developing countries will, according to FAO scenarios, continue in the near future. However, they will continue at a slower rate than in the past as more and more countries approach medium-high levels. The average of the developing countries may rise from the current 2 650 kcal per person per day to 3 070 kcal by 2050. By the middle of the twenty-first century, more than 90 percent of the world's population may be living in countries with per capita food consumption of more than 2 700 kcal per day, compared to 51 percent at present and only 4 percent three decades ago. As in the past, great improvements in China and a few other populous countries will continue to play a significant role in these developments.

However, not all countries are likely to achieve adequate food consumption levels. This is especially the case for countries that currently have high rates of undernourishment, high population growth rates, poor prospects for rapid economic growth and often meagre agricultural resources. Today, 32 countries are in this category, with an average undernourishment rate of 42 percent. The population of these poor countries is expected to increase from the current 580 million to 1.39 billion by 2050, and food consumption could, under fairly optimistic assumptions, increase from the current 2 000 kcal/person/day to 2 450 kcal in the next 30 years. This will not be sufficient for good nutrition in several of these countries, hence the conclusion that

[3] Based on FAO, 2006i.

reducing undernourishment may be a very slow process in these countries.

Despite the slow pace of progress in reducing the occurrence of undernourishment, FAO's projections do imply considerable overall improvements. In the developing countries the number of the well fed could increase from 3.9 billion in 1999–2001 (83 percent of the population) to 6.2 billion (93 percent) in 2030 and to 7.2 billion (96 percent) by 2050. The problem of undernourishment will tend to become smaller both in terms of absolute numbers affected and, even more, in terms of the proportion of the population that is undernourished.

OPPORTUNITIES AND CHALLENGES IN THE FUTURE

Population growth in the poorest countries

Global population growth has been the major driving force for growth in food demand and production. The population will continue to grow, but longer-term projections suggest that population growth may slow by the middle of this century. World population is expected to increase from the current 6.7 billion to 9.2 billion by 2050 (UN, 2007). From 2050, world population will be increasing by 30 million per year.

Almost all of this increase is expected to take place in developing countries, and especially in the group of the 50 least-developed countries. These countries may still have inadequate food consumption levels in 2050, and, therefore, there is significant scope for further increases in demand for food even when population growth slows down.

Slowing agricultural production growth[4]

Annual growth of world agricultural output is expected to fall to 1.5 percent over the next decades and further to 0.9 percent in the succeeding 20 years to 2050 (FAO, 2006i), compared with 2.3 percent per year since 1961.

All the major commodity sectors (except for the milk sector) are expected to take part in the deceleration of agricultural growth. The cereals sector has already been in such a downward trend for some time now, and is expected to continue to have the lowest growth rate of the major commodity sectors during the next 50 years.

Water

Agriculture accounts for 70 percent of all water use in the world and as much as 95 percent in many developing countries, almost all for irrigating crops (Millennium Ecosystem Assessment, 2005b). Per capita use of water has decreased from about 700 to 600 cubic metres per year since 1980 (Millennium Ecosystem Assessment, 2005b),

[4] Based on FAO, 2006i.

and water productivity in agriculture increased by at least 100 percent between 1961 and 2001 (FAO, 2003d). But total water use is still increasing and is expected to continue to increase because of population growth, urban expansion and increasing industrialization.

Today, more than 1.2 billion people live in areas of physical water scarcity (Comprehensive Assessment of Water Management in Agriculture, 2007), and by 2025 over 3 billion people are likely to experience water stress (UNDP, 2006). The gap between available water supply and water demand is increasing in many parts of the world, limiting future expansion of irrigation. In areas where water supply is already limited, water scarcity is likely to be the most serious constraint on agricultural growth and development, especially in drought-prone areas (Millennium Ecosystem Assessment, 2005b).

Bioenergy

Recent high petroleum prices are creating new markets for agricultural products that can be used as feedstock for the production of biofuels. The competitiveness of biofuels may be further enhanced if the savings of greenhouse gas emissions resulting from substituting ethanol for gasoline are to be monetized in the form of tradable carbon credits (Certified Emission Reductions of greenhouse gases) through the Clean Development Mechanism under the provisions of the Kyoto Protocol. If world agriculture were to become a major source of feedstock for the biofuel industry, this would have as yet unknown implications for food security and for the environment. Bioenergy is a new area that deserves increased attention and further analysis so that the implications of its development for food security and poverty alleviation can be understood.

Climate change

There are still large uncertainties as to when, how and where climate change will have an impact on agricultural production and food security, but it is generally agreed that agricultural impacts will be more adverse in tropical areas than in temperate areas (Stern, 2007; IPCC, 2007b, Parry *et al.,* 2004, 2005; Fischer *et al.,* 2005). Model-based scenarios predict slight to moderate reductions of potential crop yields (Stern, 2007). While the adverse impacts of climate change will affect the poor disproportionately, actual impacts will depend at least as much on socio-economic conditions as on the biophysical processes involved. Policies and investments supporting trade, sustainable agricultural practices and technological progress can help mitigate the effects of climate change on agriculture and food security while increasing the capacity of people and societies to adapt (FAO, 2006i).

Part III

STATISTICAL ANNEX


Part III

TABLE A1
Total and agricultural population (including forestry and fisheries)

Countries	Total population (Thousands)					Agricultural population (Thousands)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Afghanistan	15 069	13 913				10 939	9 778			
Albania	2 671	3 280	3 116	3 166	3 194	1 534	1 787	1 502	1 465	1 457
Algeria	18 747	25 014	30 252	31 800	32 339	6 684	6 514	7 260	7 375	7 406
American Samoa	33	47	58	62	63	16	20	20	20	20
Angola	7 056	9 352	12 399	13 625	14 078	5 392	6 969	8 912	9 680	9 962
Antigua and Barbuda	63	63	72	73	73	21	18	17	16	16
Argentina	28 098	32 527	37 073	38 428	38 871	3 790	4 075	3 753	3 629	3 585
Armenia			3 115	3 061	3 052			400	359	348
Australia	14 580	16 886	19 151	19 731	19 913	949	931	877	859	853
Austria	7 551	7 733	8 103	8 116	8 120	755	598	415	367	352
Azerbaijan			8 158	8 370	8 447			2 180	2 133	2 118
Bahamas	210	255	303	314	317	12	13	11	10	10
Bahrain	347	490	677	724	739	14	10	7	7	6
Bangladesh	85 034	109 422	137 952	146 736	149 664	61 751	71 290	76 810	77 387	77 454
Barbados	249	257	267	270	271	25	17	11	10	10
Belarus			10 034	9 895	9 852			1 327	1 162	1 113
Belgium	9 858	9 968	10 251	10 318	10 340	296	261	187	169	164
Belize	144	186	240	256	261	55	63	74	76	77
Benin	3 461	4 654	6 225	6 736	6 918	2 340	2 948	3 360	3 438	3 463
Bhutan	1 318	1 694	2 064	2 257	2 325	1 245	1 594	1 935	2 114	2 176
Bolivia	5 355	6 670	8 316	8 808	8 973	2 757	3 051	3 574	3 716	3 762
Bosnia and Herzegovina			3 963	4 161	4 186			205	168	156
Botswana	988	1 354	1 724	1 785	1 795	628	635	767	783	783
Brazil	121 624	148 787	171 795	178 470	180 654	44 009	34 496	28 285	26 471	25 869
Brunei Darussalam	193	257	334	358	366	10	5	3	2	2
Bulgaria	8 863	8 718	8 098	7 897	7 829	1 922	1 247	615	493	458
Burkina Faso	6 823	8 923	11 909	13 002	13 393	6 291	8 247	10 987	11 988	12 345
Burundi	4 134	5 604	6 283	6 825	7 068	3 838	5 136	5 677	6 135	6 341
Cambodia	6 656	9 748	13 147	14 144	14 482	5 041	7 193	9 215	9 747	9 922
Cameroon	8 754	11 663	15 113	16 018	16 296	5 928	7 387	7 958	7 867	7 807
Canada	24 512	27 695	30 766	31 510	31 744	1 743	1 032	786	728	710
Cape Verde	289	349	436	463	473	107	107	100	97	96
Central African Republic	2 308	2 946	3 713	3 865	3 912	1 954	2 360	2 698	2 708	2 705
Chad	4 507	5 822	7 862	8 598	8 854	3 961	4 842	5 914	6 222	6 319
Chile	11 148	13 101	15 223	15 805	15 996	2 349	2 472	2 417	2 375	2 359
China	1 004 204	1 160 914	1 282 320	1 311 709	1 320 892	742 341	833 139	853 602	851 028	849 417
Colombia	28 448	34 975	42 119	44 222	44 914	11 590	9 549	8 763	8 486	8 386
Comoros	387	527	705	768	790	312	408	519	555	568
Congo	1 805	2 495	3 446	3 724	3 818	1 043	1 210	1 398	1 420	1 425
Costa Rica	2 348	3 076	3 927	4 173	4 250	851	835	824	810	803
Côte d'Ivoire	8 433	12 503	15 826	16 631	16 897	5 474	7 449	7 786	7 635	7 571

TABLE A1 *(cont.)*

Countries	Total population (Thousands)					Agricultural population (Thousands)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Croatia			4 443	4 428	4 416			377	308	287
Cuba	9 711	10 624	11 201	11 300	11 328	2 604	2 216	1 832	1 717	1 679
Cyprus	612	682	783	802	808	159	94	67	60	58
Czech Republic			10 270	10 236	10 226			842	766	742
former Czechoslovakia	15 253	15 563				2 034	1 780			
Democratic People's Republic of Korea	17 201	19 958	22 266	22 664	22 776	7 695	7 569	6 705	6 334	6 206
Democratic Republic of the Congo	27 907	37 419	48 651	52 771	54 417	19 990	25 366	30 751	32 602	33 355
Denmark	5 122	5 141	5 322	5 364	5 375	362	285	201	180	174
Dominica	74	72	78	79	79	25	20	18	18	17
Dominican Republic	5 698	7 059	8 353	8 745	8 872	1 953	1 841	1 479	1 372	1 337
Ecuador	7 962	10 264	12 420	13 003	13 192	3 347	3 605	3 418	3 309	3 270
Egypt	43 935	55 762	67 799	71 931	73 390	26 541	24 760	25 013	24 977	24 954
El Salvador	4 580	5 114	6 209	6 515	6 614	2 216	2 083	2 048	2 014	1 999
Equatorial Guinea	221	354	456	494	507	173	265	321	341	348
Eritrea			3 714	4 141	4 297			2 881	3 173	3 278
Estonia			1 367	1 323	1 308			154	139	134
Ethiopia			65 597	70 678	72 420			54 039	57 319	58 408
former People's Democratic Republic of Ethiopia	38 136	51 971				33 895	44 601			
Fiji	634	725	814	839	847	301	328	325	323	322
Finland	4 781	4 988	5 177	5 207	5 215	627	453	308	273	262
France	53 888	56 736	59 304	60 144	60 434	4 496	3 118	1 989	1 736	1 659
French Polynesia	151	195	233	244	248	74	83	80	79	78
Gabon	696	953	1 257	1 329	1 351	455	491	475	452	444
Gambia	653	936	1 312	1 426	1 462	551	767	1 037	1 113	1 137
Georgia			5 258	5 126	5 074			1 048	940	905
Germany	78 276	79 439	82 284	82 476	82 526	5 405	3 196	2 069	1 804	1 724
Ghana	11 066	15 283	19 597	20 922	21 377	6 719	8 958	11 009	11 601	11 801
Greece	9 635	10 161	10 895	10 976	10 977	2 510	1 906	1 465	1 331	1 285
Guatemala	6 822	8 752	11 424	12 347	12 661	3 946	4 909	5 706	5 935	6 006
Guinea	4 686	6 131	8 114	8 480	8 620	4 256	5 346	6 804	7 014	7 095
Guinea-Bissau	792	1 017	1 368	1 493	1 538	693	868	1 133	1 225	1 257
Guyana	760	732	759	765	767	203	158	134	127	125
Haiti	5 455	6 910	8 006	8 326	8 437	3 867	4 674	4 986	5 050	5 070
Honduras	3 568	4 869	6 456	6 941	7 099	2 150	2 186	2 239	2 216	2 204
Hungary	10 702	10 367	10 012	9 877	9 831	2 206	1 756	1 205	1 070	1 028
Iceland	228	255	282	290	292	24	28	23	22	22
India	688 973	846 443	1 016 831	1 065 462	1 081 229	441 263	493 279	545 599	556 592	559 656
Indonesia	150 133	182 106	211 552	219 883	222 611	80 775	92 439	93 305	92 596	92 276
Iran (Islamic Republic of)	39 403	56 664	66 450	68 920	69 788	15 342	18 219	17 589	17 253	17 157
Iraq	12 969	17 357				3 737	2 822			

TABLE A1 *(cont.)*

Countries	Total population (Thousands)					Agricultural population (Thousands)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Ireland	3 400	3 517	3 819	3 956	3 999	635	504	388	362	354
Israel	3 763	4 523	6 042	6 433	6 560	232	187	163	153	150
Italy	56 420	56 729	57 529	57 423	57 346	7 153	4 880	3 061	2 635	2 505
Jamaica	2 135	2 370	2 580	2 651	2 676	663	585	532	517	512
Japan	116 797	123 527	127 024	127 654	127 800	12 452	8 596	4 925	4 132	3 895
Jordan	2 229	3 264	5 036	5 473	5 614	407	490	573	570	567
Kazakhstan			15 655	15 433	15 403			3 077	2 839	2 773
Kenya	16 377	23 585	30 535	31 987	32 420	13 473	18 756	23 048	23 706	23 873
Kuwait	1 373	2 120	2 239	2 521	2 595	25	25	25	27	27
Kyrgyzstan			4 920	5 138	5 208			1 263	1 231	1 220
Lao People's Democratic Republic	3 211	4 133	5 279	5 657	5 787	2 554	3 229	4 037	4 297	4 385
Latvia			2 372	2 307	2 286			283	254	245
Lebanon	2 673	2 721	3 478	3 653	3 708	380	200	129	110	105
Lesotho	1 277	1 570	1 783	1 802	1 800	531	648	699	696	691
Liberia	1 871	2 134	2 937	3 367	3 487	1 433	1 546	1 986	2 224	2 284
Libyan Arab Jamahiriya	3 047	4 305	5 238	5 551	5 659	754	481	313	275	263
Lithuania			3 499	3 444	3 422			517	451	430
Luxembourg	364	378	435	453	459	20	14	10	9	8
Madagascar	9 051	11 960	15 973	17 404	17 901	7 379	9 342	11 857	12 693	12 974
Malawi	6 178	9 414	11 363	12 105	12 337	5 136	7 725	8 821	9 215	9 327
Malaysia	13 771	17 851	22 995	24 425	24 876	5 390	4 667	4 067	3 825	3 739
Mali	7 047	9 049	11 909	13 007	13 409	6 270	7 759	9 644	10 312	10 549
Malta	324	360	389	394	396	26	10	6	6	5
Mauritania	1 609	2 031	2 646	2 893	2 980	1 148	1 132	1 400	1 508	1 546
Mauritius	966	1 057	1 186	1 221	1 233	257	175	137	127	124
Mexico	67 559	83 229	98 928	103 457	104 931	26 411	25 271	23 218	22 442	22 164
Moldova			4 284	4 267	4 263			977	868	835
Mongolia	1 663	2 213	2 501	2 594	2 630	662	707	607	576	567
Morocco	19 393	24 559	29 111	30 566	31 064	10 932	11 096	10 630	10 465	10 408
Mozambique	12 082	13 519	17 861	18 863	19 182	9 736	10 727	13 737	14 350	14 538
Myanmar	33 703	40 511	47 541	49 485	50 101	25 553	29 670	33 381	34 278	34 543
Namibia	1 018	1 407	1 892	1 987	2 011	652	802	927	926	921
Nepal	14 883	18 628	23 520	25 164	25 725	13 956	17 424	21 878	23 366	23 872
Netherlands	14 147	14 952	15 898	16 149	16 227	788	680	536	497	485
New Caledonia	143	171	215	228	233	70	74	79	79	79
New Zealand	3 117	3 364	3 784	3 875	3 904	341	339	332	327	325
Nicaragua	2 921	3 828	5 073	5 466	5 597	1 192	1 135	1 057	1 018	1 003
Niger	5 588	7 654	10 748	11 972	12 415	5 101	6 871	9 430	10 425	10 782
Nigeria	64 311	86 038	114 750	124 009	127 117	34 787	36 999	38 207	37 977	37 827
Norway	4 086	4 242	4 473	4 533	4 552	376	296	227	210	205
Occupied Palestinian Territory	1 478	2 156	3 192	3 557	3 685	272	327	374	381	384

TABLE A1 *(cont.)*

Countries	Total population (Thousands)					Agricultural population (Thousands)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Oman	1 189	1 847	2 610	2 851	2 935	596	830	964	979	983
Pakistan	80 846	110 852	142 650	153 578	157 315	53 664	61 987	72 655	75 883	76 917
Panama	1 949	2 411	2 950	3 120	3 177	639	709	683	670	665
Papua New Guinea	3 241	4 116	5 334	5 711	5 836	2 748	3 361	4 119	4 324	4 387
Paraguay	3 114	4 218	5 471	5 878	6 018	1 596	1 909	2 208	2 288	2 314
Peru	17 324	21 750	25 950	27 167	27 567	6 949	7 691	7 817	7 785	7 767
Philippines	48 085	61 110	75 708	79 999	81 408	25 068	27 856	29 786	30 034	30 078
Poland	35 578	38 107	38 668	38 587	38 551	9 466	9 193	7 333	6 785	6 609
Portugal	9 758	9 902	10 015	10 062	10 072	2 782	1 978	1 435	1 304	1 262
Qatar	231	466	581	610	619	7	12	8	6	6
Republic of Korea	38 126	42 875	46 830	47 700	47 951	12 848	7 033	4 113	3 455	3 255
Romania	22 192	23 184	22 476	22 334	22 280	7 239	5 139	3 120	2 671	2 534
Russian Federation			145 586	143 246	142 397			15 277	13 890	13 453
former Union of Soviet Socialist Republics	265 422	289 546				60 653	56 957			
Rwanda	5 155	6 702	7 666	8 387	8 481	4 782	6 147	6 959	7 574	7 644
Saint Kitts and Nevis	44	41	42	42	42	15	12	10	9	9
Saint Lucia	113	131	146	149	150	38	37	34	33	33
Saint Vincent and the Grenadines	100	110	118	120	121	34	31	28	27	27
Samoa	155	160	173	178	180	76	68	60	57	56
Sao Tome and Principe	94	116	149	161	165	70	81	96	100	102
Saudi Arabia	9 618	16 524	22 148	24 217	24 919	4 161	3 218	2 180	1 925	1 844
Senegal	5 539	7 345	9 395	10 095	10 339	4 468	5 642	6 929	7 345	7 488
Serbia and Montenegro			10 556	10 527	10 519			2 107	1 847	1 768
former Socialist Federal Republic of Yugoslavia	21 431	23 089				6 995	4 809			
Seychelles	64	71	79	81	82	54	58	62	63	63
Sierra Leone	3 239	4 044	4 427	4 971	5 168	2 263	2 724	2 753	3 011	3 103
Singapore	2 417	3 019	4 013	4 253	4 315	38	12	6	5	5
Slovakia			5 391	5 402	5 407	0	0	487	450	438
Slovenia			1 990	1 984	1 982	0	0	38	27	25
Solomon Islands	229	319	437	477	491	182	244	320	344	352
Somalia	6 430	7 147				5 036	5 381			
South Africa	29 151	36 857	43 976	45 026	45 214	7 310	7 227	6 251	5 789	5 621
Spain	37 521	39 297	40 744	41 060	41 128	6 933	4 650	2 982	2 593	2 472
Sri Lanka	14 543	16 824	18 595	19 065	19 218	7 628	8 274	8 607	8 656	8 668
Sudan	19 400	24 946	31 443	33 610	34 333	14 029	17 287	19 194	19 605	19 708
Suriname	356	401	425	436	439	84	85	81	80	80
Swaziland	597	846	1 043	1 077	1 083	302	336	355	347	343
Sweden	8 308	8 560	8 857	8 876	8 886	573	424	313	284	275
Switzerland	6 324	6 835	7 173	7 169	7 164	603	579	469	434	422
Syrian Arab Republic	8 965	12 715	16 562	17 800	18 223	3 536	4 252	4 632	4 737	4 771
Tajikistan			6 087	6 245	6 298			2 055	1 985	1 961

TABLE A1 *(cont.)*

Countries	Total population (Thousands)					Agricultural population (Thousands)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Thailand	46 328	54 385	60 929	62 833	63 465	29 839	30 926	29 833	29 269	29 060
The former Yugoslav Republic of Macedonia			2 024	2 056	2 066			260	224	213
Togo	2 523	3 453	4 558	4 909	5 017	1 736	2 260	2 721	2 842	2 873
Tonga	97	99	101	104	105	47	42	35	33	33
Trinidad and Tobago	1 082	1 216	1 289	1 303	1 307	121	134	112	106	103
Tunisia	6 470	8 205	9 518	9 832	9 937	2 513	2 334	2 344	2 311	2 299
Turkey	46 144	57 589	68 279	71 325	72 320	20 392	21 490	21 008	20 630	20 484
Turkmenistan			4 642	4 867	4 940			1 548	1 567	1 572
Uganda	12 468	17 358	23 500	25 827	26 699	10 757	14 502	18 567	20 003	20 533
Ukraine			49 692	48 523	48 151			7 914	7 019	6 748
United Arab Emirates	1 015	2 035	2 820	2 995	3 051	49	155	137	126	122
United Kingdom	55 732	56 974	58 906	59 470	59 648	1 453	1 232	1 049	1 001	986
United Republic of Tanzania	18 849	26 087	34 832	36 977	37 671	15 854	21 502	27 240	28 384	28 729
United States of America	231 440	255 750	285 001	294 043	297 043	8 556	7 662	6 305	5 944	5 828
Uruguay	2 914	3 106	3 342	3 415	3 439	431	392	374	369	368
Uzbekistan			24 909	26 093	26 479			6 888	6 697	6 626
Vanuatu	117	150	197	212	217	58	65	72	74	74
Venezuela (Bolivarian Republic of)	15 082	19 500	24 276	25 699	26 170	2 592	2 713	2 310	2 174	2 129
Viet Nam	53 023	66 073	78 147	81 377	82 481	38 798	47 029	52 617	53 797	54 185
Yemen	8 146	11 967	18 029	20 010	20 733	5 776	7 189	9 087	9 482	9 610
Zambia	5 980	8 200	10 411	10 812	10 924	4 543	6 094	7 211	7 302	7 313
Zimbabwe	7 234	10 459	12 639	12 891	12 932	5 236	7 124	7 925	7 844	7 787
World	**4 435 172**	**5 263 049**	**6 070 378**	**6 301 463**	**6 377 646**	**2 219 655**	**2 442 413**	**2 573 143**	**2 594 704**	**2 600 301**

TABLE A2
Land use

Countries	Land area (Thousand ha)	Arable land (Thousand ha)			Permanent crops (Thousand ha)			Pastures (Thousand ha)		
	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
Afghanistan	65 209	7 910	7 910		139	130		30 000	30 000	
Albania	2 740	585	579	578	117	125	121	416	417	445
Algeria	238 174	6 875	7 081	7 662	634	554	530	36 321	31 041	31 829
American Samoa	20	2	2	2	2	2	3	0	0	0
Angola	124 670	2 900	2 900	3 000	500	500	300	54 000	54 004	54 000
Antigua and Barbuda	44	8	8	8	1	2	2	3	4	4
Argentina	273 669	26 000	26 400	27 800	981	1 020	1 000	101 040	99 968	99 867
Armenia	2 820			495			65			835
Australia	768 230	44 031	47 900	50 304	155	181	296	438 740	416 400	404 900
Austria	8 245	1 536	1 426	1 399	99	79	71	2 040	1 995	1 920
Azerbaijan	8 260			1 760			240			2 562
Bahamas	1 001	7	8	7	2	2	4	2	2	2
Bahrain	71	2	2	2	4	2	4	4	4	4
Bangladesh	13 017	8 892	9 137	8 084	266	300	400	600	600	600
Barbados	43	16	16	16	1	1	1	2	2	2
Belarus	20 748			6 133			124			2 995
Belgium	3 023			862			21			507
Belize	2 281	45	52	64	7	25	35	44	49	50
Benin	11 062	1 500	1 615	2 380	85	105	265	442	550	550
Bhutan	4 700	104	113	140	18	19	20	265	300	415
Bolivia	108 438	1 943	2 100	2 928	119	155	203	31 500	33 200	33 831
Bosnia and Herzegovina	5 120			1 000			100			1 030
Botswana	56 673	402	418	377	2	3	3	25 600	25 600	25 600
Brazil	845 942	45 000	50 681	57 640	7 864	6 727	7 560	171 414	184 200	196 206
Brunei Darussalam	527	3	3	9	5	4	4	6	6	6
Bulgaria	11 063	3 827	3 856	3 526	350	300	252	2 004	2 003	1 804
Burkina Faso	27 360	2 745	3 520	4 040	40	55	60	6 000	6 000	6 000
Burundi	2 568	930	930	960	320	360	360	900	835	950
Cambodia	17 652	2 000	3 695	3 700	70	100	107	580	1 554	1 500
Cameroon	46 540	5 910	5 940	5 960	1 020	1 230	1 200	2 000	2 000	2 000
Canada	909 351	44 723	45 504	45 810	5 752	6 361	6 368	15 921	15 903	15 435
Cape Verde	403	38	41	44	2	2	3	25	25	25
Central African Republic	62 298	1 870	1 920	1 930	75	86	94	3 000	3 000	3 125
Chad	125 920	3 137	3 273	3 520	13	27	30	45 000	45 000	45 000
Chile	74 880	3 836	2 802	1 979	214	247	318	12 800	12 850	12 935
China	932 742	96 924	123 678	137 124	3 295	7 719	11 533	334 001	400 001	400 001
Colombia	103 870	3 712	3 305	2 818	1 480	1 695	1 727	40 100	40 083	40 920
Comoros	223	75	78	80	20	35	50	15	15	15
Congo	226 705	488	479	490	37	42	50	10 000	10 000	10 000
Costa Rica	5 106	283	260	225	223	250	300	2 010	2 330	2 340

TABLE A2 *(cont.)*

Countries	Land area (Thousand ha)	Arable land (Thousand ha)			Permanent crops (Thousand ha)			Pastures (Thousand ha)		
	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
Côte d'Ivoire	31 800	1 955	2 430	3 100	2 300	3 500	3 700	13 000	13 000	13 000
Croatia	5 592			1 458			128			1 570
Cuba	10 982	2 630	3 031	3 224	700	810	780	2 607	2 900	2 550
Cyprus	924	103	106	98	65	51	42	5	5	4
Czech Republic	7 727			3 082			236			961
former Czechoslovakia		5 035	4 964		134	131		1 682	1 641	
Democratic People's Republic of Korea	12 041	2 285	2 288	2 600	180	180	200	50	50	50
Democratic Republic of the Congo	34 150	6 620	6 670	6 700	980	1 190	1 100	15 000	15 000	15 000
Denmark	4 243	2 639	2 561	2 281	14	10	8	252	217	358
Dominica	75	7	5	5	10	11	14	2	2	2
Dominican Republic	4 838	1 070	1 050	1 096	350	450	500	2 092	2 090	2 100
Ecuador	27 684	1 542	1 604	1 616	920	1 321	1 363	4 016	4 921	5 087
Egypt	99 545	2 286	2 284	2 801	159	364	490	0	0	0
El Salvador	2 072	558	550	640	242	260	250	610	640	794
Equatorial Guinea	2 805	130	130	130	100	100	100	104	104	104
Eritrea	10 100			560			3			6 967
Estonia	4 239			843			12			131
Ethiopia	100 000			10 000			695			20 000
former People's Democratic Republic of Ethiopia		13 000	10 750		715	662		45 400	44 900	
Fiji	1 827	90	160	200	80	80	85	120	170	175
Finland	30 459	2 369	2 269	2 183	3	6	9	164	122	26
France	55 010	17 472	17 999	18 440	1 400	1 191	1 142	12 850	11 380	10 124
French Polynesia	366	2	2	3	22	21	20	20	20	20
Gabon	25 767	290	295	325	162	162	170	4 700	4 700	4 665
Gambia	1 000	155	182	285	4	5	5	400	450	459
Georgia	6 949			793			269			1 938
Germany	34 895	12 030	11 971	11 804	500	443	216	5 989	5 618	5 048
Ghana	22 754	1 900	2 700	3 950	1 700	1 500	2 150	8 400	8 405	8 350
Greece	12 890	2 903	2 899	2 741	1 022	1 068	1 113	5 255	5 255	4 675
Guatemala	10 843	1 270	1 300	1 395	480	485	570	1 300	2 500	2 602
Guinea	24 572	702	728	975	440	500	625	10 700	10 788	10 700
Guinea-Bissau	2 812	255	300	300	48	117	248	1 080	1 080	1 080
Guyana	19 685	480	480	480	15	22	30	1 220	1 230	1 230
Haiti	2 756	780	780	780	320	320	320	500	497	490
Honduras	11 189	1 484	1 462	1 068	273	358	359	1 500	1 500	1 508
Hungary	9 211	5 027	5 054	4 602	306	234	201	1 294	1 186	1 051

TABLE A2 *(cont.)*

Countries	Land area (Thousand ha)	Arable land (Thousand ha)			Permanent crops (Thousand ha)			Pastures (Thousand ha)		
	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
Iceland	10 025	8	7	7				2 274	2 274	2 274
India	297 319	162 955	162 788	160 555	5 300	6 650	9 200	12 100	11 602	11 040
Indonesia	181 157	18 000	20 253	20 500	8 000	11 720	13 100	12 000	13 110	11 177
Iran (Islamic Republic of)	163 620	12 981	15 190	14 324	732	1 310	2 002	44 000	44 000	44 000
Iraq	43 737	5 250	5 300		189	290		4 000	4 000	
Ireland	6 889	1 108	1 041	1 077	2	3	2	4 617	4 605	3 333
Israel	2 171	325	343	338	88	88	86	120	148	142
Italy	29 411	9 483	9 012	8 479	2 953	2 960	2 805	5 126	4 868	4 353
Jamaica	1 083	135	119	174	105	100	110	257	257	229
Japan	36 450	4 874	4 768	4 474	587	475	356	600	450	428
Jordan	8 824	299	290	242	38	90	157	790	791	791
Kazakhstan	269 970			21 535			136			185 098
Kenya	56 914	3 800	4 200	4 500	480	500	560	21 300	21 300	21 300
Kuwait	1 782	1	4	10	0	1	2	134	136	136
Kyrgyzstan	19 180			1 335			55			9 291
Lao People's Democratic Republic	23 080	780	799	877	26	61	81	800	800	878
Latvia	6 205			1 845			29			611
Lebanon	1 023	210	183	190	91	122	142	10	12	16
Lesotho	3 035	292	317	330	4	4	4	2 000	2 000	2 000
Liberia	9 632	371	400	380	205	215	215	2 000	1 993	2 000
Libyan Arab Jamahiriya	175 954	1 753	1 805	1 815	327	350	335	13 000	13 300	13 300
Lithuania	6 268			2 933			59			497
Luxembourg	259			62			1			65
Madagascar	58 154	2 540	2 720	2 900	500	605	600	24 000	24 000	24 000
Malawi	9 408	1 518	1 815	2 100	82	115	140	1 840	1 840	1 850
Malaysia	32 855	1 000	1 700	1 820	3 800	5 248	5 785	259	276	285
Mali	122 019	2 010	2 053	4 634	40	40	40	30 000	30 000	30 000
Malta	32	12	12	8	1	1	1			
Mauritania	102 522	210	400	488	4	6	12	39 250	39 250	39 250
Mauritius	203	100	100	100	7	6	6	7	7	7
Mexico	190 869	23 000	24 000	24 800	1 530	1 900	2 500	74 499	77 500	80 000
Moldova	3 288			1 821			335			388
Mongolia	156 650	1 182	1 370	1 174		1	2	123 405	124 285	129 294
Morocco	44 630	7 530	8 707	8 767	500	736	885	20 900	20 900	21 000
Mozambique	78 409	2 870	3 450	3 900	230	230	235	44 000	44 000	44 000
Myanmar	65 755	9 573	9 567	9 909	449	502	589	363	359	314
Namibia	82 329	655	660	816	2	2	4	38 000	38 000	38 000
Nepal	14 300	2 270	2 287	2 324	29	66	105	1 890	1 800	1 757
Netherlands	3 388	790	879	910	32	30	34	1 198	1 097	1 012
New Caledonia	1 828	7	9	6	8	6	4	250	217	234
New Zealand	26 799	2 616	2 511	1 500	914	1 354	1 841	14 156	13 490	13 863

TABLE A2 *(cont.)*

Countries	Land area (Thousand ha)	Arable land (Thousand ha)			Permanent crops (Thousand ha)			Pastures (Thousand ha)		
	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
Nicaragua	12 140	1 070	1 300	1 917	175	195	234	4 815	4 815	4 815
Niger	126 670	10 212	11 036	14 483	8	11	17	20 500	22 000	23 000
Nigeria	91 077	27 850	29 539	28 200	2 535	2 535	2 650	40 000	40 000	39 200
Norway	30 625	817	864	883				119	112	157
Occupied Palestinian Territory	602	104	111	111	113	115	120	158	151	150
Oman	30 950	23	35	38	28	45	42	1 000	1 000	1 000
Pakistan	77 088	19 994	20 484	21 302	306	456	658	5 000	5 000	5 000
Panama	7 443	435	499	540	120	155	148	1 300	1 470	1 500
Papua New Guinea	45 286	167	192	205	495	580	650	110	135	175
Paraguay	39 730	1 620	2 110	2 850	115	89	88	15 800	21 100	21 700
Peru	128 000	3 220	3 500	3 700	330	420	585	15 129	17 916	16 900
Philippines	29 817	5 228	5 480	5 650	4 400	4 400	5 000	997	1 260	1 500
Poland	30 436	14 621	14 388	13 993	340	345	337	4 046	4 060	4 083
Portugal	9 150	2 423	2 344	1 800	718	781	715	838	838	1 437
Qatar	1 100	4	10	18	1	1	3	50	50	50
Republic of Korea	9 873	2 060	1 953	1 718	136	156	200	51	70	55
Romania	22 971	9 834	9 450	9 381	663	591	527	4 467	4 728	4 949
Russian Federation	1 638 134			124 374			1 864			90 924
former Union of Soviet Socialist Republics		226 417	224 400		5 100	4 520		321 800	327 300	
Rwanda	2 467	760	880	900	255	305	250	700	694	520
Saint Kitts and Nevis	36	8	8	7	6	2	1	1	2	2
Saint Lucia	61	5	5	4	12	13	14	3	3	2
Saint Vincent and the Grenadines	39	5	5	7	5	7	7	2	2	2
Samoa	283	55	55	59	67	67	68	1	1	2
Sao Tome and Principe	96	1	2	6	35	39	45	1	1	1
Saudi Arabia	214 969	1 890	3 390	3 592	72	91	193	85 000	120 000	170 000
Senegal	19 253	2 341	2 325	2 355	9	25	45	5 700	5 744	5 650
Serbia and Montenegro	10 200			3 406			330			1 851
former Socialist Federal Republic of Yugoslavia		7 153	7 020		731	718		6 401	6 346	
Seychelles	46	1	1	1	4	5	6			
Sierra Leone	7 162	450	486	490	49	54	60	2 204	2 204	2 200
Singapore	67	2	1	1	6	1	1			
Slovakia	4 808			1 450			126			865
Slovenia	2 014			173			31			314

TABLE A2 *(cont.)*

Countries	Land area (Thousand ha)	Arable land (Thousand ha)			Permanent crops (Thousand ha)			Pastures (Thousand ha)		
	2000	1980	1990	2000	1980	1990	2000	1980	1990	2000
Solomon Islands	2 799	12	17	18	42	52	56	39	39	40
Somalia	62 734	984	1 022		16	20		43 000	43 000	
South Africa	121 447	12 440	13 440	14 753	814	860	959	81 420	82 500	83 928
Spain	49 900	15 558	15 335	13 400	4 941	4 837	4 904	10 739	10 300	11 462
Sri Lanka	6 463	850	875	895	1 030	1 025	1 015	439	439	440
Sudan	237 600	12 360	13 000	16 233	100	235	420	98 000	110 000	117 180
Suriname	15 600	40	57	57	9	11	10	20	20	21
Swaziland	1 720	183	180	178	6	12	13	1 102	1 076	1 200
Sweden	41 033	2 979	2 845	2 706	4	4	3	725	568	447
Switzerland	4 000	391	391	413	20	21	24	1 609	1 609	1 095
Syrian Arab Republic	18 378	5 230	4 885	4 542	454	741	810	8 378	7 869	8 359
Tajikistan	13 996			930			128			3 254
Thailand	51 089	16 515	17 494	15 865	1 783	3 109	3 380	640	780	800
The former Yugoslav Republic of Macedonia	2 543			555			44			636
Togo	5 439	1 950	2 100	2 510	85	90	120	1 000	1 000	1 000
Tonga	72	16	16	15	14	12	11	4	4	4
Trinidad and Tobago	513	70	74	75	46	46	47	11	11	11
Tunisia	15 536	3 191	2 909	2 864	1 510	1 942	2 126	3 999	3 793	4 561
Turkey	76 963	25 354	24 647	23 826	3 125	3 030	2 553	10 100	12 000	12 378
Turkmenistan	46 993			1 850			65			30 700
Uganda	19 710	4 080	5 000	5 060	1 600	1 850	2 100	5 000	5 112	5 112
Ukraine	57 935			32 564			932			7 910
United Arab Emirates	8 360	16	35	60	7	20	187	200	230	305
United Kingdom	24 193	6 918	6 620	5 876	78	66	52	11 473	11 517	11 036
United Republic of Tanzania	88 359	3 100	3 500	4 000	900	900	1 000	43 000	43 000	43 000
United States of America	915 896	188 755	185 742	176 018	1 869	2 034	2 050	237 539	239 172	234 000
Uruguay	17 502	1 403	1 260	1 373	46	45	42	13 632	13 520	13 543
Uzbekistan	42 540			4 475			350			22 800
Vanuatu	1 219	18	20	20	85	85	85	25	35	42
Venezuela (Bolivarian Republic of)	88 205	2 957	2 832	2 595	713	778	810	17 350	18 250	18 240
Viet Nam	32 549	5 940	5 339	6 200	630	1 045	1 938	288	342	642
Yemen	52 797	1 366	1 523	1 545	97	103	124	16 065	16 065	16 065
Zambia	74 339	5 094	5 249	5 260	14	19	27	30 000	30 000	30 000
Zimbabwe	38 685	2 505	2 890	3 220	100	120	130	17 100	17 163	17 200
World	**13 004 202**	**1 345 989**	**1 395 973**	**1 397 656**	**102 020**	**119 883**	**135 821**	**3 244 404**	**3 368 403**	**3 442 078**

TABLE A3
Water use and irrigated land

Countries	Share in total water use (Percentage)			Irrigated land (Thousand ha)				
	Agricultural	Industrial	Domestic					
	2000	2000	2000	1979–1981	1989–1991	1999–2001	2002	2003
Afghanistan				2 505	2 720			
Albania	62.0	11.1	26.9	372	415	340	346	353
Algeria	64.9	13.2	21.9	258	444	568	569	569
American Samoa								
Angola	60.0	17.1	22.9	80	80	80	80	80
Antigua and Barbuda								
Argentina	73.7	9.5	16.8	1 550	1 550	1 550	1 550	1 550
Armenia	65.8	4.4	29.8			286	286	286
Australia	75.3	10.0	14.7	1 548	1 892	2 367	2 545	2 545
Austria	0.9	64.0	35.1	4	4	4	4	4
Azerbaijan	67.5	27.7	4.8			1 455	1 455	1 455
Bahamas				1	1	1	1	1
Bahrain	56.7	3.3	40.0	1	2	4	4	4
Bangladesh	96.2	0.7	3.2	1 512	2 851	4 198	4 597	4 725
Barbados	22.2	44.4	33.3	1	5	5	5	5
Belarus	30.1	46.6	23.3			131	131	131
Belgium						40	40	40
Belize	20.0	73.3	6.7	1	2	3	3	3
Benin	45.4	23.1	31.5	9	10	12	12	12
Bhutan	94.1	1.2	4.7	27	39	40	40	40
Bolivia	80.6	6.9	12.5	137	123	130	132	132
Bosnia and Herzegovina						3	3	3
Botswana	41.2	18.0	40.7	2	1	1	1	1
Brazil	61.8	18.0	20.3	1 600	2 650	2 903	2 920	2 920
Brunei Darussalam				1	1	1	1	1
Bulgaria	18.8	78.2	3.0	1 189	1 251	624	592	588
Burkina Faso	86.3	0.8	13.0	10	19	25	25	25
Burundi	77.1	5.9	17.0	14	15	21	21	21
Cambodia	98.0	0.5	1.5	120	240	270	270	270
Cameroon	73.7	8.1	18.2	15	23	26	26	26
Canada	11.8	68.7	19.6	595	721	773	785	785
Cape Verde				2	3	3	3	3
Central African Republic	4.0	16.0	80.0		0	1	2	2
Chad	82.6		17.4	13	16	26	30	30
Chile	63.5	25.2	11.3	1 255	1 600	1 900	1 900	1 900
China	67.7	25.7	6.6	45 304	47 234	54 324	54 937	54 596
Colombia	45.9	3.7	50.3	400	650	900	900	900
Comoros	47.0	5.0	48.0					
Congo	8.7	21.7	69.6	1	1	2	2	2
Costa Rica	53.4	17.2	29.5	61	77	108	108	108
Côte d'Ivoire	64.5	11.8	23.7	44	66	73	73	73
Croatia						3	5	11

TABLE A3 *(cont.)*

Countries	Share in total water use (Percentage)			Irrigated land (Thousand ha)				
	Agricultural	Industrial	Domestic					
	2000	2000	2000	1979–1981	1989–1991	1999–2001	2002	2003
Cuba	68.8	12.2	19.0	765	892	870	870	870
Cyprus	70.8	0.0	29.2	30	36	40	40	40
Czech Republic	2.3	57.0	40.7			24	24	24
former Czechoslovakia				137	244			
Democratic People's Republic of Korea	55.0	25.2	19.8	1 120	1 420	1 460	1 460	1 460
Democratic Republic of the Congo	30.6	16.7	52.8	6	10	11	11	11
Denmark	42.5	25.2	32.3	384	432	447	448	449
Dominica								
Dominican Republic	66.1	1.8	32.2	165	225	273	275	275
Ecuador	82.2	5.3	12.5	620	817	865	865	865
Egypt	86.4	5.9	7.8	2 453	2 621	3 310	3 422	3 422
El Salvador	59.4	15.6	25.0	36	40	45	45	45
Equatorial Guinea	0.9	15.7	83.3					
Eritrea	94.5	0.2	5.3			21	21	21
Estonia	5.1	38.0	57.0			4	4	4
Ethiopia	93.6	0.4	6.0			290	290	290
former People's Democratic Republic of Ethiopia				160	162			
Fiji	71.4	14.3	14.3	1	1	3	3	3
Finland	2.7	83.6	13.7	60	63	64	64	64
France	9.8	74.5	15.7	1 369	1 980	2 628	2 600	2 600
French Polynesia					1	1	1	1
Gabon	41.7	8.3	50.0	4	5	7	7	7
Gambia	65.4	11.8	22.9	1	1	2	2	2
Georgia	59.0	21.1	19.9			469	469	469
Germany	19.8	67.9	12.3	460	481	485	485	485
Ghana	66.4	9.7	23.9	20	28	31	31	31
Greece	80.4	3.2	16.3	950	1 200	1 441	1 431	1 453
Guatemala	80.1	13.4	6.5	87	117	130	130	130
Guinea	90.1	2.0	7.9	90	90	95	95	95
Guinea-Bissau	82.3	4.6	13.1	17	17	24	25	25
Guyana	97.6	0.6	1.8	124	143	150	150	150
Haiti	93.9	1.0	5.1	70	84	92	92	92
Honduras	80.2	11.6	8.1	66	70	79	80	80
Hungary	32.1	58.6	9.3	190	201	223	230	230
Iceland	0.1	66.6	33.3					
India	86.5	5.5	8.1	38 448	46 760	55 983	55 983	55 808
Indonesia	91.3	0.7	8.0	4 080	4 402	4 477	4 500	4 500
Iran (Islamic Republic of)	90.9	2.3	6.8	5 181	7 000	7 576	7 600	7 650
Iraq				1 743	3 200			

TABLE A3 *(cont.)*

Countries	Share in total water use (Percentage)			Irrigated land (Thousand ha)				
	Agricultural 2000	Industrial 2000	Domestic 2000	1979–1981	1989–1991	1999–2001	2002	2003
Ireland	0.0	77.0	23.0					
Israel	62.4	6.8	30.7	204	202	194	194	194
Italy	45.1	36.7	18.2	2 400	2 615	2 699	2 750	2 750
Jamaica	48.8	17.1	34.1	24	25	25	25	25
Japan	62.5	17.9	19.7	3 056	2 846	2 641	2 607	2 592
Jordan	65.0	4.0	31.0	37	63	75	75	75
Kazakhstan	81.8	16.5	1.7			3 556	3 556	3 556
Kenya	63.9	6.3	29.7	40	55	85	90	103
Kuwait	52.3	2.3	45.5	1	3	10	13	13
Kyrgyzstan	93.8	3.1	3.2			1 072	1 072	1 072
Lao People's Democratic Republic	90.0	5.7	4.3	107	135	174	175	175
Latvia	13.3	33.3	53.3			20	20	20
Lebanon	66.7	0.7	32.6	86	86	104	104	104
Lesotho	20.0	40.0	40.0	1	2	3	3	3
Liberia	54.5	18.2	27.3	2	3	3	3	3
Libyan Arab Jamahiriya	83.0	2.9	14.1	223	435	470	470	470
Lithuania	7.4	14.8	77.8			7	7	7
Luxembourg								
Madagascar	95.7	1.5	2.8	646	1 000	1 086	1 086	1 086
Malawi	80.2	5.0	14.9	18	20	52	56	56
Malaysia	62.1	21.1	16.9	322	343	365	365	365
Mali	90.1	0.9	9.0	60	78	224	236	236
Malta	19.8	1.0	79.2	1	1	2	2	2
Mauritania	88.2	2.9	8.8	49	49	49	49	49
Mauritius	67.7	2.8	29.5	16	17	20	21	22
Mexico	77.1	5.5	17.4	4 980	5 600	6 300	6 320	6 320
Moldova	32.9	57.6	9.5			303	300	300
Mongolia	52.3	27.3	20.5	36	78	84	84	84
Morocco	87.4	2.9	9.8	1 208	1 258	1 397	1 445	1 445
Mozambique	87.3	1.6	11.1	65	103	115	118	118
Myanmar	98.2	0.5	1.2	1 041	1 026	1 814	1 985	1 870
Namibia	71.0	4.7	24.3	4	4	7	8	8
Nepal	96.5	0.6	2.9	521	984	1 146	1 170	1 170
Netherlands	33.9	59.9	6.2	480	554	565	565	565
New Caledonia				2	4	9	10	10
New Zealand	42.2	9.5	48.3	183	281	285	285	285
Nicaragua	83.1	2.3	14.6	60	60	61	61	61
Niger	95.4	0.5	4.1	23	66	72	73	73
Nigeria	68.8	10.1	21.1	200	221	245	270	282
Norway	10.5	66.7	22.8	74	97	127	127	127
Occupied Palestinian Territory				19	18	16	16	15

TABLE A3 *(cont.)*

Countries	Share in total water use (Percentage)			Irrigated land (Thousand ha)				
	Agricultural	Industrial	Domestic					
	2000	2000	2000	1979–1981	1989–1991	1999–2001	2002	2003
Oman	90.4	2.2	7.4	38	57	69	72	72
Pakistan	96.0	2.0	1.9	14 753	16 107	17 953	17 990	18 230
Panama	28.0	4.9	67.1	28	31	42	43	43
Papua New Guinea	1.4	42.3	56.3					
Paraguay	71.4	8.2	20.4	58	65	67	67	67
Peru	81.6	10.1	8.3	1 143	1 188	1 199	1 200	1 200
Philippines	74.0	9.4	16.6	1 218	1 547	1 550	1 550	1 550
Poland	8.3	78.7	13.0	105	100	100	100	100
Portugal	78.2	12.2	9.6	630	631	650	650	650
Qatar	72.4	3.4	24.1	3	6	13	13	13
Republic of Korea	48.0	16.4	35.6	889	987	880	880	878
Romania	57.0	34.4	8.6	2 301	3 124	3 082	3 077	3 077
Russian Federation	17.8	63.5	18.8			4 600	4 600	4 600
former Union of Soviet Socialist Republics				17 410	20 800			
Rwanda	68.0	8.0	24.0	4	4	9	9	9
Saint Kitts and Nevis								
Saint Lucia				1	2	3	3	3
Saint Vincent and the Grenadines				1	1	1	1	1
Samoa								
Sao Tome and Principe				10	10	10	10	10
Saudi Arabia	89.0	1.2	9.8	567	1 583	1 620	1 620	1 620
Senegal	93.0	2.6	4.4	62	85	104	120	120
Serbia and Montenegro						23	32	32
former Socialist Federal Republic of Yugoslavia				150	161			
Seychelles	7.4	27.6	65.0					
Sierra Leone	92.1	2.6	5.3	20	28	30	30	30
Singapore								
Slovakia						181	183	183
Slovenia						3	3	3
Solomon Islands								
Somalia				133	200			
South Africa	62.7	6.0	31.2	1 119	1 200	1 498	1 498	1 498
Spain	68.0	18.5	13.4	3 028	3 387	3 719	3 780	3 780
Sri Lanka	95.2	2.5	2.4	462	522	641	638	743
Sudan	96.7	0.7	2.7	1 700	1 817	1 865	1 863	1 863
Suriname	92.5	3.0	4.5	42	46	51	51	51
Swaziland	96.5	1.2	2.3	40	45	50	50	50
Sweden	8.8	54.4	36.8	70	114	115	115	115
Switzerland	1.9	73.9	24.1	25	25	25	25	25
Syrian Arab Republic	94.9	1.8	3.3	548	717	1 221	1 333	1 333

TABLE A3 *(cont.)*

Countries	Share in total water use (Percentage)			Irrigated land (Thousand ha)				
	Agricultural 2000	Industrial 2000	Domestic 2000	1979–1981	1989–1991	1999–2001	2002	2003
Tajikistan	91.6	4.7	3.7			719	721	722
Thailand	95.0	2.5	2.5	3 007	4 248	4 973	4 986	4 986
The former Yugoslav Republic of Macedonia						55	55	55
Togo	45.0	2.4	52.6	1	7	7	7	7
Tonga								
Trinidad and Tobago	6.5	25.8	67.7	3	4	4	4	4
Tunisia	82.0	4.2	13.8	232	328	393	394	394
Turkey	74.2	11.0	14.8	2 712	4 024	4 743	5 215	5 215
Turkmenistan	97.5	0.8	1.7			1 800	1 800	1 800
Uganda	40.0	16.7	43.3	6	9	9	9	9
Ukraine	52.5	35.4	12.2			2 393	2 262	2 208
United Arab Emirates	68.3	8.7	23.0					
United Kingdom	2.9	75.4	21.7	140	162	170	170	170
United Republic of Tanzania	89.4	0.5	10.1	117	144	163	184	184
United States of America	41.3	46.0	12.7	20 582	20 800	22 543	22 384	22 385
Uruguay	96.2	1.3	2.5	77	125	188	202	210
Uzbekistan	93.2	2.1	4.7			4 281	4 281	4 281
Vanuatu								
Venezuela (Bolivarian Republic of)	47.4	7.0	45.5	367	472	575	575	575
Viet Nam	68.1	24.1	7.8	1 685	2 867	3 000	3 000	3 000
Yemen	95.3	0.6	4.1	291	354	497	500	550
Zambia	75.9	7.5	16.7	19	30	133	156	156
Zimbabwe	78.9	7.1	14.0	80	106	174	174	174
World	**70.0**	**20.0**	**10.0**	**209 657**	**244 196**	**275 090**	**277 247**	**277 098**

TABLE A4
Production of cereals and meat

Countries	Cereals (Thousand tonnes)					Meat (Thousand tonnes)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Afghanistan	4 060	2 754				240	238			
Albania	916	792	522	489	499	42	51	66	75	76
Algeria	1 958	2 481	1 872	4 266	3 998	185	436	546	564	581
American Samoa						0	0	0	0	0
Angola	371	298	546	721	725	81	99	139	139	139
Antigua and Barbuda	0	0	0	0	0	1	1	1	1	1
Argentina	24 579	19 988	36 569	33 961	34 212	3 703	3 539	4 001	3 762	4 175
Armenia			294	305	443			49	53	54
Australia	21 150	21 390	36 232	41 652	31 520	2 752	3 009	3 743	3 852	3 769
Austria	4 388	5 115	4 711	3 996	5 009	720	842	971	998	987
Azerbaijan			1 507	1 993	2 087			109	134	144
Bahamas	1	1	0	0	0	7	6	8	8	8
Bahrain						7	10	14	13	13
Bangladesh	20 983	27 987	37 960	40 876	41 044	241	305	428	449	449
Barbados	2	2	0	0	0	12	15	15	14	16
Belarus			4 283	5 116	6 589			625	605	629
Belgium			2 436	2 561	2 932			1 754	1 740	1 821
Belize	27	33	56	56	49	4	7	11	17	18
Benin	366	566	970	1 043	1 109	41	43	46	49	54
Bhutan	159	102	126	108	127	5	7	7	7	7
Bolivia	663	845	1 221	1 486	1 341	209	263	405	440	446
Bosnia and Herzegovina			1 146	792	1 439			35	32	35
Botswana	37	61	23	38	45	50	59	58	53	54
Brazil	30 805	37 702	50 148	67 453	63 812	5 224	8 228	15 332	18 388	19 919
Brunei Darussalam	3	1	0	1	1	5	6	16	18	19
Bulgaria	8 129	8 872	5 231	3 831	7 463	659	740	482	401	414
Burkina Faso	1 166	1 975	2 698	3 564	2 902	53	111	176	202	212
Burundi	219	296	261	287	280	21	29	23	23	23
Cambodia	1 334	2 591	4 201	5 026	4 427	27	120	193	210	214
Cameroon	866	890	1 272	1 584	1 684	115	175	214	219	219
Canada	42 727	52 917	49 502	50 174	52 684	2 514	2 799	4 006	4 217	4 592
Cape Verde	6	10	27	12	4	2	5	8	8	9
Central African Republic	103	101	170	201	192	46	74	110	124	127
Chad	508	677	1 161	1 618	1 213	61	98	117	122	125
Chile	1 742	2 997	2 624	3 693	3 956	356	507	955	1 041	1 126
China	286 488	390 171	420 308	376 123	413 166	14 526	30 644	62 833	71 155	74 306
Colombia	3 339	4 090	3 668	4 062	4 409	829	1 186	1 377	1 494	1 587
Comoros	18	19	21	21	21	2	2	2	2	2
Congo	15	11	8	9	9	18	21	27	28	31
Costa Rica	337	266	292	229	234	100	148	187	182	190
Côte d'Ivoire	866	1 225	2 019	1 808	2 205	118	125	162	170	171
Croatia			3 017	2 355	3 268			130	147	149

TABLE A4 *(cont.)*

Countries	Cereals (Thousand tonnes)					Meat (Thousand tonnes)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Cuba	551	547	841	1 076	888	272	316	230	194	200
Cyprus	87	107	101	142	107	35	65	102	108	109
Czech Republic			6 914	5 762	8 783			800	771	750
former Czechoslovakia	9 762	12 228				1 413	1 562			
Democratic People's Republic of Korea	6 004	7 201	3 554	4 324	4 461	236	320	203	242	246
Democratic Republic of the Congo	900	1 471	1 624	1 569	1 570	173	204	217	212	211
Denmark	7 346	9 211	9 203	9 051	8 963	1 303	1 559	2 027	2 114	2 158
Dominica	0	0	0	0	0	1	1	1	1	1
Dominican Republic	450	531	662	656	620	124	221	329	298	328
Ecuador	686	1 422	1 800	1 967	2 128	168	255	491	579	591
Egypt	8 134	12 672	19 356	20 682	21 315	440	754	1 315	1 371	1 437
El Salvador	719	785	798	791	822	57	72	111	117	127
Equatorial Guinea						0	0	1	1	1
Eritrea			207	99	83			30	32	32
Estonia			552	506	608			57	68	71
Ethiopia			8 654	8 720	9 280			529	597	593
former People's Democratic Republic of Ethiopia	5 739	5 894				528	599			
Fiji	19	30	16	17	16	13	20	22	26	27
Finland	2 993	3 845	3 548	3 788	3 616	305	340	339	376	382
France	46 078	57 683	63 426	54 940	70 534	5 423	5 767	6 538	6 408	6 255
French Polynesia						2	2	2	2	2
Gabon	11	23	27	32	32	24	27	31	31	32
Gambia	69	99	176	204	213	6	6	6	7	7
Georgia			631	742	663			104	109	109
Germany	32 044	37 910	46 473	39 426	51 097	6 925	6 987	6 377	6 602	6 798
Ghana	726	1 155	1 674	2 041	1 943	111	143	160	172	177
Greece	4 951	5 491	4 828	4 535	5 040	525	528	496	463	478
Guatemala	1 122	1 413	1 165	1 147	1 172	108	147	231	248	248
Guinea	678	632	1 015	1 161	1 142	22	26	49	53	56
Guinea-Bissau	102	165	162	121	171	11	14	18	19	19
Guyana	267	214	505	506	506	14	6	15	27	27
Haiti	419	405	423	398	367	65	59	90	101	100
Honduras	492	664	591	587	108	81	86	136	187	202
Hungary	13 001	14 603	12 158	8 770	16 737	1 425	1 547	1 125	1 200	1 047
Iceland						26	19	24	27	26
India	138 182	195 478	238 012	233 406	232 360	2 620	3 881	5 272	5 941	6 032
Indonesia	33 605	51 258	60 484	63 024	65 314	676	1 446	1 722	2 223	2 392
Iran (Islamic Republic of)	8 855	12 973	14 002	20 930	21 810	647	986	1 558	1 621	1 646
Iraq	1 803	2 541				149	233			
Ireland	2 009	1 950	2 117	2 147	2 501	629	831	1 056	976	979

TABLE A4 *(cont.)*

Countries	Cereals (Thousand tonnes)					Meat (Thousand tonnes)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Israel	239	331	182	324	294	186	236	460	560	576
Italy	18 025	17 921	20 588	17 864	23 267	3 514	3 924	4 127	4 020	4 079
Jamaica	7	3	2	1	1	52	71	100	103	103
Japan	14 318	13 946	12 444	10 826	11 990	3 002	3 499	2 983	3 019	3 028
Jordan	88	105	44	80	53	34	65	126	125	132
Kazakhstan			13 885	14 739	12 334			637	693	737
Kenya	2 279	2 958	2 921	3 351	2 730	280	370	448	483	497
Kuwait	0	1	3	3	3	40	42	74	71	75
Kyrgyzstan			1 654	1 633	1 709			197	194	188
Lao People's Democratic Republic	1 056	1 443	2 321	2 518	2 733	30	45	78	94	87
Latvia			882	932	1 059			62	71	73
Lebanon	41	80	123	146	145	69	80	172	198	201
Lesotho	198	170	198	180	248	23	25	22	22	22
Liberia	254	191	175	100	110	15	17	19	21	21
Libyan Arab Jamahiriya	225	284	216	213	213	142	132	150	142	142
Lithuania			2 350	2 623	2 856			177	196	214
Luxembourg			149	164	179			41	46	46
Madagascar	2 178	2 541	2 756	3 129	3 391	210	250	280	266	297
Malawi	1 341	1 560	2 336	2 142	1 843	32	42	57	59	59
Malaysia	2 061	1 886	2 154	2 331	2 268	289	634	923	1 070	1 158
Mali	1 082	2 114	2 596	2 858	2 845	124	161	204	257	247
Malta	8	8	11	12	12	8	15	19	20	19
Mauritania	48	131	166	153	125	50	62	78	89	89
Mauritius	1	2	0	0	0	9	16	27	33	32
Mexico	20 391	23 553	28 822	30 315	32 751	2 535	2 839	4 468	4 870	5 040
Moldova			2 199	1 583	2 944			91	84	86
Mongolia	320	718	151	165	139	234	257	275	157	200
Morocco	3 583	7 456	3 485	8 473	8 604	248	447	592	604	600
Mozambique	649	629	1 591	1 813	2 007	66	81	90	90	90
Myanmar	12 986	14 111	21 818	24 163	24 822	252	259	444	550	639
Namibia	73	103	101	107	107	64	65	77	110	109
Nepal	3 640	5 680	7 055	7 684	7 581	128	186	237	251	257
Netherlands	1 280	1 327	1 590	1 740	1 754	1 926	2 685	2 823	2 223	2 350
New Caledonia	3	1	4	6	4	4	4	6	6	6
New Zealand	789	783	888	899	866	1 143	1 204	1 294	1 426	1 433
Nicaragua	392	453	693	972	773	83	72	105	136	150
Niger	1 702	2 120	2 714	3 102	2 672	98	97	134	133	133
Nigeria	7 427	18 100	21 288	22 616	22 783	669	753	968	1 042	1 067
Norway	1 129	1 410	1 246	1 287	1 426	195	215	268	275	290
Occupied Palestinian Territory			40	68	62			96	85	99
Oman	2	5	6	6	6	12	25	33	38	41

TABLE A4 *(cont.)*

Countries	Cereals (Thousand tonnes)					Meat (Thousand tonnes)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Pakistan	17 200	21 038	28 422	28 964	30 311	714	1 327	1 697	1 848	1 917
Panama	253	336	303	403	403	69	101	170	164	168
Papua New Guinea	4	4	11	10	11	215	272	350	387	393
Paraguay	472	818	1 205	1 643	1 979	210	337	387	351	414
Peru	1 430	1 983	3 566	3 927	3 389	357	497	816	939	958
Philippines	10 942	14 350	16 917	18 116	19 910	785	1 091	1 882	2 309	2 364
Poland	18 466	27 594	25 017	23 391	29 635	2 745	2 960	2 927	3 472	3 271
Portugal	1 210	1 683	1 528	1 186	1 363	437	556	730	679	697
Qatar	1	3	6	7	7	7	14	12	14	13
Republic of Korea	8 452	8 412	7 606	6 355	7 325	471	930	1 673	1 776	1 747
Romania	18 109	18 286	15 479	12 962	24 314	1 646	1 562	1 014	1 147	779
Russian Federation			67 190	65 562	76 231			4 399	4 945	4 981
former Union of Soviet Socialist Republics	159 029	184 357				15 255	19 531			
Rwanda	271	289	234	298	319	26	31	38	47	50
Saint Kitts and Nevis						0	1	1	1	1
Saint Lucia	0					2	2	2	2	2
Saint Vincent and the Grenadines	1	2	1	1	1	1	1	1	1	1
Samoa						3	5	5	5	5
Sao Tome and Principe	0	3	2	3	3	0	0	1	1	1
Saudi Arabia	303	4 214	2 404	2 949	2 792	126	411	629	631	643
Senegal	850	996	1 040	1 452	1 085	69	111	165	162	167
Serbia and Montenegro			7 682	5 541	9 873			913	843	808
former Socialist Federal Republic of Yugoslavia	15 521	16 512				1 463	1 448			
Seychelles						1	2	2	2	2
Sierra Leone	542	566	254	309	309	16	19	21	23	23
Singapore						155	167	119	111	93
Slovakia			2 814	2 490	3 793			354	332	312
Slovenia			490	402	586			183	184	180
Solomon Islands	13		5	5	6	2	3	3	3	3
Somalia	305	497				119	163			
South Africa	14 195	12 744	11 775	11 825	12 352	1 084	1 375	1 658	1 848	1 887
Spain	14 709	19 306	20 198	21 412	24 747	2 601	3 459	4 955	5 479	5 531
Sri Lanka	2 130	2 370	2 839	3 106	2 668	52	56	101	124	130
Sudan	2 931	2 771	3 888	6 380	3 643	445	419	668	715	715
Suriname	258	229	178	194	195	11	15	8	9	9
Swaziland	92	91	97	70	71	20	17	22	21	21
Sweden	5 407	5 677	5 309	5 352	5 508	544	507	558	551	554
Switzerland	843	1 331	1 118	878	1 130	467	480	425	433	432
Syrian Arab Republic	3 069	2 598	4 577	6 223	5 249	172	219	343	391	391
Tajikistan			496	866	860			30	45	49

TABLE A4 *(cont.)*

Countries	Cereals (Thousand tonnes)					Meat (Thousand tonnes)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Thailand	20 316	23 624	30 132	31 420	28 277	932	1 399	1 987	2 211	1 817
The former Yugoslav Republic of Macedonia			559	472	684			25	28	28
Togo	301	505	737	816	787	16	29	31	33	34
Tonga						2	2	2	2	2
Trinidad and Tobago	13	17	7	6	6	24	28	41	61	62
Tunisia	1 146	1 626	1 449	2 312	2 155	97	147	244	243	245
Turkey	25 232	28 283	30 235	30 807	34 050	714	1 148	1 352	1 494	1 583
Turkmenistan			1 717	2 667	2 785			153	210	224
Uganda	1 171	1 597	2 200	2 413	2 625	149	200	267	263	259
Ukraine			28 878	19 662	40 997			1 625	1 725	1 595
United Arab Emirates	1	2	0	0	0	22	55	81	91	88
United Kingdom	18 840	22 644	21 691	21 511	22 030	3 009	3 340	3 476	3 271	3 270
United Republic of Tanzania	3 010	4 201	4 226	4 261	5 020	185	275	332	363	362
United States of America	301 133	292 217	334 614	348 897	389 066	24 325	28 827	37 567	38 911	38 891
Uruguay	1 012	1 230	1 923	2 171	2 523	415	456	550	530	602
Uzbekistan			4 094	6 106	5 855			497	560	592
Vanuatu	1	1	1	1	1	4	6	7	6	7
Venezuela (Bolivarian Republic of)	1 550	2 037	2 775	3 116	3 714	672	777	1 280	1 238	1 170
Viet Nam	12 218	20 008	33 984	37 705	39 341	529	1 065	1 982	2 482	2 664
Yemen	897	693	689	418	497	71	123	171	206	207
Zambia	990	1 467	934	1 365	1 364	81	95	127	127	127
Zimbabwe	2 275	2 393	2 144	1 259	837	114	137	188	205	207
World	**1 573 227**	**1 903 961**	**2 084 615**	**2 085 774**	**2 270 360**	**136 219**	**179 648**	**234 671**	**253 688**	**260 098**

TABLE A5
Production of fish and forest products (2004)

Countries	Capture fisheries and aquaculture (Thousand tonnes)			Forest products (Thousand m³)				Forest products (Thousand tonnes)	
	Freshwater and diadromous fish	Marine fish	Other aquatic animals	Woodfuel	Industrial roundwood	Sawnwood	Wood-based panels	Wood pulp	Paper and paperboard
Afghanistan									
Albania	2	2	1	221	75	97	37		3
Algeria	1	136	4	7 545	119	13	48		41
American Samoa		4							
Angola	10	224	6	3 487	1 096	5	11	15	
Antigua and Barbuda		2	1						
Argentina	37	761	155	3 972	9 706	1 388	1 112	782	1 511
Armenia	1			62	6	2	2		2
Australia	21	156	90	3 092	25 685	4 038	2 083	1 107	3 097
Austria	3			3 539	12 943	11 133	3 419	1 934	4 852
Azerbaijan	9	0	0	6	7	0	0		148
Bahamas		1	10		17	1			
Bahrain	0	8	6						
Bangladesh	1 756	234	112	27 694	282	388	9	19	46
Barbados		2			5				
Belarus	5			1 097	6 446	2 304	815	61	279
Belgium	2	23	3	550	4 215	1 215	2 698	531	2 131
Belize	0	0	14	126	62	35			
Benin	19	14	7	162	332	31			
Bhutan	0			4 479	133	31	32		
Bolivia	6	1		2 228	650	347	12		
Bosnia and Herzegovina	8	0	0	1 316	2 677	888	27		
Botswana	0			655	105				
Brazil	420	436	160	136 637	110 470	21 200	6 283	9 580	8 221
Brunei Darussalam	0	2	1	12	217	90			
Bulgaria	5	3	3	2 187	2 646	332	533	92	171
Burkina Faso	9			11 727	1 183	2			
Burundi	14			8 390	333	83			
Cambodia	270	34	23	9 386	125	4	5		
Cameroon	55	52	1	9 407	1 800	702	88		
Canada	176	614	529	2 901	196 667	60 655	16 575	26 424	20 578
Cape Verde		8	0	2					
Central African Republic	15			2 000	832	69	2		
Chad	70			6 362	761	2			
Chile	569	4 615	426	13 111	29 432	8 015	1 927	3 338	1 170
China	19 124	11 542	18 242	191 044	95 061	12 211	44 914	4 080	53 463
Colombia	93	97	22	8 469	1 993	622	225	209	899
Comoros		15	0		9				
Congo	26	17	1	1 219	896	157	36		
Costa Rica	21	17	8	3 445	1 687	812	65	3	20
Côte d'Ivoire	6	48	1	8 655	1 678	512	340		

TABLE A5 *(cont.)*

Countries	Capture fisheries and aquaculture (Thousand tonnes)			Forest products (Thousand m³)				Forest products (Thousand tonnes)	
	Freshwater and diadromous fish	Marine fish	Other aquatic animals	Woodfuel	Industrial roundwood	Sawnwood	Wood-based panels	Wood pulp	Paper and paperboard
Croatia	3	33	4	954	2 887	582	103	109	464
Cuba	28	23	14	2 767	808	181	149		18
Cyprus	0	4	0	3	7	5	2		
Czech Republic	24			1 190	14 411	3 940	1 390	732	934
former Czechoslovakia									
Democratic People's Republic of Korea	9	174	86	5 737	1 500	280		56	80
Democratic Republic of the Congo	218	5		69 777	3 653	40	3		3
Denmark	44	966	123	817	810	196	373		402
Dominica		1	0			66			
Dominican Republic	3	10	3	556	6				130
Ecuador	8	333	59	5 427	1 211	755	261	2	100
Egypt	574	270	21	16 792	268	2	56		460
El Salvador	4	27	14	4 173	682	16			56
Equatorial Guinea	1	2	0	447	364	4	15		
Eritrea	0	7	0	2 406	2				
Estonia	4	70	14	2 200	8 100	2 000	388	70	66
Ethiopia	10			93 029	2 928	18	93		16
former People's Democratic Republic of Ethiopia									
Fiji	0	42	5	37	346	84	16		
Finland	60	89		4 519	49 281	13 544	2 029	12 619	14 036
France	49	503	289	2 500	32 450	9 860	6 046	2 503	10 249
French Polynesia	0	12	0						
Gabon	9	34	4	1 070	3 500	133	222		
Gambia	3	28	0	638	113	1			
Georgia	0	3	0			50	10		
Germany	68	218	33	5 847	48 657	19 850	14 108	2 244	20 392
Ghana	81	314	5	20 678	1 350	480	435		
Greece	7	142	42	1 057	469	191	842		266
Guatemala	8	3	7	15 905	419	366	43		31
Guinea	4	89		11 635	651	26			
Guinea-Bissau	0	6	0	422	170	16			
Guyana	1	37	19	866	481	36	54		
Haiti	0	6	2	1 993	239	14			
Honduras	5	11	22	8 699	920	437	9	7	95
Hungary	20			2 672	2 988	205	638		579
Iceland	8	1 696	33						
India	3 029	2 345	714	303 839	19 146	17 500	2 341	1 827	4 145
Indonesia	1 152	3 852	852	76 564	32 497	4 330	5 393	5 482	7 223

TABLE A5 *(cont.)*

Countries	Capture fisheries and aquaculture (Thousand tonnes)			Forest products (Thousand m³)				Forest products (Thousand tonnes)	
	Freshwater and diadromous fish	Marine fish	Other aquatic animals	Woodfuel	Industrial roundwood	Sawnwood	Wood-based panels	Wood pulp	Paper and paperboard
Iran (Islamic Republic of)	150	307	18	77	743	68	665	240	415
Iraq									
Ireland	16	244	79	20	2 542	939	841		45
Israel	18	8	0	2	25		181		275
Italy	39	182	184	5 814	2 883	1 580	5 596	492	9 667
Jamaica	4	9	5	570	282	66			
Japan	369	3 346	1 463	114	15 615	13 603	5 288	10 586	29 253
Jordan	1	0		253	4				25
Kazakhstan	34			171	130	265	10		58
Kenya	120	6	2	20 370	1 792	78	83	98	165
Kuwait	0	3	2						
Kyrgyzstan	0			18	9	22			2
Lao People's Democratic Republic	95			5 928	392	182	13		
Latvia	1	121	3	970	11 784	3 988	394		38
Lebanon	1	3	0	82	7	9	46		42
Lesotho	0			2 047					
Liberia	4	6	0	5 576	337	20	30		
Libyan Arab Jamahiriya	0	46		536	116	31			6
Lithuania	5	149	7	1 260	4 860	1 450	393		99
Luxembourg				13	264	133	400		
Madagascar	33	83	22	10 770	183	893	5	1	9
Malawi	57			5 102	520	45	18		
Malaysia	82	1 136	289	3 119	22 000	5 598	6 963	123	978
Mali	101			4 965	413	13			
Malta		2	0						
Mauritania	5	177	17	1 581	6				
Mauritius	0	10	0	6	8	3			
Mexico	115	1 080	344	38 269	6 913	2 962	430	338	4 391
Moldova	5			30	27	5	10		
Mongolia	0			186	445	300	2		
Morocco	2	854	40	298	563	83	35	177	129
Mozambique	19	12	14	16 724	1 319	28	3		
Myanmar	825	1 092	71	37 560	4 196	1 056	118	1	43
Namibia	2	565	4						
Nepal	40			12 702	1 260	630	30		13
Netherlands	11	501	89	290	736	273	8	119	3 459
New Caledonia		3	3		5	3			
New Zealand	6	444	182		19 722	4 369	2 219	1 596	920
Nicaragua	1	10	16	5 906	93	45	8		
Niger	52			8 596	411	4			

TABLE A5 *(cont.)*

Countries	Capture fisheries and aquaculture (Thousand tonnes)			Forest products (Thousand m³)				Forest products (Thousand tonnes)	
	Freshwater and diadromous fish	Marine fish	Other aquatic animals	Woodfuel	Industrial roundwood	Sawnwood	Wood-based panels	Wood pulp	Paper and paperboard
Nigeria	226	251	32	60 852	9 418	2 000	95	23	19
Norway	630	2 461	69	1 229	7 551	2 230	493	2 528	2 294
Occupied Palestinian Territory		3	0						
Oman		153	13						
Pakistan	184	348	38	25 599	2 679	1 180	354	28	700
Panama	1	184	14	1 219	93	30	7		
Papua New Guinea	12	219	3	5 533	1 708	60	45		
Paraguay	24			5 944	4 044	550	161		13
Peru	44	9 239	352	7 300	1 635	671	97		91
Philippines	516	1 929	279	13 070	2 975	339	777	175	1 056
Poland	60	157	10	3 396	29 337	3 743	6 491	1 027	2 635
Portugal	1	202	25	600	10 953	1 100	1 316	1 949	1 674
Qatar		11	0						
Republic of Korea	30	1 132	819	2 463	2 089	4 366	3 860	545	10 511
Romania	11	2		3 015	12 762	4 588	951	262	462
Russian Federation	416	2 505	131	48 000	134 000	21 500	7 159	6 885	6 789
former Union of Soviet Socialist Republics									
Rwanda	8			5 000	495	79			
Saint Kitts and Nevis		0	0						
Saint Lucia	0	1	0						
Saint Vincent and the Grenadines		9							
Samoa	0	3	2	70	61	21			
Sao Tome and Principe		4	0		9	5			
Saudi Arabia	2	45	19						
Senegal	52	374	19	5 243	794	23			
Serbia and Montenegro	5	0	0	2 097	1 423	575	77	21	159
former Socialist Federal Republic of Yugoslavia									
Seychelles		94	1						
Sierra Leone	17	112	5	5 403	124	5			
Singapore	3	2	3			25	355		87
Slovakia	3			304	6 936	1 837	508	520	798
Slovenia	2	1	0	725	1 826	461	474	153	558
Solomon Islands		36	0	138	554	12			
Somalia									
South Africa	2	867	16	12 000	21 159	2 171	1 022	2 076	3 774
Spain	38	769	360	2 055	14 235	3 730	4 754	1 905	5 490
Sri Lanka	31	237	19	5 646	694	61	22	3	25
Sudan	56	5		17 482	2 173	51	2		3

TABLE A5 *(cont.)*

Countries	Capture fisheries and aquaculture (Thousand tonnes)			Forest products (Thousand m³)				Forest products (Thousand tonnes)	
	Freshwater and diadromous fish	Marine fish	Other aquatic animals	Woodfuel	Industrial roundwood	Sawnwood	Wood-based panels	Wood pulp	Paper and paperboard
Suriname	0	19	14	44	161	59	1		
Swaziland	0			560	330	102	8	191	
Sweden	9	262	5	5 900	61 400	16 900	681	12 106	11 589
Switzerland	3			1 000	3 700	1 505	897	271	1 777
Syrian Arab Republic	14	3	0	18	40	9	27		1
Tajikistan	0								
Thailand	546	2 270	1 202	19 985	8 700	288	685	916	3 420
The former Yugoslav Republic of Macedonia	1			699	132	28			16
Togo	9	21	0	4 424	254	13			
Tonga		1	0		2	2			
Trinidad and Tobago		9	1	35	51	33			
Tunisia	2	91	20	2 138	214	20	104		94
Turkey	70	519	55	5 278	11 225	6 215	3 833	225	1 643
Turkmenistan	15	0		3					
Uganda	377		0	36 235	3 175	264	5		3
Ukraine	38	158	33	8 396	6 466	2 019	1 308	27	702
United Arab Emirates	0	90	1						
United Kingdom	175	523	162	231	8 042	2 782	3 533	344	6 240
United Republic of Tanzania	299	46	3	21 505	2 314	24	4	54	25
United States of America	708	3 523	1 336	43 608	414 702	87 436	44 262	54 301	83 612
Uruguay	2	110	11	4 267	2 132	230	6	41	96
Uzbekistan	4			18	8				11
Vanuatu	0	65	30	91	28	28			
Venezuela (Bolivarian Republic of)	55	356	101	3 793	1 526	947	233	142	723
Viet Nam	896	1 334	849	21 250	5 237	2 900	117	278	888
Yemen		240	16	353					
Zambia	70			7 219	834	157	18		4
Zimbabwe	16			8 115	992	397	77	42	80
World	**36 080**	**71 821**	**31 112**	**1 771 978**	**1 645 682**	**415 553**	**224 929**	**174 635**	**354 490**

TABLE A6
Value of agricultural exports and share in total exports

Countries	Agricultural exports (US$ million)					Share of agricultural exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Afghanistan	300	147				51.58	66.84			
Albania	111	106	19	28	25		29.19	6.71	6.16	4.18
Algeria	119	46	29	55	55	0.92	0.38	0.16	0.22	0.17
American Samoa	4	11	5	0	0	2.91	3.59	1.59	0.09	0.09
Angola	157	9	3	2	2	9.63	0.26	0.04	0.02	0.01
Antigua and Barbuda	1	2	0	1	1	2.22	4.83	0.16	0.25	0.29
Argentina	5 816	6 414	10 873	13 867	15 839	69.86	56.74	42.72	46.90	45.84
Armenia			33	77	79			11.15	11.19	10.97
Australia	8 475	11 460	15 271	15 173	20 871	42.74	30.05	26.34	20.16	26.02
Austria	726	1 350	3 531	5 637	7 475	4.46	3.53	5.18	5.80	6.37
Azerbaijan			67	154	189			4.02	5.94	5.24
Bahamas	14	34	46	43	46	0.28	1.51	1.52	0.72	0.77
Bahrain	13	6	29	54	43	0.38	0.17	0.54	0.81	0.57
Bangladesh	184	157	107	103	114	26.91	10.44	1.89	1.78	1.73
Barbados	54	51	70	66	72	27.35	25.54	26.46	26.43	25.96
Belarus			528	817	1 076			7.66	8.20	7.83
Belgium			17 176	22 595	26 304			9.07	8.84	8.59
Belize	57	88	133	123	121	54.35	69.37	69.66	59.95	59.10
Benin	38	83	187	257	228	80.43	29.86	54.87	94.74	75.11
Bhutan	4	11	14	14	10	21.85	14.69	12.10	11.70	8.59
Bolivia	82	159	402	494	616	8.51	17.88	33.68	30.94	28.71
Bosnia and Herzegovina			44	77	113			6.84	7.74	9.14
Botswana	84	82	116	62	52	18.85	4.49	4.54	2.05	1.50
Brazil	8 665	8 750	14 215	20 914	27 215	44.31	26.95	26.44	28.62	28.21
Brunei Darussalam	2	9	1	2	1	0.06	0.41	0.04	0.04	0.03
Bulgaria	1 851	1 443	555	799	1 066	18.51	13.24	11.94	10.74	10.75
Burkina Faso	70	92	130	291	314	86.40	68.72	54.02	77.51	61.03
Burundi	80	77	38	30	23	97.03	94.09	78.11	79.04	48.43
Cambodia	5	41	34	40	55	41.03	32.68	2.74	1.94	2.16
Cameroon	593	512	293	587	654	49.77	30.00	16.27	25.54	25.16
Canada	6 800	8 887	15 878	17 598	20 574	10.68	7.16	6.14	6.46	6.50
Cape Verde	1	2	0	0	0	35.33	29.56	2.44	2.10	3.00
Central African Republic	51	53	27	17	1	48.55	41.96	18.08	12.98	0.56
Chad	115	128	125	115	123	80.55	70.61	66.62	60.37	64.75
Chile	362	1 188	2 942	3 655	4 268	8.56	13.80	16.12	17.19	13.33
China	5 041	14 527	16 648	20 460	20 827	8.89	6.65	2.98	2.53	2.02
Colombia	2 546	2 413	2 917	2 818	3 390	74.86	36.65	23.64	21.55	20.63
Comoros	12	15	6	20	26	83.13	75.52	28.66	50.04	65.61
Congo	15	12	20	33	40	2.01	1.21	0.93	1.43	1.76
Costa Rica	672	890	1 681	1 782	2 014	68.50	59.87	29.63	29.37	31.98
Côte d'Ivoire	1 812	1 650	2 130	3 216	3 093	66.38	57.12	51.13	58.55	49.54
Croatia			394	673	659			8.82	10.87	8.21
Cuba	4 560	3 897	858	610	620	87.20	84.86	53.25	35.87	36.50

TABLE A6 *(cont.)*

Countries	Agricultural exports (US$ million)					Share of agricultural exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Cyprus	180	283	429	262	227	34.88	31.39	43.87	28.43	23.98
Czech Republic			1 242	1 737	2 546			4.20	3.56	3.71
former Czechoslovakia	626	689				4.37	5.53			
Democratic People's Republic of Korea	135	58	26	21	22	11.96	3.65	2.70	2.23	2.33
Democratic Republic of the Congo	205	135	38	22	39	16.83	13.19	11.01	5.47	9.71
Denmark	5 006	7 929	9 023	11 398	13 185	31.05	23.71	17.65	17.14	17.17
Dominica	7	34	22	14	15	56.92	65.94	42.31	35.28	37.10
Dominican Republic	635	396	556	588	646	62.71	51.18	65.03	55.25	48.45
Ecuador	635	837	1 476	1 974	1 958	28.20	31.69	31.56	32.68	25.65
Egypt	675	450	575	938	1 314	24.92	15.19	9.63	11.43	12.57
El Salvador	715	298	503	397	427	73.89	49.04	18.13	12.68	12.63
Equatorial Guinea	18	7	8	4	7	79.86	11.83	0.85	0.39	0.73
Eritrea			2	1	3			5.58	2.56	9.38
Estonia			274	475	302			7.59	8.45	5.08
Ethiopia			290	450	380			61.85	74.76	49.59
former People's Democratic Republic of Ethiopia	377	279				92.82	89.39			
Fiji	200	196	163	198	213	63.40	42.24	28.42	29.42	31.36
Finland	706	717	1 022	1 312	1 516	5.38	2.95	2.33	2.47	2.47
France	17 250	31 549	33 844	42 127	46 642	16.66	14.88	10.44	10.75	10.40
French Polynesia	8	6	8	18	25	25.79	5.10	2.71	11.28	12.70
Gabon	12	6	12	9	17	0.57	0.26	0.44	0.26	0.41
Gambia	26	12	12	19	22	63.19	37.01	49.22	64.79	74.39
Georgia			123	169	184			41.58	34.98	28.36
Germany	10 531	20 101	23 836	32 847	39 240	5.32	5.06	4.29	4.37	4.30
Ghana	641	403	521	1 037	1 212	64.40	41.39	31.75	52.13	52.07
Greece	1 289	2 565	2 669	2 973	3 122	28.82	31.58	24.89	21.78	20.55
Guatemala	918	793	1 449	1 307	1 417	72.53	68.53	56.77	52.51	48.22
Guinea	31	27	31	41	51	7.94	3.56	4.65	4.94	5.39
Guinea-Bissau	8	13	51	48	62	57.46	74.26	84.79	69.40	90.43
Guyana	155	116	218	183	190	45.11	42.63	43.09	35.71	32.23
Haiti	71	38	26	21	20	40.22	22.12	8.50	6.04	5.10
Honduras	588	627	575	560	824	74.52	75.50	44.60	41.66	53.71
Hungary	2 115	2 376	2 276	3 231	3 585	23.32	24.26	8.17	7.61	6.54
Iceland	28	36	31	43	51	3.19	2.34	1.55	1.79	1.76
India	2 452	2 843	4 942	6 504	7 058	29.90	16.13	11.71	11.39	9.83
Indonesia	2 314	2 962	4 815	6 992	9 401	10.73	11.55	8.64	10.91	13.19
Iran (Islamic Republic of)	188	526	1 031	1 600	1 427	1.22	3.09	4.21	4.71	3.51
Iraq	57	63				0.29	0.81	0.09	0.42	0.92
Ireland	2 817	5 233	6 425	7 519	9 246	35.91	22.89	8.33	8.11	8.87
Israel	871	1 186	1 051	1 181	1 430	16.58	10.15	3.69	3.72	3.71
Italy	5 783	10 786	15 737	20 645	24 424	7.66	6.73	6.58	6.90	7.00

TABLE A6 *(cont.)*

Countries	Agricultural exports (US$ million)					Share of agricultural exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Jamaica	133	217	287	292	266	14.45	19.71	19.08	21.36	16.78
Japan	908	1 174	1 898	1 695	1 873	0.71	0.40	0.44	0.36	0.33
Jordan	197	137	303	440	563	34.39	12.36	15.10	14.29	14.51
Kazakhstan			577	733	693			7.42	5.67	3.45
Kenya	668	666	1 033	1 291	1 296	53.99	61.13	57.30	53.49	48.29
Kuwait	109	37	55	28	16	0.60	0.57	0.34	0.13	0.06
Kyrgyzstan			92	102	113			19.28	17.52	15.76
Lao People's Democratic Republic	1	35	31	15	20	6.47	27.57	9.63	3.86	5.57
Latvia			160	351	308			8.57	12.12	7.80
Lebanon	206	136	149	239	252	21.32	26.28	19.62	15.66	14.44
Lesotho	15	15	7	6	6	28.72	23.96	3.00	1.23	1.21
Liberia	136	62	64	83	96	24.41	16.36	12.86	16.60	19.21
Libyan Arab Jamahiriya	0	38	33	14	12	0.00	0.34	0.38	0.17	0.14
Lithuania			455	757	997			11.98	10.58	10.76
Luxembourg			495	709	732			5.46	5.33	4.51
Madagascar	303	179	135	192	118	82.89	57.87	31.27	48.04	29.54
Malawi	232	362	433	469	392	89.40	93.61	94.92	99.83	81.06
Malaysia	3 740	4 519	6 153	9 581	10 917	31.35	15.26	6.82	9.13	8.63
Mali	182	252	268	333	336	90.62	78.31	43.87	35.69	36.07
Malta	30	35	50	100	76	6.68	3.21	2.36	4.43	3.05
Mauritania	40	41	25	18	18	19.76	9.44	6.92	4.40	4.53
Mauritius	257	363	308	355	407	67.00	32.40	19.66	18.01	19.20
Mexico	1 860	2 874	7 385	8 725	9 879	12.82	11.26	9.19	9.96	9.76
Moldova			323	498	592			64.39	63.03	60.12
Mongolia	170	145	137	79	63	42.74	24.26	29.44	12.84	10.18
Morocco	516	612	759	981	964	22.95	15.49	10.39	11.19	9.97
Mozambique	155	44	52	104	124	57.13	33.32	10.79	10.38	12.38
Myanmar	237	171	380	419	379	54.24	37.60	19.28	16.89	14.99
Namibia	194	166	136	291	237	14.01	14.47	11.50	23.10	12.95
Nepal	51	56	74	155	95	39.45	28.71	11.11	23.64	13.25
Netherlands	15 405	29 465	30 034	41 914	47 818	22.40	22.88	13.20	14.16	13.36
New Caledonia	2	2	3	3	3	0.58	0.32	0.34	0.27	0.34
New Zealand	3 296	4 941	5 979	7 954	10 031	65.60	53.62	48.11	46.66	50.58
Nicaragua	442	215	364	392	512	83.74	70.00	61.42	64.77	84.62
Niger	78	60	74	63	27	15.76	21.52	26.27	30.71	13.19
Nigeria	525	233	415	612	487	2.55	2.01	2.39	3.08	1.56
Norway	340	352	427	545	611	2.02	1.11	0.78	0.81	0.75
Occupied Palestinian Territory	80	53	67	54	54	23.72	26.73	18.89	18.14	18.02
Oman	35	69	418	481	402	1.00	1.44	4.21	4.12	3.01
Pakistan	916	1 170	1 093	1 234	1 254	39.17	21.90	12.50	10.34	9.37
Panama	217	286	315	271	320	56.74	65.39	38.11	31.33	33.91
Papua New Guinea	332	250	319	359	401	35.04	19.03	16.36	16.25	15.70

TABLE A6 *(cont.)*

Countries	Agricultural exports (US$ million)					Share of agricultural exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Paraguay	240	742	671	1 020	1 350	77.36	82.27	67.53	61.11	67.98
Peru	337	319	682	863	1 137	9.32	9.51	10.11	9.49	9.01
Philippines	1 849	1 240	1 447	1 953	2 051	34.43	14.97	3.98	5.27	5.17
Poland	999	1 577	2 558	4 160	6 679	6.45	11.48	8.06	7.76	8.93
Portugal	429	909	1 443	2 091	2 439	10.37	6.02	5.79	6.58	6.82
Qatar		10	10	17	20		0.30	0.10	0.13	0.11
Republic of Korea	591	1 125	1 609	1 901	2 135	3.29	1.69	1.04	0.98	0.84
Romania	1 306	299	433	603	765	12.13	4.34	4.29	3.43	3.26
Russian Federation			935	2 339	2 197			1.01	1.72	1.20
former Union of Soviet Socialist Republics	2 824	2 463				3.85	2.85			
Rwanda	82	97	40	29	34	92.93	89.74	55.28	46.33	34.86
Saint Kitts and Nevis	14	12	9	9	11	65.84	41.81	19.40	16.03	19.56
Saint Lucia	22	76	33	29	35	60.76	65.88	65.66	64.55	42.78
Saint Vincent and the Grenadines	15	56	31	28	20	85.61	74.23	65.19	73.24	60.12
Samoa	14	8	5	7	6	91.06	89.24	29.26	47.93	37.82
Sao Tome and Principe	15	4	4	6	4	63.93	78.06	29.75	43.09	28.17
Saudi Arabia	91	413	389	385	372	0.09	1.03	0.59	0.40	0.39
Senegal	140	186	135	175	182	26.73	26.66	17.68	15.47	14.31
Serbia and Montenegro			286	511	688			16.77	30.00	32.24
former Socialist Federal Republic of Yugoslavia	1 037	1 177				11.64	8.48			
Seychelles	3	1	1	2	6	16.50	1.39	0.61	0.74	3.21
Sierra Leone	58	21	8	12	14	30.80	13.54	23.09	8.91	7.69
Singapore	1 498	2 668	2 780	2 563	3 004	8.24	5.12	2.22	1.78	1.67
Slovakia			410	691	1 010			3.55	3.23	3.67
Slovenia			298	471	531			3.36	3.69	3.36
Solomon Islands	25	21	34	41	42	35.57	27.23	30.52	35.40	35.99
Somalia	129	63				90.48	52.51			
South Africa	2 125	1 863	2 151	2 937	3 421	9.85	8.07	7.53	8.09	7.48
Spain	3 504	7 749	14 179	21 442	24 294	17.77	14.52	12.65	13.73	13.61
Sri Lanka	663	684	968	1 012	1 143	64.43	37.71	19.58	19.74	19.85
Sudan	533	531	358	438	395	92.81	97.64	25.15	16.79	15.15
Suriname	48	38	56	31	18	10.27	8.36	10.43	4.81	2.15
Swaziland	179	311	307	150	269	53.78	56.90	31.99	15.67	28.03
Sweden	753	1 180	1 861	2 813	3 351	2.61	2.15	2.25	2.76	2.74
Switzerland	1 021	1 826	2 140	2 751	3 269	3.69	3.10	2.64	2.73	2.75
Syrian Arab Republic	274	612	672	851	983	14.06	17.26	15.03	12.16	14.05
Tajikistan			103	217	204			14.59	27.15	22.31
Thailand	3 410	5 760	7 285	10 284	11 926	54.32	24.13	11.52	13.17	12.41
The former Yugoslav Republic of Macedonia			209	235	260			17.11	17.24	15.65
Togo	72	104	103	132	131	28.22	40.64	27.87	21.45	35.69
Tonga	7	9	7	15	14	87.40	68.40	39.47	46.42	44.88

TABLE A6 *(cont.)*

Countries	Agricultural exports (US$ million)					Share of agricultural exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Trinidad and Tobago	78	109	229	222	116	2.24	5.80	6.07	4.29	1.82
Tunisia	191	322	493	470	974	8.76	9.52	8.09	5.85	10.06
Turkey	1 949	3 238	3 975	4 831	5 958	59.22	25.45	13.91	10.22	9.44
Turkmenistan			256	55	86			12.17	1.53	2.42
Uganda	341	206	272	115	359	99.26	90.52	56.52	20.53	40.53
Ukraine			1 810	2 722	3 415			12.80	11.79	10.45
United Arab Emirates	225	636	893	1 177	1 404	1.26	3.18	1.19	1.34	1.60
United Kingdom	7 699	12 431	15 256	17 192	21 185	7.70	7.21	5.51	5.63	6.11
United Republic of Tanzania	419	269	472	385	481	73.29	68.03	70.92	34.13	36.19
United States of America	41 418	44 668	55 293	62 305	63 893	19.91	11.36	7.49	8.60	7.81
Uruguay	497	727	981	1 220	1 624	48.65	44.77	44.64	55.49	55.05
Uzbekistan			972	852	835			30.16	22.86	16.65
Vanuatu	18	12	13	11	22	48.17	58.45	54.06	75.63	91.44
Venezuela (Bolivarian Republic of)	82	247	352	204	210	0.48	1.64	1.37	0.85	0.62
Viet Nam	95	667	2 260	2 488	3 312	22.29	31.09	16.51	12.33	16.42
Yemen	29	64	66	117	103	4.13	10.53	1.99	3.13	2.76
Zambia	9	24	105	115	201	0.73	1.82	9.96	11.52	16.79
Zimbabwe	487	670	921	740	846	37.65	41.10	43.70	25.61	22.94
World	**224 117**	**319 336**	**414 279**	**523 885**	**604 329**	**12.00**	**10.00**	**7.00**	**7.00**	**7.00**

TABLE A7
Value of agricultural imports and share in total imports

Countries	Agricultural imports (US$ million)					Share of agricultural imports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Afghanistan	147	174				18.32	22.02			
Albania	38	119	268	359	289		17.24	22.48	19.25	12.72
Algeria	2 098	2 693	2 582	3 062	4 050	20.81	30.18	27.41	24.69	22.25
American Samoa	17	34	20	13	15	9.04	9.23	4.17	4.28	4.77
Angola	374	471	405	825	983	27.10	33.14	13.04	24.22	27.50
Antigua and Barbuda	20	37	30	31	29	20.67	16.82	4.29	5.73	5.33
Argentina	586	301	1 292	735	886	6.59	5.45	5.55	5.31	3.95
Armenia			204	218	272			23.78	17.06	20.15
Australia	918	1 751	2 975	3 886	4 470	4.94	4.52	4.74	4.48	4.63
Austria	1 683	2 727	4 550	6 367	7 426	7.68	5.89	6.25	6.40	6.31
Azerbaijan			219	314	419			18.03	11.95	11.94
Bahamas	119	222	350	232	247	1.95	8.95	18.45	10.53	11.21
Bahrain	216	279	391	525	545	6.75	7.63	9.38	9.28	8.41
Bangladesh	483	735	1 726	1 833	1 984	25.46	23.41	21.32	21.05	17.56
Barbados	89	118	157	191	140	17.46	17.14	14.17	15.95	9.89
Belarus			903	1 058	1 450			11.48	9.15	8.87
Belgium			14 538	20 241	23 042			8.16	8.62	8.08
Belize	37	43	67	63	78	25.26	18.96	15.70	11.43	14.19
Benin	95	105	181	214	381	28.90	43.93	27.46	24.19	44.51
Bhutan	5	15	23	23	28	7.85	14.88	10.55	12.69	15.82
Bolivia	120	103	233	254	231	14.55	13.45	13.19	15.73	12.54
Bosnia and Herzegovina			515	670	993			21.52	20.37	25.01
Botswana	102	210	375	358	155	15.18	11.66	21.45	16.76	5.44
Brazil	2 340	2 420	3 865	3 600	3 598	10.20	11.12	6.87	7.11	5.46
Brunei Darussalam	81	165	197	244	193	15.50	16.49	15.21	18.22	11.69
Bulgaria	700	678	403	642	849	7.25	6.64	6.27	5.98	5.89
Burkina Faso	73	106	173	138	152	21.93	19.60	28.23	15.00	13.67
Burundi	29	22	19	30	42	18.16	9.50	14.23	19.34	24.09
Cambodia	66	14	231	143	162	33.08	7.13	16.10	4.96	4.61
Cameroon	125	209	240	346	401	8.70	15.03	15.90	15.71	16.70
Canada	4 551	6 979	11 443	14 206	15 194	7.62	5.99	5.07	5.92	5.55
Cape Verde	26	41	79	102	113	40.65	31.12	31.83	37.79	41.77
Central African Republic	25	39	26	25	29	30.71	24.57	21.71	20.98	24.44
Chad	9	27	42	73	74	10.39	7.66	9.81	7.25	7.40
Chile	731	402	1 200	1 482	1 655	14.14	5.56	6.92	7.67	6.65
China	10 612	17 254	23 544	31 886	41 688	17.86	8.55	4.44	4.12	4.15
Colombia	451	348	1 431	1 668	1 859	10.32	6.72	12.26	11.96	11.12
Comoros	13	18	15	30	34	43.01	37.36	23.73	34.76	40.42
Congo	61	86	146	220	261	16.28	15.69	23.89	36.59	43.48
Costa Rica	123	174	451	572	691	8.91	9.37	7.33	7.47	8.35
Côte d'Ivoire	449	428	437	637	711	17.31	20.27	11.87	18.12	19.82
Croatia			701	1 190	1 403			8.47	8.37	8.45

TABLE A7 *(cont.)*

Countries	Agricultural imports (US$ million)					Share of agricultural imports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Cuba	1 059	1 038	797	901	927	17.66	16.78	17.17	18.01	18.54
Cyprus	170	248	679	513	638	15.11	9.65	17.81	11.51	11.60
Czech Republic			1 856	2 759	3 921			5.75	5.38	5.64
former Czechoslovakia	2 009	1 302				13.53	10.42			
Democratic People's Republic of Korea	247	300	384	292	455	16.73	11.10	29.54	22.47	34.99
Democratic Republic of the Congo	186	223	217	287	317	25.47	27.29	46.30	47.77	52.85
Denmark	2 310	3 071	4 424	6 072	7 108	12.32	9.95	9.71	10.57	10.43
Dominica	11	28	30	29	31	28.48	24.93	23.70	22.96	25.76
Dominican Republic	207	302	556	745	837	15.37	16.86	9.49	14.63	15.59
Ecuador	167	185	392	625	735	7.94	9.06	9.72	9.56	9.34
Egypt	2 551	2 925	3 510	2 741	3 014	43.64	35.80	20.52	18.49	16.77
El Salvador	163	206	644	793	884	15.72	14.76	13.73	13.76	14.76
Equatorial Guinea	7	14	12	48	57	22.32	23.08	2.67	9.65	11.30
Eritrea			59	105	130			12.15	24.37	30.30
Estonia			574	898	732			11.97	11.28	8.40
Ethiopia			266	591	423			17.27	22.16	12.82
former People's Democratic Republic of Ethiopia	93	208				13.79	24.96			
Fiji	80	87	113	158	187	14.42	13.12	13.40	13.50	14.69
Finland	1 062	1 341	1 911	2 546	2 954	7.73	5.49	5.78	5.99	5.82
France	13 991	21 943	23 896	30 657	34 638	11.54	9.49	7.35	7.69	7.45
French Polynesia	98	157	186	253	286	18.60	17.83	14.50	15.77	18.96
Gabon	108	117	170	127	226	15.21	14.47	17.65	12.25	16.52
Gambia	37	70	73	67	163	26.50	37.70	31.89	33.38	71.07
Georgia			232	262	403			35.87	22.93	21.79
Germany	26 041	37 707	34 623	45 588	50 822	13.78	10.90	7.12	7.54	7.09
Ghana	114	180	404	629	1 038	10.46	14.18	13.52	16.16	19.90
Greece	1 158	2 893	3 311	4 744	5 754	11.88	15.07	11.26	10.57	10.95
Guatemala	149	191	657	843	962	9.66	11.14	13.34	13.00	12.32
Guinea	57	126	155	209	216	18.60	18.46	17.34	21.75	19.78
Guinea-Bissau	17	24	37	46	41	29.47	31.41	66.47	66.10	58.73
Guyana	53	36	100	90	89	13.85	11.58	17.42	15.71	13.71
Haiti	113	201	351	397	470	31.79	57.53	34.21	33.42	35.95
Honduras	146	111	445	533	650	15.78	11.59	15.75	16.29	16.58
Hungary	1 108	709	1 028	1 681	2 284	11.43	7.36	3.29	3.56	3.85
Iceland	101	143	186	247	292	10.49	8.85	7.57	8.87	8.50
India	1 356	964	3 590	4 904	5 108	10.20	4.44	7.02	6.88	5.43
Indonesia	1 517	1 755	4 292	4 406	5 181	14.53	8.22	14.55	10.43	9.95
Iran, (Islamic Republic of)	2 266	2 842	2 963	2 771	3 055	19.94	14.97	19.05	9.37	8.09
Iraq	1 869	1 733				20.53	37.43			

TABLE A7 *(cont.)*

Countries	Agricultural imports (US$ million)					Share of agricultural imports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Ireland	1 385	2 193	3 409	4 446	4 960	13.12	11.18	6.89	8.25	8.18
Israel	936	1 204	1 842	2 009	2 425	11.93	7.95	5.52	5.87	5.91
Italy	13 944	23 400	21 512	26 831	31 694	15.52	13.56	9.32	9.02	9.03
Jamaica	210	264	432	432	438	17.30	14.11	12.68	11.34	10.77
Japan	17 519	29 114	35 334	36 989	41 478	13.28	12.79	10.21	9.65	9.11
Jordan	535	621	834	1 020	1 379	21.23	25.61	19.09	17.75	16.86
Kazakhstan			437	621	934			8.64	7.38	7.30
Kenya	153	194	467	440	483	7.29	9.20	14.12	11.85	10.61
Kuwait	921	717	1 237	976	1 093	14.75	14.38	16.07	8.88	9.11
Kyrgyzstan			75	96	102			13.95	13.41	10.89
Lao People's Democratic Republic	32	13	75	93	120	34.80	6.36	13.88	17.71	23.70
Latvia			678	1 101	792			21.09	20.99	11.32
Lebanon	587	779	1 161	1 285	1 346	19.01	25.57	17.66	17.93	14.33
Lesotho	107	139	140	79	65	23.49	19.33	19.06	7.72	6.35
Liberia	97	83	78	93	118	19.23	31.06	19.52	23.21	29.44
Libyan Arab Jamahiriya	1 224	1 236	1 206	784	1 148	17.93	23.73	26.09	17.42	25.50
Lithuania			557	789	1 013			10.05	8.05	8.25
Luxembourg			1 001	1 474	1 723			8.47	9.12	8.70
Madagascar	103	59	96	165	90	17.87	13.27	15.02	19.51	10.62
Malawi	32	78	50	159	58	8.20	13.08	8.48	23.25	6.19
Malaysia	1 339	2 211	3 851	4 333	5 842	13.32	7.50	5.23	5.18	5.55
Mali	60	110	144	162	148	15.04	18.50	18.27	14.34	13.05
Malta	161	190	259	362	400	18.99	10.24	8.67	11.20	10.91
Mauritania	89	150	202	291	345	32.96	66.55	55.79	60.59	71.85
Mauritius	152	201	282	353	408	26.21	13.36	13.66	14.16	15.38
Mexico	2 664	4 578	9 691	12 179	13 439	13.98	14.14	9.23	10.88	10.44
Moldova			91	233	283			12.08	16.60	16.01
Mongolia	62	63	93	119	174	10.49	7.66	16.62	14.90	21.67
Morocco	932	820	1 618	1 671	2 058	22.71	12.74	14.54	11.75	11.74
Mozambique	98	219	220	303	342	13.57	25.40	17.34	17.87	20.17
Myanmar	40	96	329	345	421	8.33	12.91	15.43	16.52	18.90
Namibia	71	100	226	206	280	4.39	8.40	16.86	11.53	12.86
Nepal	37	122	225	369	187	11.75	19.46	15.29	22.58	9.90
Netherlands	10 815	17 005	17 780	25 100	28 707	15.43	13.24	8.42	9.48	8.99
New Caledonia	81	112	132	174	209	19.62	13.36	8.67	8.27	9.97
New Zealand	317	648	1 115	1 536	1 790	6.44	7.41	8.46	8.21	8.07
Nicaragua	121	120	288	296	301	16.17	17.94	15.85	15.74	16.03
Niger	89	117	130	133	136	16.84	31.74	34.78	32.50	26.14
Nigeria	2 148	567	1 410	2 172	2 264	14.07	10.01	14.63	20.02	15.99
Norway	1 186	1 440	1 871	2 662	3 051	7.66	5.65	5.55	6.74	6.37
Occupied Palestinian Territory	32	29	549	522	528	4.89	3.12	22.17	29.03	29.35

TABLE A7 *(cont.)*

Countries	Agricultural imports (US$ million)					Share of agricultural imports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Oman	263	506	1 139	1 147	1 169	14.98	18.38	21.76	16.86	13.29
Pakistan	791	1 326	1 893	1 779	2 208	17.17	18.28	18.38	13.65	12.30
Panama	130	163	396	444	642	9.31	11.67	12.05	14.38	17.87
Papua New Guinea	174	209	198	194	215	17.97	15.41	19.71	16.28	14.71
Paraguay	76	114	345	238	275	15.66	10.99	12.18	10.20	9.15
Peru	539	589	1 007	1 109	1 359	22.43	16.97	14.10	13.45	13.85
Philippines	623	1 191	2 550	2 891	3 132	7.99	9.65	7.32	7.32	7.40
Poland	2 908	1 216	3 166	3 922	5 494	16.72	11.05	6.54	5.77	6.16
Portugal	1 595	2 753	4 013	4 935	5 800	18.38	11.81	10.08	10.45	10.57
Qatar	202	271	360	501	448	13.81	17.14	12.60	11.50	9.29
Republic of Korea	3 457	6 572	7 963	9 661	10 616	15.08	9.26	5.67	5.40	4.73
Romania	1 402	980	1 005	1 759	2 145	11.98	12.11	7.70	7.33	6.57
Russian Federation			7 952	10 994	12 363			22.63	14.58	12.84
former Union of Soviet Socialist Republics	17 473	18 481				26.32	19.87			
Rwanda	36	46	64	35	60	14.46	14.77	22.07	13.44	21.22
Saint Kitts and Nevis	8	19	30	33	58	20.44	16.48	18.65	18.83	35.23
Saint Lucia	25	58	78	86	51	21.04	20.68	23.36	26.88	13.24
Saint Vincent and the Grenadines	18	28	30	42	34	33.40	20.98	18.45	21.13	17.24
Samoa	14	18	21	32	41	21.94	22.69	18.28	22.94	26.54
Sao Tome and Principe	5	9	11	19	20	21.00	29.75	22.93	31.01	33.36
Saudi Arabia	4 107	3 651	4 908	6 025	6 203	13.71	14.74	16.45	16.33	13.94
Senegal	268	385	468	749	847	26.35	31.89	29.32	31.79	29.60
Serbia and Montenegro			446	755	868			11.30	12.93	12.12
former Socialist Federal Republic of Yugoslavia	1 546	1 944				10.34	12.04			
Seychelles	19	29	45	63	49	20.43	16.81	10.68	15.24	9.85
Sierra Leone	85	104	130	175	153	24.48	61.98	37.35	31.52	25.15
Singapore	1 922	3 547	4 014	3 961	4 366	8.33	6.03	3.46	3.10	2.66
Slovakia			831	1 164	1 606			6.43	5.32	5.45
Slovenia			783	891	1 114			7.74	6.44	6.48
Solomon Islands	10	18	19	23	10	14.68	16.61	13.57	19.42	8.29
Somalia	148	82				40.05	25.42			
South Africa	708	930	1 278	1 861	2 650	4.41	5.41	4.69	4.57	5.49
Spain	4 110	8 002	11 208	16 319	19 798	13.41	9.50	7.53	7.82	7.95
Sri Lanka	373	514	753	831	926	20.93	19.67	11.82	12.46	11.61
Sudan	297	284	420	396	638	18.96	24.76	27.70	14.60	23.53
Suriname	49	51	106	97	107	9.79	11.03	21.65	13.79	14.59
Swaziland	40	96	197	92	71	7.35	14.64	16.96	7.70	5.90
Sweden	2 191	3 208	4 067	5 792	6 648	7.24	6.25	5.96	6.93	6.70
Switzerland	2 962	4 513	4 827	6 194	6 725	9.21	6.95	5.87	6.42	6.02

TABLE A7 *(cont.)*

Countries	Agricultural imports (US$ million)					Share of agricultural imports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Syrian Arab Republic	614	677	791	1 050	1 193	14.77	27.97	18.77	19.81	22.52
Tajikistan			112	106	111			16.54	12.07	8.04
Thailand	557	1 576	2 644	3 528	3 830	6.26	4.90	4.57	4.75	4.06
The former Yugoslav Republic of Macedonia			238	325	404			12.85	14.13	14.05
Togo	86	104	56	92	98	17.12	20.91	9.79	10.95	17.59
Tonga	10	16	20	19	22	31.10	27.96	26.19	18.97	22.57
Trinidad and Tobago	333	249	324	363	419	11.87	18.03	10.13	9.31	8.63
Tunisia	518	608	784	976	1 181	15.28	12.09	8.86	8.94	9.27
Turkey	267	1 827	2 769	4 179	4 659	3.66	9.27	6.08	6.03	4.78
Turkmenistan			132	142	99			7.05	5.65	3.07
Uganda	36	31	146	223	281	11.19	5.10	9.83	17.84	13.94
Ukraine			965	2 110	1 691			6.97	9.17	5.83
United Arab Emirates	1 035	1 734	2 830	3 902	4 825	12.14	14.60	5.80	6.73	8.32
United Kingdom	15 757	21 802	27 054	35 054	41 406	14.81	10.37	8.10	8.94	8.94
United Republic of Tanzania	114	82	332	296	406	9.62	5.90	20.17	13.94	16.21
United States of America	18 204	26 384	44 380	53 480	59 874	7.70	5.21	3.81	4.10	3.92
Uruguay	153	121	389	323	322	10.13	8.63	11.80	14.66	11.05
Uzbekistan			350	152	166			11.41	5.12	4.36
Vanuatu	13	14	18	19	20	20.07	16.72	18.50	24.73	15.39
Venezuela (Bolivarian Republic of)	1 679	936	1 684	1 762	2 206	15.70	11.86	11.25	19.04	13.21
Viet Nam	374	226	1 312	1 512	1 968	27.03	8.86	9.03	5.99	7.80
Yemen	714	699	769	1 004	1 050	23.79	40.32	33.94	27.33	28.58
Zambia	102	47	89	109	97	10.50	5.13	11.28	7.81	5.75
Zimbabwe	40	56	131	219	465	3.39	2.98	6.93	11.59	21.92
World	**244 702**	**345 084**	**439 286**	**550 135**	**634 508**	**12.00**	**10.00**	**7.00**	**7.00**	**7.00**

TABLE A8
Share of processed food products in total food trade

Countries	Share in total food imports (Percentage)					Share in total food exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Afghanistan	80.90	66.05				70.48	77.17			
Albania	64.60	62.34	65.75	57.25	53.21	16.48	24.47	66.70	40.58	71.06
Algeria	62.34	62.58	50.73	50.79	54.03	90.83	67.82	39.57	54.53	59.57
American Samoa	64.38	60.26	59.34	71.78	71.10	100.00	100.00	100.00	100.00	100.00
Angola	69.97	82.75	78.25	81.94	83.78	16.47			73.99	70.25
Antigua and Barbuda	77.08	70.62	68.61	72.88	68.53	94.40	27.62	89.49	63.18	62.72
Argentina	58.72	58.49	62.94	54.04	48.81	35.44	60.64	60.62	62.01	64.54
Armenia			54.13	59.72	57.00			96.75	97.89	97.54
Australia	80.72	84.94	88.96	86.85	88.48	52.70	55.95	56.92	61.94	56.37
Austria	59.32	63.42	66.47	67.70	67.72	61.26	63.00	69.68	72.14	75.86
Azerbaijan			41.25	47.74	40.71			78.59	68.14	64.20
Bahamas	69.40	67.11	75.27	79.73	77.94	92.79	93.50	73.71	73.61	69.19
Bahrain	55.34	54.73	59.71	67.59	70.23	87.68	92.84	94.64	78.26	75.88
Bangladesh	52.54	51.95	61.69	55.55	58.81	31.38	9.24	10.94	14.01	41.30
Barbados	64.71	68.80	72.21	72.41	67.07	98.22	96.19	98.19	98.03	98.16
Belarus			62.61	72.62	70.32			74.99	78.18	78.77
Belgium			66.17	64.77	64.81			69.27	70.50	70.41
Belize	84.53	84.56	80.98	83.03	83.92	93.48	79.25	70.44	53.25	48.33
Benin	60.70	78.67	62.44	63.43	78.20	58.35	20.58	33.11	54.69	30.62
Bhutan	94.96	81.59	74.98	88.18	86.04		23.27	50.74	74.13	63.94
Bolivia	61.92	62.07	58.32	53.06	58.86	69.06	50.38	88.42	90.71	90.05
Bosnia and Herzegovina			66.97	71.13	69.34			48.81	90.41	87.79
Botswana	81.44	74.58	74.49	76.64	68.49	93.51	90.82	97.39	96.90	87.74
Brazil	21.12	46.92	48.56	41.61	52.36	80.42	75.74	63.76	56.64	54.74
Brunei Darussalam	74.00	66.98	74.85	74.05	76.49	62.95	36.49	85.17	75.76	59.22
Bulgaria	53.46	57.04	72.57	70.27	65.32	60.67	54.49	56.67	57.24	52.48
Burkina Faso	79.02	72.44	83.06	90.96	88.27	12.48	9.78	14.78	46.12	34.82
Burundi	93.89	94.04	85.44	53.32	40.19	100.00	100.00	98.70	96.07	93.76
Cambodia	96.07	99.88	85.88	76.00	87.72			72.34	60.56	36.44
Cameroon	72.60	91.46	72.75	73.69	72.49	32.17	31.10	27.22	32.62	20.11
Canada	59.78	62.37	67.37	66.84	67.06	24.03	29.00	45.74	51.89	52.39
Cape Verde	63.09	75.23	75.99	74.21	80.50	11.07	0.79	87.96	100.00	100.00
Central African Republic	61.71	70.52	81.66	89.60	95.16	7.87	3.49	1.37	0.05	
Chad	74.50	98.82	96.70	97.15	93.28	0.55	1.35	2.27	1.36	0.08
Chile	54.26	75.94	72.29	75.57	77.01	29.06	32.67	51.03	44.78	48.61
China	28.68	49.26	47.81	46.45	46.06	61.40	56.89	60.42	57.32	65.83
Colombia	49.85	34.55	48.73	45.35	44.06	41.84	32.72	50.50	59.40	55.10
Comoros	76.20	76.01	82.08	69.48	74.21	5.63	0.20	0.07	0.02	0.01
Congo	75.00	77.49	79.76	69.25	73.46	31.67	96.70	97.91	94.48	98.19
Costa Rica	55.78	44.70	51.24	52.36	49.05	23.68	17.16	34.11	36.60	38.31
Côte d'Ivoire	61.92	62.87	64.78	67.86	73.43	26.77	22.25	26.22	30.28	27.40
Croatia			65.16	67.36	66.55			80.64	83.76	87.02
Cuba	60.24	60.30	63.19	62.57	55.86	98.05	96.12	96.60	90.96	91.49

TABLE A8 *(cont.)*

Countries	Share in total food imports (Percentage)					Share in total food exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Cyprus	56.46	64.22	71.23	73.27	76.02	36.82	38.48	46.62	51.14	42.95
Czech Republic			68.24	68.81	67.39			70.40	76.25	76.05
former Czechoslovakia	45.09	63.85				69.85	60.05			
Democratic People's Republic of Korea	34.92	38.61	54.81	63.94	52.44	86.96	34.37	0.78	0.80	0.89
Democratic Republic of the Congo	36.26	58.25	66.84	75.72	65.39	69.95	46.10	42.44	67.79	63.16
Denmark	74.57	76.42	75.24	75.54	75.54	63.46	58.74	60.11	61.59	61.11
Dominica	72.00	75.63	79.11	82.98	81.61	10.46	5.41	10.38	14.42	11.12
Dominican Republic	61.18	60.97	74.41	64.94	68.72	83.38	69.54	60.11	55.32	61.04
Ecuador	47.89	46.27	57.60	64.58	64.85	47.23	12.16	18.11	17.97	19.74
Egypt	46.92	45.29	41.53	36.79	43.76	43.97	38.35	65.22	64.85	60.79
El Salvador	59.56	65.19	66.39	64.00	63.86	62.34	65.76	88.64	92.00	92.26
Equatorial Guinea	78.38	89.71	67.00	86.54	84.06		1.28	0.39	0.69	0.33
Eritrea			50.18	37.26	32.30			43.46	15.44	3.65
Estonia			60.83	64.09	74.30			56.55	61.02	84.34
Ethiopia			39.10	32.74	44.61			12.65	16.14	9.78
former People's Democratic Republic of Ethiopia	40.38	51.00				25.88	29.83			
Fiji	58.79	54.06	57.83	54.43	55.44	98.53	96.46	93.15	91.94	90.26
Finland	50.01	59.40	71.52	74.67	74.71	83.93	81.45	82.24	78.50	76.54
France	51.51	56.69	67.06	67.83	68.63	56.92	57.68	66.25	67.28	67.85
French Polynesia	67.85	74.62	75.94	78.46	78.16	96.76	78.42	91.95	78.54	88.30
Gabon	63.47	71.65	71.42	69.26	68.37	9.40	57.40	87.96	93.39	98.36
Gambia	92.41	94.88	90.00	95.36	94.59	98.33	89.54	88.45	99.27	90.19
Georgia			41.25	53.71	67.30			90.41	88.65	85.46
Germany	49.34	55.80	61.31	61.37	62.95	73.15	70.04	75.53	76.75	76.57
Ghana	59.58	70.17	64.14	76.01	77.63	9.96	9.43	12.31	21.95	20.89
Greece	41.05	57.30	58.44	59.76	61.02	71.39	63.04	71.79	74.49	72.22
Guatemala	45.60	69.14	72.95	69.63	67.45	57.01	55.87	52.96	55.97	55.37
Guinea	96.83	94.97	87.00	81.78	88.59		1.05	8.62	35.49	8.38
Guinea-Bissau	92.34	96.35	97.54	95.57	94.42	53.32	4.42	0.73	0.37	0.27
Guyana	64.09	59.03	70.12	75.22	75.92	99.77	99.63	99.01	98.50	97.69
Haiti	67.53	84.29	83.16	78.62	78.42	37.23	45.39	24.87	22.03	22.97
Honduras	41.68	65.66	73.19	73.74	69.78	28.85	12.06	32.79	41.89	30.72
Hungary	71.71	63.73	76.66	74.70	68.93	35.57	38.53	45.30	47.22	44.98
Iceland	80.99	79.70	81.03	78.13	75.96	19.48	64.31	38.98	28.78	25.62
India	80.80	50.07	71.15	71.50	72.34	68.32	71.97	67.00	60.65	65.28
Indonesia	74.44	51.85	61.32	56.38	53.22	78.37	70.94	76.56	82.38	87.48
Iran (Islamic Republic of)	58.03	50.23	45.78	59.09	62.67	48.55	8.13	41.16	32.98	31.06
Iraq	48.99	53.98				1.82	2.95			
Ireland	62.10	74.59	73.34	72.57	73.92	59.01	77.99	81.87	84.55	85.51
Israel	31.99	46.43	61.14	60.62	58.84	38.47	57.21	48.54	50.75	46.91

TABLE A8 *(cont.)*

Countries	Share in total food imports (Percentage)					Share in total food exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Italy	35.50	43.18	51.35	53.61	55.98	67.75	72.90	78.95	80.05	82.98
Jamaica	56.18	63.52	71.86	71.06	68.05	76.55	69.05	74.35	78.84	81.54
Japan	34.10	43.93	50.27	48.78	48.23	93.76	89.34	93.91	88.70	90.86
Jordan	45.37	46.68	53.22	60.27	57.68	17.24	27.18	47.50	52.54	55.42
Kazakhstan			89.10	85.44	91.21			11.86	18.13	14.97
Kenya	65.78	73.16	62.24	73.85	61.34	71.40	54.03	54.10	51.38	48.39
Kuwait	42.54	45.75	55.46	57.20	55.83	53.03	77.44	87.82	97.19	95.31
Kyrgyzstan			53.36	82.43	86.22			60.05	59.90	64.90
Lao People's Democratic Republic	100.00	98.84	98.22	97.83	98.09			2.58	14.14	6.56
Latvia			69.85	69.33	69.58			87.75	80.06	87.23
Lebanon	38.93	59.90	57.52	54.80	60.31	8.74	18.44	58.85	72.04	45.74
Lesotho	63.91	57.55	47.31	45.73	38.34	15.92	89.88	82.57	73.04	99.54
Liberia	84.55	90.32	67.21	77.12	78.85	29.17	40.25	51.10	12.99	18.70
Libyan Arab Jamahiriya	55.40	65.86	63.99	78.98	72.08		31.60	88.09	50.35	36.32
Lithuania			70.26	66.69	67.86			73.63	68.66	74.14
Luxembourg			73.25	75.00	73.74			66.62	72.20	71.02
Madagascar	99.65	82.36	91.63	95.97	88.59	12.84	19.74	12.95	7.87	15.16
Malawi	70.04	44.09	70.62	73.26	80.40	94.08	86.50	82.30	73.82	71.11
Malaysia	62.10	60.02	61.55	58.57	62.17	90.35	84.91	91.27	94.73	95.53
Mali	82.63	85.04	88.77	89.57	89.33	7.45	6.95	9.33	13.04	10.58
Malta	59.23	69.58	79.21	78.15	79.89	72.18	84.21	95.79	95.27	94.53
Mauritania	76.52	77.62	82.10	76.49	75.31		0.28	0.41	0.81	0.95
Mauritius	81.92	72.96	71.19	69.11	71.52	99.90	98.91	96.20	98.54	99.06
Mexico	33.38	49.40	48.43	52.55	52.44	29.20	34.33	47.20	47.93	47.90
Moldova			60.69	60.67	70.66			80.24	83.50	82.22
Mongolia	76.43	94.13	73.75	74.98	82.14	0.56	2.08	6.98	1.32	28.29
Morocco	46.31	54.22	37.84	44.80	40.52	27.13	46.12	34.07	32.94	42.90
Mozambique	52.31	60.07	70.03	60.50	57.95	95.61	88.30	96.28	46.72	36.99
Myanmar	99.33	97.67	90.71	89.51	90.32	88.25	33.48	17.40	16.67	9.71
Namibia	28.64	24.73	69.96	71.67	83.71	13.31	39.14	63.59	75.63	67.53
Nepal	37.12	54.42	59.69	63.09	49.36	11.69	16.41	63.61	75.62	72.07
Netherlands	58.48	61.35	60.63	60.71	62.37	60.14	61.13	66.87	68.02	68.46
New Caledonia	75.98	69.59	80.45	80.74	81.70	68.44		53.69	34.79	38.94
New Zealand	69.24	73.93	79.39	80.92	80.77	61.22	62.61	68.32	66.74	64.96
Nicaragua	47.23	69.81	73.23	74.16	81.13	61.74	68.66	65.72	65.27	67.75
Niger	73.96	67.43	91.84	94.90	90.10	1.42	1.32	5.40	7.43	20.95
Nigeria	73.15	62.73	63.88	69.68	67.16	27.66	11.29	15.04	13.12	16.17
Norway	50.78	65.90	69.02	69.04	70.60	95.92	94.70	95.49	97.30	95.48
Occupied Palestinian Territory	47.31	67.39	63.89	65.39	64.53	42.70	17.04	33.00	34.53	35.08
Oman	59.65	52.61	59.84	62.95	63.94	44.08	35.85	70.26	84.02	85.77
Pakistan	64.31	60.60	63.79	64.18	68.20	90.69	82.45	83.87	70.23	80.95
Panama	71.71	73.87	74.73	74.84	83.43	34.80	17.88	22.46	22.73	22.32

TABLE A8 *(cont.)*

Countries	Share in total food imports (Percentage)					Share in total food exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Papua New Guinea	77.33	77.45	71.02	64.24	67.84	55.15	63.10	82.27	59.12	65.02
Paraguay	75.24	94.49	83.20	67.36	82.18	33.90	18.86	34.45	33.50	42.22
Peru	48.22	57.74	57.92	56.09	58.84	77.00	81.21	63.00	54.75	52.15
Philippines	57.80	66.48	67.45	69.47	76.09	91.80	79.76	71.54	73.62	74.39
Poland	35.77	57.08	64.27	66.73	65.81	55.38	50.09	73.81	68.65	69.98
Portugal	32.26	48.54	56.82	56.77	57.78	92.75	88.94	84.95	83.39	82.47
Qatar	51.21	46.19	51.13	57.27	56.71		37.32	22.82	47.48	59.69
Republic of Korea	50.72	41.01	49.99	51.05	52.19	79.16	63.95	69.10	83.43	85.99
Romania	30.45	47.27	60.65	48.40	49.09	34.29	42.09	35.01	37.39	42.09
Russian Federation			61.63	61.20	57.54			63.86	39.89	58.42
former Union of Soviet Socialist Republics	46.52	54.12				54.53	65.93			
Rwanda	82.58	80.97	73.67	76.93	87.20	0.98	81.12	88.49	38.36	33.81
Saint Kitts and Nevis	77.80	74.40	77.73	77.95	84.52	98.49	99.83	99.42	99.37	99.18
Saint Lucia	75.28	71.18	75.80	78.19	68.17	36.05	13.24	26.97	41.65	6.44
Saint Vincent and the Grenadines	53.38	60.35	62.15	67.30	61.95	21.66	19.93	30.12	39.28	7.40
Samoa	72.72	60.75	51.73	66.74	70.80	64.45	64.20	91.04	89.64	87.55
Sao Tome and Principe	82.42	93.22	94.20	90.87	90.16	9.24	3.85	1.25	0.79	3.76
Saudi Arabia	48.92	52.64	54.09	51.35	59.76	59.05	27.33	72.38	84.30	77.37
Senegal	74.24	65.75	74.38	74.74	72.93	95.58	96.35	90.41	91.55	82.95
Serbia and Montenegro			63.53	75.52	76.93			79.56	69.53	82.19
former Socialist Federal Republic of Yugoslavia	33.77	46.87				54.84	53.65			
Seychelles	83.21	77.32	78.76	72.68	81.46	88.24	70.85	68.20	61.18	93.90
Sierra Leone	78.16	77.98	77.35	79.31	79.65	14.03	13.21	25.92	13.23	11.12
Singapore	64.83	62.60	64.48	66.63	69.85	74.65	76.87	76.92	87.80	90.37
Slovakia			70.38	70.56	69.07			72.73	74.47	72.67
Slovenia			62.78	66.62	64.63			76.95	83.47	83.26
Solomon Islands	89.25	84.15	85.55	92.81	80.69	88.79	73.13	80.23	76.76	76.65
Somalia	81.36	82.84				0.91				
South Africa	58.93	63.79	73.06	69.37	70.18	45.23	53.72	58.19	55.88	53.02
Spain	24.25	54.10	60.99	62.43	63.86	51.70	47.99	49.90	49.24	50.67
Sri Lanka	78.50	65.94	58.53	58.91	60.13	59.55	62.40	53.89	56.35	59.62
Sudan	77.15	52.85	46.31	46.03	36.27	31.85	25.45	20.58	18.95	19.90
Suriname	65.40	64.22	62.98	77.54	78.46	85.85	70.42	58.51	21.94	46.05
Swaziland	60.12	59.43	65.18	62.45	56.74	87.91	91.49	94.82	84.06	90.68
Sweden	69.66	67.86	70.86	71.01	71.70	53.04	78.03	82.36	83.34	85.86
Switzerland	54.69	62.78	68.97	68.51	69.58	95.38	97.13	98.34	98.25	98.31
Syrian Arab Republic	62.59	57.99	64.40	65.60	62.03	28.51	21.75	13.45	15.91	25.98
Tajikistan			45.21	68.74	82.31			66.71	55.40	49.09
Thailand	81.96	79.50	69.08	66.71	65.44	79.20	85.84	86.47	86.48	92.57
The former Yugoslav Republic of Macedonia			64.03	65.30	60.86			70.18	68.00	64.71

TABLE A8 *(cont.)*

Countries	Share in total food imports (Percentage)					Share in total food exports (Percentage)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Togo	79.84	72.69	57.62	56.98	56.69	1.33	53.92	61.44	70.60	57.61
Tonga	75.62	72.60	62.70	62.85	64.95	75.58	7.10	9.87	3.26	6.84
Trinidad and Tobago	62.69	55.37	72.86	73.61	71.69	85.61	93.87	94.66	94.18	90.65
Tunisia	46.00	46.91	47.14	50.90	53.28	70.39	70.97	81.19	72.39	85.31
Turkey	86.65	54.12	54.31	46.20	54.23	52.68	59.85	71.93	72.44	76.76
Turkmenistan			87.52	87.83	87.50			10.00	29.82	23.31
Uganda	84.51	87.55	81.67	61.34	58.49		0.95	37.74	35.48	45.71
Ukraine			61.95	56.86	65.81			50.90	68.01	64.34
United Arab Emirates	54.50	52.05	55.13	54.40	61.65	64.96	55.59	71.03	64.05	58.83
United Kingdom	61.57	68.54	69.64	69.11	69.64	70.54	72.02	83.85	82.05	85.10
United Republic of Tanzania	60.86	95.94	74.86	64.72	57.78	24.83	26.74	20.00	20.00	20.90
United States of America	78.41	69.44	67.23	70.10	71.87	26.63	36.61	45.81	44.08	42.57
Uruguay	35.80	43.84	71.11	56.01	67.35	54.61	69.26	75.77	74.49	75.81
Uzbekistan			56.95	82.46	59.23			52.98	35.97	17.75
Vanuatu	89.71	89.28	90.01	89.97	89.05	90.27	80.20	91.61	73.22	92.70
Venezuela (Bolivarian Republic of)	55.83	59.88	68.61	76.95	70.51	21.07	46.98	70.93	82.20	68.61
Viet Nam	63.06	92.52	84.63	76.78	75.33	81.94	79.00	79.69	84.14	86.29
Yemen	53.41	57.31	64.76	56.89	49.47	73.07	37.95	26.74	46.06	48.92
Zambia	35.30	51.52	71.19	58.78	83.42	81.71	33.80	85.02	66.49	30.44
Zimbabwe	56.51	63.06	65.15	33.70	45.07	58.20	56.46	63.64	55.99	65.43
World	**51.85**	**57.17**	**61.50**	**62.13**	**63.01**	**53.57**	**58.38**	**63.11**	**63.60**	**64.93**

TABLE A9
Per capita GDP and per capita agricultural GDP of the agricultural population

Countries	Per capita GDP (US$ constant 2000 prices)					Per capita agricultural GDP of the agricultural population (US$ constant 2000 prices)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Afghanistan										
Albania	1 094	927	1 189	1 393	1 467	371	367	634	709	795
Algeria	1 847	1 793	1 768	1 917	1 984	340	513	645	782	825
American Samoa										
Angola	926	902	737	818	880	116	98	60	80	88
Antigua and Barbuda	4 238	7 746	9 375	10 110	10 534	1 000	1 056	1 294	2 313	2 375
Argentina	7 306	5 884	7 574	6 856	7 387	2 326	2 362	3 577	3 868	4 189
Armenia			622	882	974			1 163	1 496	1 641
Australia	13 995	16 271	20 444	21 853	22 303	7 921	10 223	15 166	20 079	20 826
Austria	15 631	19 381	23 299	24 139	24 658	3 469	5 120	10 149	11 567	13 082
Azerbaijan			646	851	938			389	491	524
Bahamas	13 738	15 682	15 743	16 210	16 372	7 250	9 231	13 000	15 300	15 600
Bahrain	11 173	9 704	11 756	12 943	14 930	8 286	14 300	34 143	40 143	55 167
Bangladesh	235	258	330	359	371	108	116	149	160	164
Barbados	7 707	8 673	9 513	9 274	9 668	6 640	7 941	11 727	11 300	15 700
Belarus			1 135	1 357	1 513			1 017	1 340	1 447
Belgium	15 093	18 420	22 043	22 671	23 279	5 861	8 395	15 278	18 089	19 079
Belize	1 931	2 532	3 396	3 887	3 973	873	1 063	1 635	2 947	3 026
Benin	317	305	362	387	387	131	163	243	278	295
Bhutan	102	154	236	263	268	63	77	89	90	129
Bolivia	1 077	872	1 007	1 021	1 038	258	272	304	323	312
Bosnia and Herzegovina			1 145	1 219	1 269			2 566	4 286	4 833
Botswana	1 137	2 352	3 027	3 408	3 544	212	244	184	184	192
Brazil	3 116	3 162	3 469	3 499	3 636	441	736	1 223	1 512	1 589
Brunei Darussalam										
Bulgaria	1 367	1 733	1 551	1 821	1 939	880	1 159	2 629	3 296	3 635
Burkina Faso	187	203	222	236	238	66	70	78	77	88
Burundi	131	145	110	106	108	65	64	54	53	52
Cambodia	526	256	272	298	309	347	174	148	150	148
Cameroon	679	670	590	636	655	330	319	477	576	621
Canada	16 681	19 168	22 960	24 315	24 835	6 466	13 489	19 108	23 152	24 428
Cape Verde	633	868	1 209	1 309	1 351	206	411	630	691	708
Central African Republic	320	276	256	235	234	153	142	176	198	197
Chad	155	203	183	217	276	72	77	93	117	202
Chile	2 471	3 117	4 937	5 185	5 434	1 120	1 805	2 305	2 635	2 814
China	238	487	1 066	1 321	1 441	93	145	209	227	241
Colombia	1 607	1 848	1 980	2 038	2 086	796	1 288	1 224	1 210	1 109
Comoros	357	332	289	284	281	138	147	156	168	167
Congo	965	1 113	922	952	965	112	133	123	141	149
Costa Rica	3 192	3 111	4 051	4 235	4 333	811	1 119	1 670	1 800	1 867
Côte d'Ivoire	967	668	675	615	591	295	239	315	330	338
Croatia			4 171	4 769	4 958			3 613	4 351	4 784
Cuba	2 418	2 934	2 469	2 573	2 681	496	773	830	931	995

TABLE A9 *(cont.)*

Countries	Per capita GDP (US$ constant 2000 prices)					Per capita agricultural GDP of the agricultural population (US$ constant 2000 prices)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Cyprus	5 387	8 755	11 656	12 353	12 714	786	2 415	5 179	6 267	6 724
Czech Republic			5 404	5 880	6 123			2 293	2 477	2 623
former Czechoslovakia										
Democratic People's Republic of Korea	301	423	691	475	490	148	335	688	510	539
Democratic Republic of the Congo	252	204	90	87	90	97	98	87	78	81
Denmark	20 900	24 467	29 612	30 393	31 059	6 083	10 463	18 985	19 828	21 109
Dominica	1 824	3 097	3 423	3 139	3 203	1 360	2 300	2 278	2 056	2 647
Dominican Republic	1 498	1 602	2 333	2 434	2 447	811	848	1 486	1 727	2 263
Ecuador	1 363	1 310	1 294	1 368	1 438	469	655	497	561	582
Egypt	854	1 150	1 460	1 524	1 558	328	463	620	682	710
El Salvador	1 919	1 632	2 113	2 134	2 138	583	535	629	632	674
Equatorial Guinea	1 448	692	2 941	3 715	3 982	289	200	290	270	290
Eritrea			184	173	170			42	28	30
Estonia			3 983	4 951	5 317			1 792	1 878	2 000
Ethiopia			101	99	109			55	48	56
former People's Democratic Republic of Ethiopia										
Fiji	1 916	1 777	2 069	2 174	2 235	664	723	745	759	975
Finland	15 284	19 559	22 867	24 249	25 107	6 646	7 658	12 526	14 549	15 492
France	15 788	19 068	21 948	22 579	22 987	5 426	8 825	16 365	17 562	20 934
French Polynesia	10 636	14 159	14 511	15 656	15 766	649	1 000	1 263	1 456	1 500
Gabon	4 731	4 113	3 931	3 910	3 924	705	699	672	810	874
Gambia	325	325	322	323	341	149	117	127	111	125
Georgia			585	729	799			631	772	717
Germany	15 672	19 439	22 583	22 886	23 238	2 691	5 478	10 047	11 188	12 236
Ghana	235	215	255	273	281	183	148	164	175	179
Greece	8 558	8 845	10 281	11 508	11 990	2 817	3 836	5 051	5 015	6 350
Guatemala	1 715	1 476	1 682	1 669	1 672	743	678	768	775	804
Guinea	426	341	386	402	405	108	86	105	114	118
Guinea-Bissau	163	183	154	135	137	84	92	98	99	102
Guyana	820	622	950	956	969	611	759	1 433	2 118	2 184
Haiti	830	659	491	469	445	391	340	201	201	192
Honduras	957	895	914	936	958	232	303	360	429	451
Hungary	3 645	4 054	4 645	5 235	5 470	638	922	1 507	1 693	2 040
Iceland	21 601	25 318	29 596	30 845	32 226	24 958	24 857	28 696	48 000	50 455
India	222	312	452	510	538	126	159	192	200	201
Indonesia	392	601	778	853	886	182	227	278	312	325
Iran (Islamic Republic of)	1 318	1 150	1 441	1 652	1 738	413	537	774	932	983
Iraq										
Ireland	9 734	13 152	24 566	28 200	29 264	6 150	10 829	28 531	36 365	39 008
Israel	12 591	15 092	18 640	17 984	18 395	5 720	10 219	19 344	21 170	22 527

TABLE A9 *(cont.)*

Countries	Per capita GDP (US$ constant 2000 prices)					Per capita agricultural GDP of the agricultural population (US$ constant 2000 prices)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Italy	12 889	16 144	18 609	19 164	19 420	3 409	4 898	9 060	9 421	9 336
Jamaica	2 458	2 808	2 881	2 931	2 962	640	904	996	992	1 021
Japan	23 909	33 078	37 073	38 198	39 184	6 847	10 385	13 143	15 341	16 714
Jordan	1 824	1 580	1 683	1 765	1 849	221	369	283	339	347
Kazakhstan			1 186	1 614	1 770			515	640	662
Kenya	361	372	344	341	343	88	87	78	78	79
Kuwait	21 601	14 359	16 275	15 911	15 719					
Kyrgyzstan			278	301	317			377	434	456
Lao People's Democratic Republic	222	225	327	359	372	176	173	223	232	235
Latvia			3 277	4 141	4 535			1 085	1 374	1 478
Lebanon	10 239	3 280	4 820	5 110	5 353	5 026	5 355	7 992	9 964	11 095
Lesotho	307	389	485	526	543	205	191	205	197	198
Liberia	755	266	177	120	118	758	282	201	140	139
Libyan Arab Jamahiriya	4 517	5 656	6 660	7 319	7 503	1 387	3 119	8 470	11 229	12 270
Lithuania			3 281	4 117	4 420			1 493	1 874	2 023
Luxembourg	19 365	30 735	44 023	45 558	46 987	4 900	7 286	12 900	12 000	27 000
Madagascar	330	265	244	226	232	91	91	86	83	83
Malawi	159	134	150	147	149	51	41	68	70	72
Malaysia	1 847	2 558	3 825	4 069	4 277	999	1 577	1 915	2 242	2 359
Mali	218	182	210	234	232	96	101	105	115	107
Malta	4 870	6 506	9 537	9 541	9 629	1 808	7 000	18 500	18 833	22 800
Mauritania	326	308	353	373	386	88	111	133	121	122
Mauritius	1 600	2 524	3 766	4 161	4 294	829	1 543	1 978	2 173	2 282
Mexico	5 088	4 959	5 753	5 737	5 903	639	751	957	1 050	1 106
Moldova			305	367	394			338	368	395
Mongolia	497	566	378	405	442	429	463	451	368	444
Morocco	924	1 099	1 165	1 259	1 282	332	582	501	700	725
Mozambique	179	161	214	254	269	75	63	70	80	85
Myanmar										
Namibia	1 975	1 639	1 798	1 871	1 926	273	279	343	346	363
Nepal	148	182	233	236	240	80	94	96	99	98
Netherlands	15 651	18 518	23 148	23 077	23 288	6 405	10 787	17 343	15 746	16 363
New Caledonia	9 692	13 386	12 349	13 171	13 176	986	1 541	1 684	1 899	1 949
New Zealand	10 592	11 678	13 820	15 041	15 586	6 686	9 802	13 084	8 376	8 800
Nicaragua	1 113	738	776	769	779	465	404	673	769	783
Niger	275	199	172	175	170	92	82	78	80	76
Nigeria	427	373	366	393	397	187	228	308	348	364
Norway	21 633	27 445	37 310	38 505	39 457	6 019	8 615	14 044	14 462	19 273
Occupied Palestinian Territory			1 381	871	730			824	593	630
Oman	4 696	6 896	7 718	7 807	7 848	178	292	397	432	446
Pakistan	334	451	510	527	547	144	188	239	240	242

TABLE A9 *(cont.)*

Countries	Per capita GDP (US$ constant 2000 prices)					Per capita agricultural GDP of the agricultural population (US$ constant 2000 prices)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
Panama	3 263	2 960	3 912	3 995	4 168	698	797	1 148	1 340	1 418
Papua New Guinea	587	542	639	596	599	185	181	212	195	197
Paraguay	1 530	1 504	1 425	1 351	1 358	565	688	729	826	834
Peru	2 283	1 697	2 028	2 130	2 205	373	412	628	693	708
Philippines	985	909	994	1 055	1 100	355	360	401	445	466
Poland	3 371	2 947	4 267	4 587	4 835	298	342	740	839	870
Portugal	5 971	8 194	10 574	10 674	10 770	1 091	1 662	2 337	4 283	4 470
Qatar										
Republic of Korea	3 305	6 639	10 786	12 290	12 793	1 218	2 724	5 382	5 807	6 973
Romania	1 880	1 881	1 674	1 911	2 075	588	1 031	1 522	1 905	2 403
Russian Federation			1 760	2 141	2 309			978	1 266	1 222
former Union of Soviet Socialist Republics										
Rwanda	280	266	237	254	261	112	93	108	119	117
Saint Kitts and Nevis	2 841	5 220	7 738	8 000	8 310	667	667	800	889	1 333
Saint Lucia	2 389	3 802	4 610	4 537	4 667	868	1 595	1 147	788	1 485
Saint Vincent and the Grenadines	1 540	2 455	2 822	2 933	3 025	588	1 161	1 036	1 111	1 370
Samoa	1 174	1 138	1 335	1 382	1 411	329	368	617	596	643
Sao Tome and Principe	585	336	315	329	333	71	86	104	100	108
Saudi Arabia	15 907	8 763	8 392	8 434	8 625	636	2 362	4 233	4 975	5 469
Senegal	420	421	466	492	509	126	119	122	119	126
Serbia and Montenegro		0	817	919	986			680	869	973
former Socialist Federal Republic of Yugoslavia										
Seychelles	4 500	5 493	7 646	7 012	6 793	352	276	274	270	254
Sierra Leone	287	252	150	210	217	201	183	118	170	177
Singapore	8 942	14 461	21 982	22 223	23 746	6 368	12 583	18 167	19 400	21 400
Slovakia			3 773	4 245	4 474			1 747	2 018	1 566
Slovenia			9 547	10 454	10 942			13 500	17 000	20 440
Solomon Islands										
Somalia										
South Africa	3 267	3 003	3 009	3 228	3 334	416	531	616	662	690
Spain	8 549	10 944	13 732	14 706	15 137	1 830	3 559	6 114	7 034	8 563
Sri Lanka	448	581	857	929	976	244	287	332	338	335
Sudan	288	293	388	432	449	114	116	224	57	60
Suriname	2 573	2 097	2 129	2 319	2 410	869	906	1 099	1 163	1 725
Swaziland	894	1 188	1 330	1 381	1 403	407	443	414	409	423
Sweden	18 952	22 835	26 758	28 250	29 235	5 890	9 833	13 022	15 306	17 004
Switzerland	28 354	31 964	34 043	34 618	35 231	4 461	5 660	7 810	8 578	8 972
Syrian Arab Republic	978	862	1 100	1 109	1 122	662	575	889	934	1 000
Tajikistan			164	210	231			130	189	178
Thailand	807	1 452	1 998	2 246	2 359	221	317	367	431	413

TABLE A9 *(cont.)*

Countries	Per capita GDP (US$ constant 2000 prices)					Per capita agricultural GDP of the agricultural population (US$ constant 2000 prices)				
	1979–1981	1989–1991	1999–2001	2003	2004	1979–1981	1989–1991	1999–2001	2003	2004
The former Yugoslav Republic of Macedonia			1 720	1 734	1 769			1 331	1 438	1 540
Togo	362	310	292	289	291	121	150	171	172	176
Tonga	1 021	1 202	1 505	1 577	1 590	617	714	1 057	1 152	1 152
Trinidad and Tobago	6 811	4 929	6 208	7 576	8 021	545	627	1 027	991	806
Tunisia	1 328	1 476	2 048	2 229	2 332	480	744	1 023	1 103	1 209
Turkey	1 873	2 373	2 779	2 951	3 171	1 009	1 059	1 221	1 265	1 329
Turkmenistan			624	989	1 140			435	618	964
Uganda	241	177	251	271	277	163	96	108	112	115
Ukraine			637	810	915			573	658	807
United Arab Emirates	44 881	22 213	24 293	22 871	22 832	62 286	19 542	33 504	36 429	38 254
United Kingdom	15 743	19 795	24 312	25 681	26 399	6 900	10 700	12 452	13 249	17 567
United Republic of Tanzania	355	257	262	300	313	165	131	140	153	160
United States of America	22 361	27 400	33 915	35 175	36 352	8 329	12 375	22 323	25 338	27 651
Uruguay	5 064	4 854	5 972	5 165	5 759	2 267	2 628	3 289	3 772	4 122
Uzbekistan			553	595	632			602	722	751
Vanuatu	1 145	1 147	1 218	1 094	1 101	414	446	472	811	838
Venezuela (Bolivarian Republic of)	5 907	4 945	4 823	3 964	4 567	1 389	1 606	2 076	2 155	2 582
Viet Nam	201	228	400	470	499	110	108	145	157	159
Yemen	491	465	524	529	524	180	109	147	164	169
Zambia	461	370	312	341	353	84	81	88	89	92
Zimbabwe	553	587	564	604	613	120	117	141	178	182
World	**3 973**	**4 531**	**5 189**	**5 352**	**5 505**	**328**	**384**	**436**	**453**	**472**

TABLE A10
Dietary energy, protein and fat consumption

Countries	Energy (kcal/person/day)			Protein (g/person/day)			Fat (g/person/day)		
	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003
Afghanistan	2 280	1 960		64	55		40	40	
Albania	2 690	2 560	2 860	79	79	96	62	66	86
Algeria	2 640	2 880	3 040	67	78	82	62	71	68
American Samoa									
Angola	2 110	1 770	2 070	51	42	45	50	46	43
Antigua and Barbuda	2 120	2 450	2 320	66	81	73	76	100	83
Argentina	3 210	2 960	2 980	107	94	94	116	103	100
Armenia			2 260			68			47
Australia	3 070	3 210	3 120	105	109	107	115	132	134
Austria	3 330	3 490	3 740	96	101	111	146	156	162
Azerbaijan			2 620			77			41
Bahamas	2 470	2 720	2 710	71	81	92	79	91	96
Bahrain									
Bangladesh	1 980	2 060	2 200	44	44	48	15	19	25
Barbados	3 040	3 130	3 110	85	96	92	94	108	99
Belarus			2 960			87			99
Belgium			3 640			92			162
Belize	2 770	2 580	2 840	69	64	76	74	64	69
Benin	2 040	2 320	2 530	49	55	62	48	43	48
Bhutan									
Bolivia	2 130	2 120	2 220	55	54	57	52	49	58
Bosnia and Herzegovina			2 710			72			58
Botswana	2 030	2 240	2 180	65	69	68	44	57	51
Brazil	2 680	2 780	3 060	64	68	83	65	82	93
Brunei Darussalam	2 590	2 790	2 850	72	82	82	55	72	73
Bulgaria	3 620	3 460	2 850	104	107	89	107	116	95
Burkina Faso	1 720	2 290	2 460	51	67	71	33	46	56
Burundi	2 030	1 860	1 640	68	57	45	16	14	10
Cambodia	1 710	1 810	2 060	39	43	51	13	21	32
Cameroon	2 280	2 090	2 270	57	50	59	48	44	46
Canada	2 930	3 030	3 590	93	96	106	120	129	147
Cape Verde	2 540	2 930	3 220	68	71	76	54	68	99
Central African Republic	2 300	1 870	1 940	36	40	46	64	61	64
Chad	1 640	1 740	2 160	50	51	66	39	44	67
Chile	2 670	2 540	2 860	71	70	80	60	63	85
China	2 330	2 680	2 940	54	65	82	33	53	90
Colombia	2 290	2 410	2 580	49	54	60	47	56	65
Comoros	1 800	1 900	1 750	39	44	42	35	43	42
Congo	2 040	1 890	2 150	38	40	43	41	44	54
Costa Rica	2 510	2 730	2 850	62	68	71	60	70	78
Côte d'Ivoire	2 830	2 470	2 630	59	52	54	50	50	59
Croatia			2 770			74			87

TABLE A10 *(cont.)*

Countries	Energy (kcal/person/day)			Protein (g/person/day)			Fat (g/person/day)		
	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003
Cuba	2 880	2 880	3 190	70	68	78	78	80	53
Cyprus	2 790	3 050	3 240	77	95	105	104	123	132
Czech Republic			3 240			93			115
former Czechoslovakia	3 360	3 520		99	102		123	131	
Democratic People's Republic of Korea	2 300	2 450	2 160	74	80	63	37	48	35
Democratic Republic of the Congo	2 110	2 190	1 610	33	33	25	34	35	26
Denmark	3 100	3 190	3 450	87	102	110	135	132	140
Dominica	2 240	2 970	2 770	58	76	83	59	83	76
Dominican Republic	2 270	2 270	2 290	50	50	49	57	65	78
Ecuador	2 360	2 490	2 710	50	50	57	60	87	99
Egypt	2 900	3 180	3 350	72	84	93	65	58	58
El Salvador	2 300	2 450	2 560	56	60	67	50	54	61
Equatorial Guinea									
Eritrea			1 520			47			29
Estonia			3 160			90			96
Ethiopia			1 860			54			20
former People's Democratic Republic of Ethiopia	1 860	1 640		59	48		25	24	
Fiji	2 500	2 600	2 960	62	68	74	88	97	97
Finland	3 040	3 160	3 150	94	99	102	129	127	127
France	3 390	3 540	3 640	112	117	118	148	163	170
French Polynesia	2 760	2 850	2 900	76	87	99	91	102	124
Gabon	2 420	2 450	2 670	71	69	73	44	49	55
Gambia	1 770	2 380	2 280	43	52	52	40	52	77
Georgia			2 520			71			52
Germany	3 330	3 390	3 490	96	98	100	136	142	141
Ghana	1 700	2 010	2 650	40	44	55	35	36	38
Greece	3 310	3 570	3 680	105	112	117	124	141	145
Guatemala	2 290	2 340	2 210	58	59	56	44	44	49
Guinea	2 230	2 040	2 420	50	47	51	50	42	58
Guinea-Bissau	2 010	2 260	2 070	42	45	39	54	55	51
Guyana	2 500	2 360	2 730	63	58	76	52	31	56
Haiti	2 040	1 770	2 090	48	44	47	34	29	38
Honduras	2 120	2 310	2 360	53	55	57	42	57	65
Hungary	3 450	3 670	3 500	97	102	95	131	151	149
Iceland	3 300	3 110	3 240	132	114	124	143	123	130
India	2 080	2 370	2 440	51	57	57	33	41	52
Indonesia	2 220	2 650	2 880	47	59	64	35	51	61
Iran (Islamic Republic of)	2 730	2 930	3 090	72	77	83	61	63	61
Iraq	2 840	3 050		75	78		58	63	
Ireland	3 570	3 610	3 690	112	114	117	137	137	136
Israel	3 150	3 390	3 680	106	111	124	108	120	149

TABLE A10 *(cont.)*

Countries	Energy (kcal/person/day)			Protein (g/person/day)			Fat (g/person/day)		
	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003
Italy	3 560	3 600	3 670	106	111	113	129	151	157
Jamaica	2 610	2 530	2 680	66	63	68	64	64	75
Japan	2 710	2 820	2 770	87	95	92	69	80	86
Jordan	2 610	2 800	2 680	67	74	69	62	70	80
Kazakhstan			2 710			85			80
Kenya	2 250	2 020	2 150	62	56	59	42	45	49
Kuwait	2 980	2 410	3 060	92	73	84	88	82	113
Kyrgyzstan			3 050			101			54
Lao People's Democratic Republic	2 070	2 110	2 320	51	51	61	22	23	29
Latvia			3 020			83			109
Lebanon	2 710	3 140	3 170	75	79	89	82	102	113
Lesotho	2 360	2 420	2 630	69	68	73	33	37	37
Liberia	2 550	2 320	1 940	50	42	32	48	47	52
Libyan Arab Jamahiriya	3 450	3 270	3 330	90	82	79	109	105	107
Lithuania			3 370			110			100
Luxembourg			3 710			118			161
Madagascar	2 370	2 110	2 040	57	50	47	35	31	29
Malawi	2 270	1 930	2 140	66	53	55	40	27	33
Malaysia	2 760	2 770	2 870	59	65	75	78	97	84
Mali	1 700	2 240	2 230	51	62	63	42	49	46
Malta	3 280	3 260	3 530	102	101	118	112	114	110
Mauritania	2 050	2 540	2 780	71	79	81	55	61	71
Mauritius	2 670	2 840	2 960	61	69	80	67	72	80
Mexico	3 120	3 090	3 180	85	81	91	79	81	89
Moldova			2 730			66			54
Mongolia	2 380	2 210	2 250	80	75	79	85	80	84
Morocco	2 750	3 060	3 070	72	85	84	52	59	59
Mozambique	1 860	1 780	2 070	32	32	39	32	38	33
Myanmar	2 330	2 620	2 900	60	65	79	35	42	49
Namibia	2 230	2 070	2 260	68	59	65	42	34	52
Nepal	1 850	2 390	2 450	49	62	62	26	32	38
Netherlands	3 050	3 260	3 440	93	96	108	130	138	144
New Caledonia	2 910	2 830	2 780	78	78	82	99	103	113
New Zealand	3 080	3 170	3 200	98	95	92	124	128	118
Nicaragua	2 270	2 230	2 290	62	55	62	44	45	47
Niger	2 140	2 060	2 160	64	55	57	35	31	39
Nigeria	2 050	2 430	2 700	48	56	61	55	59	63
Norway	3 320	3 170	3 480	102	98	107	144	130	144
Occupied Palestinian Territory			2 240			61			63
Oman									
Pakistan	2 210	2 320	2 340	55	59	59	46	56	69

TABLE A10 *(cont.)*

Countries	Energy (kcal/person/day)			Protein (g/person/day)			Fat (g/person/day)		
	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003
Panama	2 270	2 270	2 260	57	59	64	67	65	65
Papua New Guinea									
Paraguay	2 580	2 470	2 530	75	70	69	70	69	87
Peru	2 130	2 010	2 570	54	50	67	38	41	48
Philippines	2 220	2 320	2 450	51	55	58	36	41	48
Poland	3 530	3 380	3 370	111	103	99	117	113	112
Portugal	2 780	3 410	3 750	76	101	119	87	120	141
Qatar									
Republic of Korea	2 990	3 020	3 040	83	82	89	37	57	78
Romania	3 210	3 020	3 520	98	91	109	95	92	101
Russian Federation			3 080			91			83
former Union of Soviet Socialist Republics	3 360	3 240		103	104		94	100	
Rwanda	2 270	1 960	2 070	54	47	49	15	16	15
Saint Kitts and Nevis	2 270	2 630	2 700	62	71	81	67	86	87
Saint Lucia	2 360	2 690	2 960	61	83	95	64	64	81
Saint Vincent and the Grenadines	2 420	2 290	2 580	55	58	71	59	68	68
Samoa	2 460	2 650	2 910	60	71	84	96	116	133
Sao Tome and Principe	2 090	2 280	2 440	46	51	48	68	83	73
Saudi Arabia	2 900	2 770	2 820	77	77	76	76	81	82
Senegal	2 280	2 260	2 310	67	68	58	54	53	69
Serbia and Montenegro			2 670			75			118
former Socialist Federal Republic of Yugoslavia	3 650	3 540		106	101		104	110	
Seychelles	2 260	2 310	2 460	66	68	84	44	53	73
Sierra Leone	2 110	1 980	1 930	45	42	44	58	56	45
Singapore									
Slovakia			2 830			77			107
Slovenia			2 970			102			108
Solomon Islands	2 220	2 060	2 250	56	52	51	53	45	41
Somalia	1 650	1 760		55	58		64	62	
South Africa	2 780	2 830	2 940	73	73	77	63	66	76
Spain	3 050	3 270	3 410	96	104	113	113	140	154
Sri Lanka	2 360	2 250	2 390	47	48	54	47	45	44
Sudan	2 180	2 160	2 260	63	67	71	75	59	69
Suriname	2 400	2 490	2 660	61	63	60	52	47	71
Swaziland	2 400	2 450	2 360	63	59	60	41	46	45
Sweden	2 980	2 970	3 160	97	95	107	124	123	125
Switzerland	3 460	3 310	3 500	96	95	96	158	151	157
Syrian Arab Republic	2 950	2 800	3 060	80	72	78	83	81	101
Tajikistan			1 840			48			40
Thailand	2 280	2 190	2 410	50	51	57	32	45	52
The former Yugoslav Republic of Macedonia			2 800			72			91

TABLE A10 *(cont.)*

Countries	Energy (kcal/person/day)			Protein (g/person/day)			Fat (g/person/day)		
	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003	1979–1981	1989–1991	2001–2003
Togo	2 190	2 180	2 320	50	52	53	33	44	48
Tonga									
Trinidad and Tobago	2 960	2 670	2 770	78	63	65	73	72	76
Tunisia	2 820	3 120	3 250	77	84	89	70	84	94
Turkey	3 230	3 510	3 340	96	101	96	77	89	90
Turkmenistan			2 750			85			70
Uganda	2 110	2 310	2 380	51	55	57	23	29	32
Ukraine			3 030			84			79
United Arab Emirates	3 300	2 950	3 220	104	94	106	130	105	92
United Kingdom	3 170	3 250	3 440	89	94	104	137	137	138
United Republic of Tanzania	2 190	2 120	1 960	54	53	47	31	31	31
United States of America	3 180	3 460	3 770	99	107	114	128	138	156
Uruguay	2 850	2 570	2 850	86	79	86	103	90	86
Uzbekistan			2 270			67			64
Vanuatu	2 560	2 530	2 590	65	58	60	98	101	87
Venezuela (Bolivarian Republic of)	2 760	2 390	2 350	70	58	62	78	69	68
Viet Nam	2 030	2 140	2 580	47	50	63	19	27	46
Yemen	1 970	2 060	2 020	59	57	57	37	40	41
Zambia	2 220	1 960	1 930	59	49	48	35	30	29
Zimbabwe	2 260	2 050	2 010	60	52	45	54	51	55
World	**2 550**	**2 700**	**2 800**	**67**	**72**	**75**	**59**	**68**	**78**

TABLE A11
Number of undernourished and proportion in total population

Countries	Number of people undernourished *(Millions)*				Proportion of undernourished in total population *(Percentage)*			
	1979–1981	1990–1992	1995–1997	2001–2003	1979–1981	1990–1992	1995–1997	2001–2003
Afghanistan								
Albania			0.2*	0.2			5*	6
Algeria	1.7	1.3	1.7	1.5	9	5	6	5
American Samoa								
Angola	2.6	5.6	5.4	5.0	37	58	49	38
Antigua and Barbuda								
Argentina	0.3	0.7	0.4	0.9	<2.5	<2.5	<2.5	<2.5
Armenia			1.8*	0.9			52*	29
Australia					<2.5	<2.5	<2.5	<2.5
Austria					<2.5	<2.5	<2.5	<2.5
Azerbaijan			2.6*	0.8			34*	10
Bahamas**	26.0	22.7	39.2	21.3	12	9	14	7
Bahrain								
Bangladesh	33.3	39.2	50.4	43.1	39	35	40	30
Barbados**	4.4	4.9	8.7	0.5	<2.5	<2.5	3	<2.5
Belarus			0.1*	0.3			<2.5*	3
Belgium					<2.5	<2.5	<2.5	<2.5
Belize**	6.4	12.7	12.1	11.4	4	7	6	5
Benin	1.3	1.0	0.9	0.9	37	20	17	14
Bhutan								
Bolivia	1.4	1.9	1.8	2.0	26	28	24	23
Bosnia and Herzegovina			0.3*	0.4			9*	9
Botswana	0.4	0.3	0.4	0.5	35	23	27	30
Brazil	18.1	18.5	16.5	14.4	15	12	10	8
Brunei Darussalam**	13.3	9.8	9.3	11.7	7	4	3	3
Bulgaria			0.7*	0.7			8*	9
Burkina Faso	4.2	1.9	2.0	2.1	62	21	19	17
Burundi	1.6	2.7	3.8	4.5	38	48	63	67
Cambodia	4.0	4.4	5.4	4.6	60	43	46	33
Cameroon	2.0	4.0	4.7	4.0	23	33	34	25
Canada					<2.5	<2.5	<2.5	<2.5
Cape Verde								
Central African Republic	0.5	1.5	1.8	1.7	23	50	52	45
Chad	3.1	3.5	3.4	2.7	69	58	49	33
Chile	0.7	1.1	0.7	0.6	7	8	5	4
China	304.0	193.6	145.6	150.0	30	16	12	12
Colombia	6.1	6.1	5.1	5.9	22	17	13	14
Comoros	0.2	0.3	0.3	0.5	54	47	55	62
Congo	0.7	1.4	1.8	1.2	41	54	59	34
Costa Rica	0.3	0.2	0.2	0.2	11	6	5	4
Côte d'Ivoire	0.7	2.3	2.3	2.2	8	18	16	14

TABLE A11 *(cont.)*

Countries	Number of people undernourished *(Millions)*				Proportion of undernourished in total population *(Percentage)*			
	1979–1981	1990–1992	1995–1997	2001–2003	1979–1981	1990–1992	1995–1997	2001–2003
Croatia			0.7*	0.3			16*	7
Cuba	0.3	0.7	1.8	0.2	3	7	17	<2.5
Cyprus**	29.5	9.6	7.9	7.1	5	<2.5	<2.5	<2.5
Czech Republic			0.1	0.1			<2.5	<2.5
former Czechoslovakia								
Democratic People's Republic of Korea	4.3	3.6	7.3	7.9	25	18	34	35
Democratic Republic of the Congo	10.0	12.2	27.2	37.0	36	31	60	72
Denmark					<2.5	<2.5	<2.5	<2.5
Dominica**	20.3	2.9	4.9	0.6	27	4	7	8
Dominican Republic	1.4	1.9	2.0	2.3	25	27	26	27
Ecuador	0.9	0.9	0.6	0.6	11	8	5	5
Egypt	3.6	2.5	2.2	2.4	8	4	3	3
El Salvador	0.8	0.6	0.8	0.7	17	12	14	11
Equatorial Guinea								
Eritrea			2.2	2.9			68	73
Estonia			0.1*				9*	3
Ethiopia			35.8	31.5			61	46
former People's Democratic Republic of Ethiopia								
Fiji	0.1	0.1	0.1		14	10	7	4
Finland					<2.5	<2.5	<2.5	<2.5
France					<2.5	<2.5	<2.5	<2.5
French Polynesia**	7.5	7.6	8.8	9.4	5	4	4	4
Gabon	0.1	0.1	0.1	0.1	12	10	8	5
Gambia	0.4	0.2	0.4	0.4	60	22	31	27
Georgia			2.4*	0.7			44*	13
Germany					<2.5	<2.5	<2.5	<2.5
Ghana	7.2	5.8	3.2	2.4	65	37	18	12
Greece					<2.5	<2.5	<2.5	<2.5
Guatemala	1.2	1.4	2.2	2.8	18	16	21	23
Guinea	1.5	2.5	2.3	2.0	32	39	31	24
Guinea-Bissau	0.3	0.3	0.4	0.5	41	24	31	37
Guyana	0.1	0.2	0.1	0.1	13	21	12	9
Haiti	2.6	4.6	4.5	3.8	48	65	59	47
Honduras	1.1	1.1	1.2	1.5	31	23	21	22
Hungary			0.1				<2.5*	<2.5
Iceland					<2.5	<2.5	<2.5	<2.5
India	261.3	214.8	201.8	212.0	38	25	21	20
Indonesia	36.5	16.4	11.8	13.8	24	9	6	6
Iran (Islamic Republic of)	2.6	2.1	2.2	2.7	7	4	3	4

TABLE A11 *(cont.)*

Countries	Number of people undernourished *(Millions)*				Proportion of undernourished in total population *(Percentage)*			
	1979–1981	1990–1992	1995–1997	2001–2003	1979–1981	1990–1992	1995–1997	2001–2003
Iraq								
Ireland					<2.5	<2.5	<2.5	<2.5
Israel					<2.5	<2.5	<2.5	<2.5
Italy					<2.5	<2.5	<2.5	<2.5
Jamaica	0.2	0.3	0.3	0.3	10	14	11	10
Japan					<2.5	<2.5	<2.5	<2.5
Jordan	0.1	0.1	0.3	0.4	6	4	7	7
Kazakhstan			0.3*	1.2			<2.5*	8
Kenya	3.3	9.5	10.0	9.7	20	39	36	31
Kuwait	0.1	0.5	0.1	0.1	4	24	5	5
Kyrgyzstan			1.0*	0.2			21*	4
Lao People's Democratic Republic	1.0	1.2	1.3	1.2	33	29	28	21
Latvia			0.1*	0.1			3*	3
Lebanon	0.2	0.1	0.1	0.1	9	<2.5	3	3
Lesotho	0.3	0.3	0.2	0.2	20	17	14	12
Liberia	0.4	0.7	1.0	1.6	21	34	42	49
Libyan Arab Jamahiriya					<2.5	<2.5	<2.5	<2.5
Lithuania			0.2*				4*	<2.5
Luxembourg					<2.5	<2.5	<2.5	<2.5
Madagascar	1.8	4.3	5.7	6.5	20	35	40	38
Malawi	1.6	4.8	4.1	4.0	26	50	40	34
Malaysia	0.4	0.5	0.4	0.6	3	3	<2.5	3
Mali	4.5	2.7	3.4	3.5	64	29	32	28
Malta					<2.5	<2.5	<2.5	<2.5
Mauritania	0.6	0.3	0.3	0.3	40	15	11	10
Mauritius	0.1	0.1	0.1	0.1	10	6	6	6
Mexico	3.1	4.6	5.0	5.1	5	5	5	5
Moldova			0.2*	0.5			5*	11
Mongolia	0.3	0.8	1.1	0.7	16	34	45	28
Morocco	1.9	1.5	1.7	1.9	10	6	6	6
Mozambique	7.1	9.2	9.5	8.3	59	66	58	45
Myanmar	6.2	4.0	3.1	2.7	18	10	7	5
Namibia	0.2	0.5	0.6	0.4	23	34	35	23
Nepal	7.7	3.9	5.6	4.1	52	20	26	17
Netherlands					<2.5	<2.5	<2.5	<2.5
New Caledonia**	9.4	17.0	19.4	23.0	7	10	10	10
New Zealand					<2.5	<2.5	<2.5	<2.5
Nicaragua	0.8	1.2	1.5	1.5	26	30	33	27
Niger	1.9	3.2	3.9	3.7	33	41	42	32
Nigeria	23.9	11.8	8.9	11.5	37	13	9	9
Norway					<2.5	<2.5	<2.5	<2.5

TABLE A11 *(cont.)*

Countries	Number of people undernourished *(Millions)*				Proportion of undernourished in total population *(Percentage)*			
	1979–1981	1990–1992	1995–1997	2001–2003	1979–1981	1990–1992	1995–1997	2001–2003
Occupied Palestinian Territory			0.3	0.6			12	16
Oman								
Pakistan	23.6	27.8	24.8	35.2	29	24	19	23
Panama	0.4	0.5	0.6	0.8	21	21	24	25
Papua New Guinea								
Paraguay	0.4	0.8	0.7	0.8	12	18	13	15
Peru	4.9	9.3	4.6	3.3	28	42	19	12
Philippines	12.9	16.2	15.4	15.2	27	26	22	19
Poland			0.4*	0.3			<2.5*	<2.5
Portugal					<2.5	<2.5	<2.5	<2.5
Qatar								
Republic of Korea	0.5	0.8	0.8	0.8	<2.5	<2.5	<2.5	<2.5
Romania			0.3*	0.1			<2.5*	<2.5
Russian Federation			6.4*	4.1			4*	3
former Union of Soviet Socialist Republics								
Rwanda	1.3	2.8	2.8	3.0	24	43	51	36
Saint Kitts and Nevis**	11.7	5.5	8.2	4.5	26	13	19	11
Saint Lucia**	21.2	10.5	9.9	7.5	19	8	7	5
Saint Vincent and the Grenadines**	14.1	24.3	30.7	14.2	14	22	27	12
Samoa**	22.3	17.7	18.2	7.1	14	11	11	4
Sao Tome and Principe**	24.7	21.1	26.7	18.3	26	18	20	12
Saudi Arabia	0.2	0.7	0.8	0.9	<2.5	4	4	4
Senegal	1.3	1.8	2.2	2.2	23	23	25	23
Serbia and Montenegro			0.5*	1.1			5*	10
former Socialist Federal Republic of Yugoslavia								
Seychelles**	10.5	10.1	8.7	7.2	17	14	11	9
Sierra Leone	1.3	1.9	1.8	2.4	40	46	44	50
Singapore								
Slovakia			0.2*	0.3			4*	6
Slovenia			0.1*	0.1			3*	3
Solomon Islands		0.1	0.1	0.1	19	33	21	20
Somalia								
South Africa	1.7	2.1	2.6	1.9	6	6	6	4
Spain					<2.5	<2.5	<2.5	<2.5
Sri Lanka	3.0	4.8	4.6	4.1	20	28	26	22
Sudan	5.7	7.9	6.5	8.8	29	31	23	27
Suriname	0.1	0.1			18	13	10	10
Swaziland	0.1	0.1	0.2	0.2	15	14	23	19

TABLE A11 *(cont.)*

Countries	Number of people undernourished *(Millions)*				Proportion of undernourished in total population *(Percentage)*			
	1979–1981	1990–1992	1995–1997	2001–2003	1979–1981	1990–1992	1995–1997	2001–2003
Sweden					<2.5	<2.5	<2.5	<2.5
Switzerland					<2.5	<2.5	<2.5	<2.5
Syrian Arab Republic	0.3	0.7	0.6	0.6	3	5	4	4
Tajikistan			1.2*	3.8			22*	61
Thailand	10.7	16.8	13.7	13.4	23	30	23	21
The former Yugoslav Republic of Macedonia			0.3*	0.1			15*	7
Togo	0.8	1.2	1.0	1.2	30	33	25	25
Tonga								
Trinidad and Tobago	0.1	0.2	0.2	0.1	6	13	15	11
Tunisia	0.2	0.1	0.1	0.1	3	<2.5	<2.5	<2.5
Turkey	1.4	1.0	1.5	2.0	3	<2.5	<2.5	3
Turkmenistan			0.5*	0.4			12*	8
Uganda	4.1	4.2	5.4	4.6	33	24	26	19
Ukraine			2.4*	1.2			<2.5*	3
United Arab Emirates		0.1	0.1	0.1	<2.5	4	<2.5	<2.5
United Kingdom					<2.5	<2.5	<2.5	<2.5
United Republic of Tanzania	5.2	9.9	15.7	16.1	28	37	50	44
United States of America					<2.5	<2.5	<2.5	<2.5
Uruguay	0.1	0.2	0.1	0.1	3	7	4	3
Uzbekistan			1.7*	6.7			8*	26
Vanuatu**	13.4	19.0	21.9	24.0	11	12	12	12
Venezuela (Bolivarian Republic of)	0.6	2.3	3.4	4.5	4	11	15	18
Viet Nam	19.7	20.6	16.7	13.8	37	31	23	17
Yemen	3.2	4.2	5.6	7.1	39	34	36	37
Zambia	1.7	4.0	4.6	5.1	29	48	48	47
Zimbabwe	2.0	4.8	5.6	5.7	28	45	47	45
World	**944.8**	**855.1**	**833.9**	**856.4**	**21**	**16**	**15**	**14**

* Data refer to 1993–95
** Number of undernourished is expressed in thousands

TABLE A12
Life expectancy and child mortality

Countries	Life expectancy at birth (Years)					Child mortality rate (Per thousand live births)				
	1980	1990	1995	2000	2003	1980	1990	1995	2000	2003
Afghanistan	40	42				280	260	257		
Albania	69	72	71	74	74	72	45	34	25	21
Algeria	59	67	70	71	71	134	69	55	45	41
American Samoa										
Angola	41	46	47	47	47	265	260	260	260	260
Antigua and Barbuda	71	74	75	75	75			21	15	12
Argentina	70	72	73	74	75	38	28	25	20	20
Armenia			72	74	75			49	37	33
Australia	74	77	78	79	80	13	10	6	6	6
Austria	72	76	77	78	79	17	9	7	6	5
Azerbaijan			69	65				98	93	91
Bahamas	68	69	69	69	70	35	29	23	17	14
Bahrain	68	71	72	73	73	30	19	18	16	15
Bangladesh	49	55	58	61	62	205	144	116	82	69
Barbados	72	75	76	75	75	29	16	16	14	13
Belarus			69	68	68			18	17	17
Belgium	73	76	77	78	78	15	9	9	6	5
Belize	69	73	73	74	71	70	49	44	41	39
Benin	48	52	53	53	53	214	185	170	160	154
Bhutan			60	62	64	227	166	133	100	85
Bolivia	52	58	61	63	64	170	120	92	75	66
Bosnia and Herzegovina			73	73	74			19	18	17
Botswana	58	57	50	39	38	84	58	66	101	112
Brazil	63	66	67	68	69	86	60	48	39	35
Brunei Darussalam	71	74	75	76	77	22	11	9	7	6
Bulgaria	71	72	71	72	72	24	16	18	16	15
Burkina Faso	44	45	45	44	43	247	210	207	207	207
Burundi	47	44	42	42	42	195	190	190	190	190
Cambodia	40	50	53	54	54	190	115	120	135	140
Cameroon	50	54	54	50	48	173	139	156	166	166
Canada	75	77	78	79	79	13	9	7	6	6
Cape Verde	61	65	68	69	69	80	60	50	40	35
Central African Republic	46	48	46	43	42	189	180	180	180	180
Chad	42	46	48	48	48	225	203	200	200	200
Chile	69	74	75	76	76	39	19	14	12	9
China	67	69	69	70	71	64	49	46	40	37
Colombia	66	68	70	71	72	56	36	29	24	21
Comoros	50	56	59	61	62	165	120	100	82	73
Congo	50	51	51	51	52	125	110	108	108	108
Costa Rica	73	77	77	78	79	26	17	16	12	10
Côte d'Ivoire	49	50	48	46	45	172	157	175	188	192
Croatia			72	73	74			11	8	7

TABLE A12 *(cont.)*

Countries	Life expectancy at birth (Years)					Child mortality rate (Per thousand live births)				
	1980	1990	1995	2000	2003	1980	1990	1995	2000	2003
Cuba	74	75	76	77	77	22	13	10	9	8
Cyprus	75	77	77	78	78	20	12	10	7	5
Czech Republic			73	75	75			8	5	4
former Czechoslovakia										
Democratic People's Republic of Korea	67	66	61	61	63	43	55	55	55	55
Democratic Republic of the Congo	49	52	49	46	45	210	205	205	205	205
Denmark	74	75	75	77	77	10	9	7	5	4
Dominica		73	75	76	77		23	20	16	14
Dominican Republic	63	66	67	67	67	92	65	53	40	35
Ecuador	63	68	68	70	71	98	57	43	32	27
Egypt	56	63	65	68	69	173	104	71	49	39
El Salvador	57	66	69	70	70	118	60	47	40	36
Equatorial Guinea	43	47	49	51	52	243	206	175	156	146
Eritrea			50	51	51			122	97	85
Estonia			68	71	71			20	11	9
Ethiopia			44	42	42			192	176	169
former People's Democratic Republic of Ethiopia										
Fiji	64	67	68	69	70	42	31	25	22	20
Finland	73	75	76	78	78	9	7	4	5	5
France	74	77	78	79	79	13	9	7	5	5
French Polynesia		70	71	73	74					
Gabon	48	52	52	53	53	115	92	91	91	91
Gambia	40	49	52	53	53	231	154	137	128	123
Georgia			73	73	74			45	45	45
Germany	73	75	76	78	78	16	9	7	6	5
Ghana	53	57	59	57	54	157	125	110	100	95
Greece	74	77	78	78	78	23	11	9	6	5
Guatemala	57	61	64	65	66	139	82	64	53	47
Guinea	40	44	46	46	46	300	240	208	175	160
Guinea-Bissau	39	42	44	45	46	290	253	235	215	204
Guyana	61	64	64	63	62	90	90	84	74	69
Haiti	51	53	54	53	52	195	150	137	125	118
Honduras	60	65	66	66	66	103	59	49	43	41
Hungary	69	69	70	71	73	26	16	12	9	8
Iceland	77	78	79	80	80	8	5	5	4	4
India	54	59	61	63	63	173	123	104	94	87
Indonesia	55	62	64	66	67	125	91	66	48	41
Iran (Islamic Republic of)	58	65	67	69	69	130	72	55	44	39
Iraq	62	61				83	50			
Ireland	73	75	76	76	78	14	9	7	6	6
Israel	73	76	77	78	79	19	12	7	6	6

TABLE A12 *(cont.)*

Countries	Life expectancy at birth (Years)					Child mortality rate (Per thousand live births)				
	1980	1990	1995	2000	2003	1980	1990	1995	2000	2003
Italy	74	77	78	80	80	17	10	7	5	4
Jamaica	71	73	74	75	76	34	20	20	20	20
Japan	76	79	80	81	82	11	6	6	5	4
Jordan		69	70	72	72	65	40	35	30	28
Kazakhstan			65	64	61			67	73	73
Kenya	55	57	53	47	45	115	97	111	120	123
Kuwait	71	75	76	77	77	35	16	14	10	9
Kyrgyzstan			66	66	65			74	70	68
Lao People's Democratic Republic	45	50	52	54	55	200	163	134	105	91
Latvia			66	70	71			20	13	12
Lebanon	65	68	69	70	71	44	37	34	32	31
Lesotho	53	58	51	41	37	155	120	103	91	84
Liberia	51	45	44	47	47	235	235	235	235	235
Libyan Arab Jamahiriya	61	69	70	72	73	70	42	29	20	16
Lithuania			69	72	72			16	12	11
Luxembourg	73	75	76	78	78	16	9	6	6	5
Madagascar	51	53	53	55	56	175	168	156	137	126
Malawi	44	45	42	39	38	265	241	216	188	178
Malaysia	67	71	72	73	73	42	21	12	9	7
Mali	42	45	44	42	41	300	250	233	224	220
Malta	73	76	77	78	79	17	14	11	8	6
Mauritania	47	49	50	51	51	175	183	183	183	183
Mauritius	66	69	70	72	72	40	25	23	20	18
Mexico	67	71	72	73	74	74	46	36	30	28
Moldova			66	68	67			36	33	32
Mongolia	58	63	64	65	66	140	104	89	75	68
Morocco	58	64	66	68	69	144	85	61	46	39
Mozambique	44	43	45	42	41	220	235	212	178	158
Myanmar	52	55	56	57	57	134	130	117	110	107
Namibia	53	58	57	47	40	108	86	77	69	65
Nepal	48	54	56	59	60	195	145	120	95	82
Netherlands	76	77	77	78	79	11	8	6	6	5
New Caledonia	68	71	72	73	74					
New Zealand	73	75	77	79	79	16	11	7	6	6
Nicaragua	59	65	67	69	69	120	68	52	43	38
Niger	40	42	44	45	46	320	320	295	270	262
Nigeria	46	49	50	47	45	216	235	238	205	198
Norway	76	77	78	79	79	11	9	6	4	4
Occupied Palestinian Territory						65	40	33	27	24
Oman	60	69	72	74	74	95	30	18	14	12
Pakistan	55	59	61	63	64	153	130	118	108	103
Panama	70	72	74	75	75	46	34	30	26	24

TABLE A12 *(cont.)*

Countries	Life expectancy at birth (Years)					Child mortality rate (Per thousand live births)				
	1980	1990	1995	2000	2003	1980	1990	1995	2000	2003
Papua New Guinea	51	55	57	57	57	108	101	98	95	93
Paraguay	67	68	69	70	71	61	37	34	31	29
Peru	60	66	68	69	70	126	80	60	42	34
Philippines	61	66	68	69	70	81	63	50	40	36
Poland	70	71	72	74	75	24	19	15	9	7
Portugal	71	74	75	76	76	31	15	9	6	5
Qatar	67	72	74	75	75	32	25	18	16	15
Republic of Korea	67	70	72	73	74	18	9	6	5	5
Romania	69	70	70	70	70	36	32	25	22	20
Russian Federation			65	65	66			22	21	21
former Union of Soviet Socialist Republics										
Rwanda	46	40	38	40	40	219	173	209	203	203
Saint Kitts and Nevis		67	69	71	72		36	30	25	22
Saint Lucia	68	71	71	72	74		24	21	19	18
Saint Vincent and the Grenadines	67	71	72	73	73		26	21	25	27
Samoa	63	66	68	69	70	98	42	29	26	24
Sao Tome and Principe		62	64	65	66		118	118	118	118
Saudi Arabia	61	69	71	73	73	85	44	34	29	26
Senegal	45	50	52	52	52	218	148	143	139	137
Serbia and Montenegro			72	73	73			19	16	14
former Socialist Federal Republic of Yugoslavia										
Seychelles		70	71	72	73		21	20	17	15
Sierra Leone	35	35	36	37	37	336	302	293	286	284
Singapore	72	74	76	78		13	8	5	4	3
Slovakia			72	73	73			12	9	8
Slovenia			73	75	76			7	5	4
Solomon Islands	60	65	67	69	70	56	36	30	25	22
Somalia	43	42				225	225			
South Africa	57	62	58	48	46	91	60	59	63	66
Spain	75	77	78	79	80	16	9	7	5	4
Sri Lanka	68	70	71	73	74	48	32	25	20	15
Sudan	48	52	55	58	59	142	120	106	97	93
Suriname	66	69	70	70	70	56	48	44	41	39
Swaziland	52	57	58	45	43	143	110	110	142	153
Sweden	76	78	79	80	80	9	6	4	4	3
Switzerland	76	77	78	80	81	11	8	6	6	5
Syrian Arab Republic	62	66	68	70	71	74	44	31	22	18
Tajikistan			68	67	66			123	120	118
Thailand	64	69	69	69	69	58	40	34	29	26
The former Yugoslav Republic of Macedonia			72	73	74			25	14	11
Togo	49	51	49	49	50	175	152	146	142	140

TABLE A12 *(cont.)*

Countries	Life expectancy at birth (Years)					Child mortality rate (Per thousand live births)				
	1980	1990	1995	2000	2003	1980	1990	1995	2000	2003
Tonga		69	70	71	72		27	24	21	19
Trinidad and Tobago	68	71	72	73	72	40	24	18	20	20
Tunisia	62	70	71	73	73	100	52	37	28	24
Turkey	61	66	67	68	69	133	78	60	45	39
Turkmenistan			66	65	65			89	99	102
Uganda	48	47	44	43	43	185	160	156	145	140
Ukraine			67	68	68			24	21	20
United Arab Emirates	68	74	75	75	75	27	14	11	9	8
United Kingdom	74	76	77	77	78	14	10	7	7	6
United Republic of Tanzania	50	50	49	44	43	175	163	164	165	165
United States of America	74	75	76	77	77	15	10	9	9	8
Uruguay	70	73	73	74	75	42	24	23	17	14
Uzbekistan			69	68	67			75	71	69
Vanuatu		65	67	68	69	110	70	56	44	38
Venezuela (Bolivarian Republic of)	68	71	72	73	74	42	27	26	23	21
Viet Nam	60	65	67	69	70	66	53	44	30	23
Yemen		52	54	57	58		142	126	117	113
Zambia	51	49	45	38	37	155	180	182	182	182
Zimbabwe	55	56	49	40	39	108	80	90	117	126
World	**63**	**65**	**66**	**66**	**67**	**118**	**95**	**89**	**83**	**80**

- **Glossary of terms**
- **References**
- **Special chapters of** *The State of Food and Agriculture*
- **Selected publications**

Glossary of terms

Agricultural biodiversity
Agricultural biodiversity is a broad term that includes all components of biological diversity of relevance to food and agriculture and all components of biological diversity that constitute the agro-ecosystem: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, that are necessary to sustain key functions of the agro-ecosystem, its structure and processes.

Biological diversity
The variability among living organisms from all sources including, *inter alia*, 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.

Buyer (of an environmental service)
An individual or group who would be positively affected by more of the service and therefore willing to provide some financial incentive for its provision.

Carbon sequestration
Storage of carbon for an extended period in a chemical form that does not contribute to global warming. The most common methods of carbon sequestration are above- and below-ground additions to biomass, additions to soil organic carbon and additions to stocks of inorganic carbon compounds that do not break down easily (e.g. calcium carbonate).

Direct use value
The value derived from marketed goods and services, normally involving private benefits.

Ecosystem
A dynamic complex of plant, animal, and micro-organism communities and the non-living environment interacting as a functional unit.

Ecosystem services
The benefits people obtain from ecosystems.

Ecosystem externality
An uncompensated provision of an ecosystem service (positive externality) or an unpenalized negative effect on the delivery of ecosystem services (negative externality). *See also* **environmental services**.

Environmental services
The subset of ecosystem services characterized by externalities.

Existence value
The benefits people obtain from knowing that an ecosystem service exists, even if they will never actually use the service themselves. *Also referred to as* **non-use value**.

Farmer
All producers of agricultural products, including crops, livestock, fish, and forest products.

Indirect use value
The benefit that people derive indirectly from services such as watershed protection, carbon sequestration, and biodiversity conservation.

Non-use value
The benefits people obtain from knowing that an ecosystem service exists, even if they will never actually use the service themselves. *Also referred to as* **existence value**.

Opportunity cost
The benefits that producers would have to forgo in order to change their practices, for example in order to provide an environmental service.

Option value
The value associated with preserving a future possibility for using an ecosystem service.

Payments for environmental services
Voluntary cash transfers between buyers and sellers for the provision of an environmental service.

Public good
A good whose use by one person does not affect its use by another person and for which it is not possible to exclude users.

Seller (of an environmental service)
An individual or group who could modify their practices to provide more of the environmental service. This report focuses on farmers.

Use value
The sum of **direct use value** and **indirect use value.**

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