A Green Growth Strategy for Food and Agriculture

Preliminary Report

OECD

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Foreword

This preliminary report is part of the OECD Green Growth Studies series. The OECD's synthesis report *Towards Green Growth* was launched at the OECD Ministerial Council Meeting on 25-26 May 2011. The present report was prepared by Wilfrid Legg, with the assistance of Hsin Huang and input from Carl-Christian Schmidt. Other colleagues at the OECD Secretariat also provided comments on earlier drafts. Françoise Bénicourt, Theresa Poincet, Véronique de Saint-Martin, and Noura Takrouri-Jolly provided secretarial and statistical assistance. The report draws on work undertaken in the OECD and on five commissioned consultant reports, prepared by Frank Asche, David Blandford, Alison Burrell, Andy Hall, and Candice Stevens, on various aspects of green growth in the agriculture and fisheries sectors. It also takes into account comments from Delegates to OECD meetings and is released under the responsibility of the Secretary-General. The consultant reports are available on the OECD website at *www.oecd.org/agriculture/greengrowth*.

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Executive Summary

This preliminary report outlines a broad strategy for green growth in the food and agriculture sector. It is part of the OECD's Green Growth Strategy that seeks to define an economic development path that is consistent with long-run environmental protection, using natural resources within their carrying capacity, while providing acceptable living standards and poverty reduction in all countries. The need for green growth arises because a "business as usual" path does not fully account for environmental limits and social concerns.

The key message from this report is that green growth is not only desirable and achievable, it is also essential if the food and nutrition requirements of future generations are to be met. This implies that productivity growth must be increased in a sustainable manner, well functioning markets must provide clear price signals that reflect the scarcity value of natural resources, and property rights must be defined so as to encourage optimal use of resources, both individually and collectively.

Green growth was identified as one of the priorities by Agriculture Ministers at their meeting at OECD in 2010. This green growth strategy for food and agriculture is the OECD's initial response to the Ministerial vision as expressed in their Communiqué:

> *"Ministers recognised that green growth offers opportunities to contribute to sustainable economic, social and environmental development, that agriculture has an important role to play in the process, as do open markets that facilitate the sharing of technologies and innovations supportive of green growth, and that, in this context, care needs to be taken to avoid all forms of protectionism. Climate change presents challenges and opportunities for the agricultural sector in reducing greenhouse gas emissions, in carbon sequestration, and the need for adaptation".*

This report aims to identify the challenges and opportunities that arise in the pursuit of a green growth path for the food and agriculture sector; the role of policies and management practices; and the indicators that could be used to track progress towards green growth.

A green-growth strategy for the food and agriculture sector, encompassing primary agriculture, fisheries, and both the upstream and downstream food supply chain, highlights priorities for attention by policy makers. Food is a necessity of life and food security is a basic interest in all countries. A green-growth strategy aims to ensure that enough food is provided, efficiently and sustainably, for a growing population. This means increasing output while managing scarce natural resources; reducing the carbon intensity and adverse environmental impacts throughout the food chain; enhancing the provision of environmental services such as carbon sequestration, flood and drought control; and conserving biodiversity.

The relationship between agriculture and green growth is complex. The food and agricultural sectors can generate both environmental harm and conserve ecosystem services. This is because the sector both depends on and impacts natural resources (land, water, and biodiversity) in the production process. Moreover, resource endowments and environmental absorptive capacities vary widely across countries and regions, and impacts can differ in the short and long run and at different stages of production and consumption. Thus the context is critical.

The food and agricultural sector has been successful in providing for an increasing and wealthier global population. Productivity growth has been strong, and has exceeded the population growth rate. Innovation and good management practices have boosted crop yields and livestock productivity, aquaculture supplies an increasing share of total fish consumption and the real price of food has declined over the long term. Many farmers and fishers are aware of the importance of their economic dependence on conserving natural resources and ecosystems, and governments have started reorienting their policy priorities to take account of the environmental consequences of food and agriculture production and consumption. As a result, there have been some improvements in the environmental performance of food and agriculture.

Nevertheless, progress has been uneven. In some countries and regions productivity growth has been low, and growth has not been sustainable. There is growing pressure on and depletion of natural resources, including land, water, marine ecosystems, fish stocks, forests, and biodiversity – which are fundamental to sustainable production. These pressures have reached critical levels in some areas. Agriculture and fisheries are particularly vulnerable to climate change and will need to adapt to changing patterns of precipitation, temperature and extreme weather events. The over-arching policy challenge is to create the right incentives that would optimise resource use from an economic, environmental and social perspective.

Policies influence the productive efficiency and environmental performance of agriculture and fisheries. Their impacts on the environment vary according to the nature and the conditions under which policy instruments are implemented. Effective resource management programmes and environmental regulations can limit the negative environmental effect of policies. Caution is needed in making broad generalizations: not all government transfers (support) are harmful to growth and the environment; not all environmentally motivated subsidies are beneficial for the environment; and the absence of government support is no guarantee that the desired level of environmental performance will be achieved. In all cases, better targeting of policies to meet clearly identified objectives is needed.

The available scientific evidence suggests that business as usual will lead to a future in which economic growth will be constrained by natural resource limits, putting the security of food supplies at risk. Identifying good policies, overcoming impediments and embracing opportunities to implement policies that will move food and agriculture on to a green-growth pathway, and developing the means to measure progress are all important. A comprehensive and coherent strategy is needed:

- **To increase productivity in a sustainable manner**: Increasing resource use efficiency throughout the supply chain will not only ensure more production relative to inputs used, but also conserve scarce natural resources and deal with waste. *This means according higher priority to research, development, innovation, education and information applied to the agriculture and food sectors.*

- **To ensure that well-functioning markets provide the right signals**: Prices that reflect the scarcity value of natural resources as well as the positive and negative environmental impacts of the food and agriculture system will contribute to resource use efficiency. *This means reducing economically and environmentally harmful subsidies while encouraging environmentally friendly measures and consumer information; improving the functioning of markets, taking account of social consequences; further integrating domestic and global markets, bearing in mind the impacts of production trade on the environment and of environmental policies on production and trade; applying the polluter pays principle through charges and regulations; providing incentives for the supply of environmental goods and services; and reducing waste and post-harvest losses.*
- **To establish and enforce well defined property rights**: Property rights help ensure optimal resource use, in particular for marine resources, land and forests, greenhouse gas emissions, and air and water quality. When resources are essentially free to private participants it can encourage over-exploitation, resulting in environmentally and socially sub-optimal outcomes. *This is a complex area and is increasingly of a global rather than purely domestic nature, and requires further attention.*

Moving beyond this broad strategy is necessary if actionable advice is to be provided to governments. More concrete policy proposals that illustrate – without prescribing – how alternative policy sets can contribute to a greener growth model for food and agriculture will be the focus of upcoming work. In this context, particular attention will be paid – in collaboration with the FAO – to the specific circumstances of developing countries.

Ultimately, the objective would be to institute an ongoing process of policy monitoring and evaluation. Over time, this could become an approach to increase collective knowledge about how policies contribute to green growth. It would be a way for countries to measure their own progress and learn from the experience of others. Most importantly, it would be a step towards reframing growth to better manage natural assets and those environmental risks that would otherwise undermine economic growth and development.

Chapter 1

Background

Green growth requires that in the coming decades enough food is provided for an increasing, and increasingly affluent, global population while reducing environmental pressure.

This preliminary report outlines a broad policy strategy that can facilitate a greener food and agriculture sector.

The pressures on natural resources, climate change and the recent economic crisis have highlighted the need for a greener model of growth. The overarching objective of the OECD's Green Growth Strategy (GGS) is to help governments identify policy priorities that can contribute to the delivery of economic growth that is also environmentally sustainable and socially equitable. Green growth is the pursuit of economic growth and development, while preventing environmental degradation, biodiversity loss and unsustainable natural resource use.

There is considerable interest in understanding the contribution of the global food system to green growth, and the role of policies in moving towards a greener growth model. Green growth was identified as one of the priorities by Agriculture Ministers at their meeting in the OECD in 2010 (*www.oecd.org/agriculture/ministerial*). In their Communiqué,

> *"Ministers recognised that green growth offers opportunities to contribute to sustainable economic, social and environmental development, that agriculture has an important role to play in the process, as do open markets that facilitate the sharing of technologies and innovations supportive of green growth, and that, in this context, care needs to be taken to avoid all forms of protectionism. Climate change presents challenges and opportunities for the agricultural sector in reducing greenhouse gas emissions, in carbon sequestration, and the need for adaptation."*

This means ensuring that in the coming decades enough food is provided for an increasing, and an increasingly affluent, global population while reducing environmental pressure on the sector ("sustainable intensification"). This requires:

- improving the resource efficiency of production and reducing waste along the food supply chain;
- managing scarce natural resources – especially land, water, fish stocks, and biodiversity in a sustainable manner;
- reducing the carbon intensity of production throughout the food supply chain; and
- internalising harmful environmental impacts, while enhancing the provision of ecosystem services that provide critical life-support functions such as biodiversity, carbon sequestration, and flood and drought control.

This report recognizes that while there is no unique policy pathway to greening the food system applicable to all countries, inaction ("business as usual") is not a costless option. This report is preliminary as it also recognizes that achieving a greener model of food and agriculture growth will require concerted action by national governments, as well as by the private sector. The implication is that the broad policy strategy outlined here needs also to be translated into more concrete policy advice for governments at different stages of development and with different resource endowments. In addition, the particular needs of developing countries warrants further attention.[1] Work will continue over the coming period to further refine a green growth strategy for food and agriculture.

Note

1. Further work is underway in collaboration with the FAO.

Chapter 2

The need for green growth for food and agriculture

Future challenges relating to greater pressure on natural resources and climate change imply that a "business as usual" growth model is not a viable option. Green growth places strong emphasis on the complementarities between the economic, social and environmental dimensions of sustainable development.

The food and agriculture sector has been successful in providing for growing global demand over a long period of time. The rate of growth in total factor productivity in agriculture has exceeded that in many other sectors, and has exceeded the population growth rate. There is a close and dynamic link between increases in population and income and productivity advances in the sector. Labour leaving agricultural activities has helped fuel economic expansion and employment growth in the rest of the economy. Crop yields and livestock productivity have risen substantially and the real price of food has declined over the long term.[1] The share of consumers' expenditure devoted to food has fallen in many countries and this has increased the amount of disposable income available for purchases of other goods and services. Many farmers and fishers are aware of the importance of their economic dependence on conserving natural resources and ecosystems, and governments have started to re-orientate their policy priorities to take account of the environmental consequences of food and agriculture production, which has led to some improvements in environmental performance.

Nevertheless, this broad picture is not true in all countries and at all times. In some countries and regions productivity growth has been low, and regional food crises and famines persist. The pressures on and depletion of natural resources (fish stocks, forests, and water), environmental damage from some production activities (e.g. nutrient run-off, soil erosion) and management practices, and waste in the food supply chain are causes for concern.

Moreover, the outlook may not be as positive as the past. First, there is a need to increase the rate of productivity growth in the sector, in particular in less developed countries. Second, there are greater pressures on land, water, energy, landscape and biodiversity resources – which are fundamental to agricultural and food production. Third, the food and agriculture sector is particularly vulnerable to climate change and will need to adapt to changing patterns of precipitation, temperature and extreme weather events. In other words, a scenario of a "business as usual" pathway is not one that can be comfortably presumed in coming decades.

Green growth is characterised by the following.

- Coherent domestic, trade and multilateral policies working in tandem with markets to provide the right signals to input suppliers, producers, processors, retailers, food service, and consumers in the food supply chain that can contribute to realising the economic growth, social equity and environmental performance potential.
- Recognition that there is not necessarily a conflict between growth and the environment if government policies provide the appropriate incentives that align economic, environmental and social other goals. Economic growth in the food and agriculture sector depends on the sustainable management of natural resources (water, air, soil, fish stocks, biodiversity) and ecosystem services.
- Placing a higher priority on innovation, which is an essential element of improving sector performance.
- An understanding that how growth occurs (production methods) is at least as important as how much growth takes place.

The concept of green growth places a strong emphasis on the complementarities between the economic, social and environmental dimensions of sustainable development. Nevertheless, there are always choices and trade-offs to be made across these dimensions and across time. In addition, the policy mix chosen by any country can have different welfare and equity implications for other countries that face different economic, environmental and social structures.

The green growth model recognizes that steps to protect and conserve environmental resources can be a driver for national and global economic progress. Economic growth is a necessary – if not sufficient – condition to address many of the social and equity concerns faced by societies. Environmental protection not only enhances long-term economic performance through a more sustainable use of the resource base, but can also contribute to equity: natural resource and environmental degradation (especially the pollution of fresh water, the mining of soil fertility and depletion of fish stocks) impacts most heavily on the poor.

It should be noted that there is an important time dimension to the green growth concept: in the short run it is possible that economic growth, as measured by GDP, could be lower when taking environmental externalities into account, but higher in the long run in so far as the natural resources on which future growth depends are better managed and conserved (Box 2.1). This inter-temporal trade-off between the short and the long run may be particularly important to less developed countries where basic needs are not fully met at present. It may be difficult to reconcile short term priorities, in particular food security, against the long term need to transition to green growth.

The potential for growth in food production while respecting the environment also varies across countries. A stylised summary of the main characteristics of the "conventional" economic and "green growth" models that are also relevant to food and agriculture is given in Table 2.1. In practice, there is a wide spectrum between the two economic models shown in the table. In this context it should be noted that the agricultural sectors in many OECD countries already incorporate some of the elements of the green growth strategy.

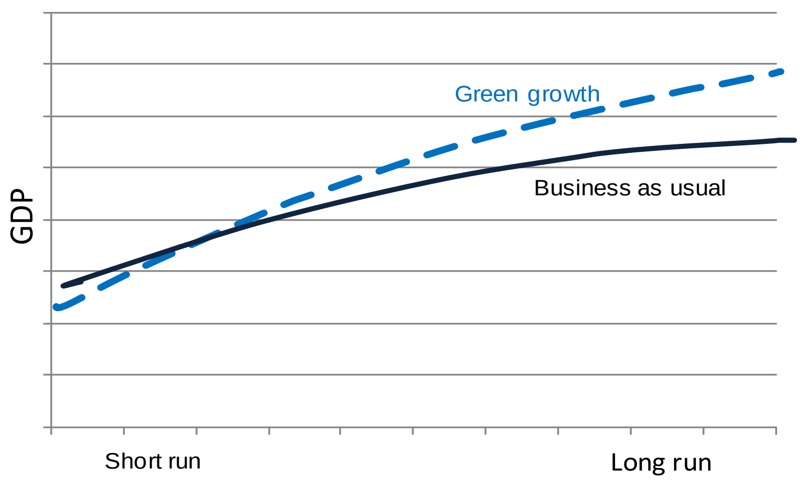
Moving towards greener growth in the food and agricultural sectors needs to be built on a strong scientific, evidence-based foundation. It will involve both synergies and trade-offs which will change over time. The implications of green growth for agriculture and the contributions of agriculture to green growth can be reciprocal or incongruent. Table 2.2 gives a broad view of the possible synergistic and conflicting effects of green growth on agriculture across and within the different pillars of sustainability: economic, environmental and social. In the cells on the main diagonal, the two perspectives are mutually reinforcing, as indicated by the positive sign. Policy pairs below the main diagonal may work against each other, particularly in the short-term (negative sign), while paired interventions within and above the main diagonal are mutually enhancing (positive sign).

In the short-term, green growth policies which place a premium on environmental protection may constrain agricultural and fisheries output, reduce global food supply and entail adjustments in the use of human, financial and natural resources. Adaptation measures may be helpful in the transition towards green growth. But the implications of green growth for agriculture and the food system in the longer-term should be mutually-reinforcing in terms of environmental sustainability (including avoiding resource depletion), economic growth and social well-being. The complementarities and differences between green growth and agriculture are reviewed in more detail below in terms of conventional economic factors (e.g. productivity, farm incomes, employment) and environmental factors (e.g. natural resource use, pollution, biodiversity), as well as broader social factors (e.g. food security, equity, poverty reduction, rural development). This report is heavily focused on primary agriculture and further work is required to include the important links between agriculture, fisheries and the entire food supply chain.

Box 2.1. Comparing output: A stylized view of business as usual and green growth

It can be argued that green growth will involve an opportunity cost in terms of reduced economic growth: some resources are consumed by actions and activities to protect environmental quality, or some output will be foregone. But this trade-off arises precisely because the cost of environmental protection is not accounted for under "business as usual", and therefore in the short run output would be higher than under a green growth trajectory. However, because production practices that deplete and/or degrade the natural resource base needed for future growth are unsustainable, in the long run the situation would be reversed. Under green growth the resource base would be preserved -or even enhanced if damages are reversible- thus leading to higher output than "business as usual". The figure below represents possible future trajectories of growth in GDP over time. It is highly stylized -the business as usual path may be flatter or even negative should implied resource use be unsustainable. Should the vertical axis depict "well-being" rather than GDP the gap between the green growth and business as usual paths might be greater. This implies that rethinking what is measured by economic growth is necessary, because single dimensional measures such as GDP do not capture the well-being of society.

Business as usual and green growth



Source: OECD Secretariat.

Table 2.1. Conventional economic and green growth models

	Conventional economic model	Green growth model
Economic-environment links	Environmental protection viewed as competing with economic growth	Environmental protection and provision of ecological services viewed as key components of economic growth
Planning perspective	Short- to medium-term perspective	Long-term perspective
Policy perspective	Government policy interventions to correct market failures	Government policy interventions to correct for market failures; encourage green technologies; management practices, structural changes, and changing consumer behaviour to facilitate adjustment
Scope of environmental responsibility	Government environmental agencies and private sector units responsible for environmental management	All government agencies, private sector units, and wider societal stakeholders responsible for environmental management
Environmental policy interventions	Improvements to existing modalities of consumption and production	Changes to patterns of economic activity to reduce environmental pressure, enhance provision of ecosystem services
Economic policy interventions	Taxes and charges on environmental externalities	Targeted support and fiscal incentives to green innovation, businesses and jobs, taxes and charges on environmental externalities
Economic indicators	Measure rate and level of economic growth, e.g. GDP, productivity	Measure quantitative and qualitative aspects of growth or well-being, including environmental quality, resource use efficiency
Environmental indicators	Measure resource use and output of pollutants	Measure linkages between economic activity, resource and energy use and environmental damage, and provision of environmental goods and services, measure output of pollutants and GHG emissions
Policy indicators	Overall level of support and production effects of changing levels of support	Changes in composition of support and production and environmental effects of changing policy measures

Table 2.2. Agriculture and green growth: illustrative examples of complementarities (+) and differences (-)

	Economic contribution of agriculture to green growth	**Environmental contribution of agriculture to green growth**	**Social contribution of agriculture to green growth**
Economic contribution of green growth to agriculture	Agriculture as a driver of economic development while Green Growth can improve agricultural performance **(+)**	Green labels and payments for eco-services can contribute to economic returns in agriculture **(+)**	Higher skilled jobs and activities can diversify and contribute to rural development **(+)**
Environmental contribution of green growth to agriculture	Environmental measures may slow agricultural growth in the short-term and may result in … **(-)**	Green Growth will yield environmental co-benefits in agriculture through resource conservation and sustainable use **(+)**	Reform of support to relieve environmental stress and payments for ecosystem services can enhance farm incomes in rural areas **(+)**
Social contribution of green growth to agriculture	Green Growth may detract from efforts to improve food security in the short-term **(-)**	Green Growth will necessitate structural adjustment measures in transition periods **(-)**	Food security, poverty reduction, and rural development will be enhanced in the long-run through Green Growth **(+)**

Note

1. It is too early to establish whether the increase in prices of 2007-08 represents a turning point in the long term decline in real food prices, although there are clear factors putting upward pressure on prices.

Chapter 3

Future challenges and opportunities

The challenges facing agriculture are complex. Global issues such as food insecurity, climate change, water availability, biodiversity and associated ecosystem service loss need to be addressed simultaneously. Innovation in food and agriculture is a key element in meeting those challenges. Increased productivity needs to balance immediate demands for feeding the world against future concerns for environmental sustainability.

As a major provider of one of the essentials of life and an industry that is heavily reliant on climatic conditions, the outlook for food demand and the potential impact of climate change are particularly important for pursuing a green growth strategy in the sector.

Increasing demand for food and agricultural raw materials

The United Nations projects that by 2050 world population will increase to over 9 billion, compared to 6.9 billion currently, an increase of roughly one third (UN, 2010). FAO estimates that in order to achieve a global average food consumption of 3 130 calories per person per day by 2050 an additional billion tonnes of cereals and 200 million tonnes of meat would need to be produced annually (compared to levels in 2005/07). Meeting these targets will require on one hand a combination of higher yields, higher cropping intensity, higher resource efficiency and some expansion in agricultural land use where feasible (primarily in sub-Saharan Africa and Latin America)[1] and on the other hand efforts to reduce food waste – especially in industrialized countries (Box 3.1) – and post-harvest losses – especially in developing countries. The land equipped for irrigation would need to expand by some 32 million hectares (11%) and harvested irrigated land by 17%, primarily in developing countries.

As noted earlier, this carries environmental risks. For example, OECD (2005) estimates that an increase in global production of food crops by 16%, relative to 2005, will be a major factor contributing to a reduction in biodiversity, mostly due to the conversion of grasslands and forested area to farmland. Bruinsma (2009) estimates that with the projected expansion in output to 2050 water consumption by agriculture would increase by almost 11% relative to 2005/07. It is clear from these estimates that responding to growth in the world's population will place increased pressure on the natural resources used by the sector and on environmental quality. Achieving green growth in agriculture to meet the demands of an expanding world population will pose a significant challenge.[2]

Global demand for agricultural products has been strong in recent years, partly as a result of dietary changes, particularly an expanding demand for animal products associated with economic growth in emerging and developing countries, and the increased use of grains and oilseeds to produce first generation biofuels. Strong demand, in combination with a number of other factors such as drought in several key grain-producing regions and a sharp increase in petroleum prices, resulted in a virtual doubling of world prices for wheat, coarse grains, rice and oilseed crops between 2005 and 2007 (OECD, 2008), followed by a sharp falls and in 2010-11 another upward surge in some commodity prices. Such dramatic changes in prices are not frequent and there is considerable uncertainty about future trends in prices. As noted earlier, productivity growth has played a major role in allowing agriculture to meet the food and raw material needs of an expanding global population at reasonably stable prices and to contribute to economic growth in the rest of the world economy. The future rate of productivity growth in agriculture will be a key determinant of future food prices. It follows that the further investments in innovation, R&D, and technology transfer will be key factors in determining whether green growth objectives can be achieved in meeting this demand.

Box 3.1. Waste in the food chain

All of the challenges of the food and agriculture chain are deepened by the growing share of food that is discarded uneaten. When food is discarded, all of the embodied energy and resources that were used in its production, including related greenhouse gas emissions, are effectively wasted. While some losses are unavoidable in transforming commodities into food ready for the table, excessive waste occurs at every stage of the food production system. Examples include: discards and by-catch from fisheries, unharvested field leavings, losses in storage, transportation and processing, unsold retail inventories and finally waste by consumers at home and in restaurants.

How important is food waste? Estimates are that around 30% (Gooch et al., 2010, Lundqvist 2009, Kantor *et. al*., 1997) of all food produced in developed countries is discarded , most of that by the final consumer and representing food that was safe and nutritious at the time of its disposal. In developing countries, maybe half that amount is wasted, mostly lost in the transit between farmers' and consumers' due to poor infrastructure. The total amount of food wasted amounts to a significant proportion of the estimated increase in food supply required between now and 2050.

Reducing the amount of food that is wasted uneaten directly increases the available food supply, while at the same time reducing the pressures on the resource base used to produce food and the climate. The principle reason behind the increasing amount of food that is wasted has been the increased availability of food and lower food prices over the past half-century. While higher food prices will reduce waste, there are many other options available to policy makers to reduce food waste without reversing the result of decades of progress. Improved packaging and reduced portion sizes, recovery of edible losses from processors and retailers (trimmings and blemished goods) and improved integration of food banks with the food system are just some of the ways food waste can be reduced. Investments to improve infrastructure in developing and developed countries can also bring large gains, in particular to reduce post-harvest losses in developing countries.

The problem of food waste is a good example of where application of green growth principles can bring large benefits. Supporting innovation and more efficient resource use in a way that leads to economic benefits and new opportunities is at the centre of the green growth strategy. Reducing waste helps free up resources, ensure food for the future, and might save money for the consumer.

Alston *et al.* (2009) note a slowdown in global productivity growth in agriculture since the early 1960s (Annex Table A.3). Average annual increases in yields of 2-3% between 1961-90 in key crops such as maize, rice, soybeans, have been followed by average annual increases of around 1% or less during 1990-2007, with the exception of maize. The growth in output per unit of land has also declined, but the productivity of labour has increased. The authors point to a significant reduction in publically funded research and development over the period as a major factor in the slowdown in productivity growth in agriculture. Whether or not this is the case, their view of declining productivity is consistent with assumptions in FAO projections of future availability of food, i.e. that yields of major crops will increase more slowly in the future than in the recent past (Bruinsma, 2008). There are contrasting views, however. Fuglie (2010) concludes that although the rate of growth in world agricultural output has declined since the 1960s the rate of increase in TFP has actually accelerated. He attributes the lower rate of growth in output to the effects of low commodity prices which have discouraged the employment of additional resources in the agricultural sector.

One implication of recent analysis is that while global agriculture could meet future demands for food to the middle of this century, although this could carry environmental risks, its ability to do so may result in higher prices for food than what has been historically the case. Higher average prices for wheat, coarse grains and oilseeds over the coming decade though continuing to decline in real terms are foreseen over the next decade in the most recent agricultural outlook report of the OECD and the FAO (OECD, 2010a).

The sustained downward pressure on real prices that has been witnessed for many decades has stimulated substantial structural adjustment with many farmers exiting the industry and remaining farms growing in size. These tendencies are unlikely to disappear even if prices are firmer than in the past. The prospect of higher prices will increase concern among poorer consumers, particularly in developing countries. Food security concerns may trigger measures to protect domestic agricultural production or consumption by restricting respectively food imports or exports. Such measures add to international price volatility, and are relatively ineffective in achieving their aims.

Climate change

The most recent assessment by the Intergovernmental Panel on Climate Change (Parry *et al.*, 2007, Table A.4) shows a mixed picture for the impact of climate change on agriculture. Moderate increases in average global temperatures (1-3^{o}C), combined with higher concentrations of carbon dioxide and associated rainfall changes could have a small beneficial impact on crop yields in mid- to high-latitude regions, but are likely to reduce yields in low-latitude regions. Global average temperature increases in excess of 3^{o}C are likely to result in lower yields in all regions. The results from a range of modelling studies suggest that temperature increases above 3^{o}C could result in upward pressure on world cereals prices (Parry *et al.*, 2007) (Annex Table 4). As a result of climatic change, some areas, particularly in Sub-Saharan Africa, could experience a significant increase in the risk of hunger. Perhaps of even greater significance than the long-run impacts on yield (which are fairly uncertain given the current state of knowledge) is that with climate change there is likely to be an increase in the frequency of extreme climatic events, such as heat stress, droughts and flooding as well as increasing risks of fires and pest and pathogen outbreaks. These are likely to increase the variability of agricultural production in many regions, and quite possibly globally.[3]

There are some management actions that farmers might take to deal with the impact of projected climatic changes on their farming activities. These management actions would also generate other environmental and economic co-benefits. These include: adopting different crop varieties that are more resistant to climatic stress and modifying the use of inputs (e.g. fertilizer and water); adopting improved practices for conserving and managing water; altering the timing or location of cropping activities; improving pest, disease and weed management practices and using species with greater resistance to pests and diseases; and using seasonal climatic forecasting to reduce production risk. Policies to mitigate climate change should be consistent with other agricultural and water access policies. The IPCC estimates that the widespread adoption of these practices could provide an estimated yield improvement of up to 10% compared to yields without such adaptation. However, little analysis has been conducted to date of the global costs and the feasibility of such adaptations to climate change in agriculture (Wreford *et al.*, 2010, OECD, 2010b).

Agriculture is a significant source of GHG emissions. One study estimates that in the absence of further abatement measures, annual global emissions of GHG from agriculture are likely to increase[4] by 30% by 2030 when compared to estimated levels in 2005 (McKinsey and Company, cited in Wreford *et al.*, 2010, p. 80). If steps are taken to reduce emissions from agriculture or in sectors closely related to agriculture this could pose a challenge for the sector. Actions that would increase in the price of energy, for example, would have an impact through the use of energy related inputs on farms and in both upstream and downstream industries.

Farmers are adept at economizing on the use of inputs in response to higher prices and regulations. For example, a study of how US farmers adapted to higher energy and fertilizer prices in 2006 showed that 23% of commercial farms (the primary users of purchased inputs) reduced their usage of both energy and fertilizer in response to higher prices (Harris *et al.*, 2008). Lower usage of energy was achieved through such measures as using machinery less intensively and servicing engines more frequently; lower usage of fertiliser was achieved through the greater use of soil testing, changes in plant populations and the use of precision application methods. The study noted that farmers with the highest energy and fertilizer costs and the lowest net incomes were most active in adopting measures to contain input usage suggesting that when changes in input costs become significant for farm profitability farmers pay particular attention to addressing these. Furthermore, there is evidence that some of the measures that farmers could take to change their practices to reduce GHG emissions (e.g. reducing nutrient surpluses, conservation agriculture) are actually win-win, in that they not only achieve reductions in carbon emissions (or its equivalent) but can also increase farm profitability (Wreford *et al. 2010*, OECD, 2010b).

Agriculture (and related activities such as forestry) can make a positive contribution to the mitigation of climate change by acting as a carbon sink. Some changes in existing cultivation practices that help to sequester carbon, such as conservation or low-till methods of crop production vary by region. For example, in the Canadian Prairies no-till methods may increase the use of chemical inputs, but reduce overall production costs and in the longer term tend to have positive impacts on yield due to improved soil structure. Field trials conducted by the *Centre de coopération internationale en recherche agronomique pour le développement* (CIRAD) show that changing from conventional practices to direct-seeding through cover can imply more pesticide use, but only in the short run. In the long run, if applied together with crop-rotation, not only is pesticide use reduced, but yields can be superior given reduced soil disturbance. Other practices include better use of agriculture residues and manure, permanent-cover, and agro-forestry. Furthermore, changes in land use, such as the conversion of cropland to permanent pasture or forest, may add to the pressure on remaining agricultural land to supply the growing demand for food and agricultural products. Consequently, trade-offs may exist between agriculture's potential role in climate change mitigation and the achievement of other environmental objectives (e.g. improving water quality), as well as with the objective of meeting the food demands of an expanding world population.

Climate change is also likely to influence fisheries and aquaculture production in various ways. For capture fisheries, climate change affects fish productivity and distribution through changes in recruitment[5], growth rates and mortality rates, as well as in the migratory patterns of some stocks. From an economic point of view, these changes will result in losers and winners, between countries as well as within national jurisdictions. With respect to aquaculture production, climate change may necessitate changes in the species composition farmed in some areas depending on tolerability of the species to temperature and other changes. Other possible impacts of climate change on aquaculture include changes in feed composition and supply as well as changes in the type, scope and extent of disease outbreaks in fish farms. Relocation of aquaculture production sites, wild harvest landing sites (e.g. ports), and fish processing facilities may be required due to extreme weather events, changing stock distribution and location relative to markets.

The expected changes in the fisheries and aquaculture sectors caused by climate change will require enhanced adaptability and flexibility in fisheries and aquaculture policies in order to be able to quickly and effectively respond as circumstances evolve. While there will continue to be a great deal of uncertainty associated with the interactions between climate change and fisheries and aquaculture over the next several years, fisheries policy makers should now turn their attention to the development and implementation of climate change adaptation strategies. These strategies must also expressly consider social and economic consequences and the distribution of impact across time and between stakeholders.

Natural resources – land, nutrients, biodiversity, water availability and energy

The growing pressures that are likely to be felt by agriculture as a result of increasing demand for its products and the potential effects of climate change are likely to be reflected in land markets. Land, particularly land that is highly productive, is likely to increase in value relative to other assets. During periods of strong agricultural growth agricultural land can be viewed as a desirable asset by both agriculturalists and non-agricultural investors. Hallam (2009) notes the recent rise in investment (in some cases referred to as "land-grabbing") from a number of countries. The main form of investment is either the purchase or the long-term leasing of agricultural land for food production. Hallam notes that land under foreign control is a small proportion of the total land area in most cases and that foreign investment can contribute to the USD 30 billion per year investment in developing countries; this amount is needed if developing countries are to double food production to meet the food needs of their growing populations by 2050. In any event, upward pressure on land prices is likely to be experienced in highly productive regions and this will add to pressure for the more intensive use of that land. Farmers who are faced with high costs of servicing their investment in land will try to maximise net returns and this may lead them to apply more variable inputs to their land, such as fertiliser and other agro-chemicals. The issue of agricultural land management in the urban fringe zones is also relevant (OECD, 2009).

It is generally agreed that there will be sufficient availability of major **crop nutrients**, such as nitrogen and phosphorus[6] (Keyzer *et al.*, 2009). However, the availability of several essential micronutrients (boron, copper, molybdenum and zinc) could become an issue as supplies become increasingly constrained by 2040-50. Higher prices and new technologies will be needed to recover these micronutrients for use in agriculture. Although global reserves of most other nutrients appear to be sufficient for purchases by OECD countries[7], there is likely to be growing pressure on supplies of some, for example, phosphates. However, there is probably around a century's worth of reserves of phosphorous globally, while increasing recycling of nutrients from waste streams will contribute to keeping the long term cost of fertilisers down. There is also often a large potential to reduce the amount of nitrogen and phosphorous used in agriculture without reducing crop yields.[8] There has been some improvement in OECD countries as shown by the decrease in nutrient run-off (as indicated by the nitrogen and phosphorous balances in Figures 5.4 and 5.5).

Agriculture production impacts biodiversity and vice versa in complex ways. These reciprocal impacts could be both positive and negative depending on the farming system and type of biodiversity under consideration. Agriculture can positively contribute to biodiversity by preserving key traits of the agri-ecological landscape and by maintaining domestic and wild species and genetic resources. On the other hand, agriculture can adversely impact biodiversity through expansion of the agricultural land base (e.g. deforestation), via intensification (e.g. excessive input use leading to species loss), or reduction of genetic variability (e.g. limited number of varieties). Yet, where intensification eases pressure for further land expansion elsewhere this can result in net overall benefits to biodiversity, such as the preservation or creation of dedicated areas rich in biodiversity. This also applies to fisheries where activities directly have an effect on other non-targeted fish stocks, for example through "by-catch" and predatory/prey relationships.

Biodiversity is commonly defined in relation to all three levels of biological life: genetic, species, and ecosystem (or landscape). Higher levels of biodiversity have mostly beneficial impacts on agriculture by providing key ecosystem services such as pollination, soil related services, and pest control. Farm genetic diversity is also beneficial to agriculture in terms of a "gene bank" that can be used to select desirable characteristics (e.g. higher yielding varieties, drought-resistance, etc.). Hence, the preservation of genetic variety is an important contribution to achieve green growth in agriculture.

There is a wide variety in the structure of agriculture ranging from semi-subsistence to commercial and from extensive to intensive. In addition, given a host of factors related to geography, weather and historical patterns, different types of agriculture dominate different regions of the world. Because the linkages are complex it is difficult to generalize. For example, in the case of commercial agriculture that results in an expanding agricultural land base (e.g. deforestation for agriculture) there are clear and overwhelming negative impacts of agriculture on biodiversity via both land conversion and intensification. However, for commercial agriculture that is not expanding in the land base (such as in the European Union), the impacts of agriculture on biodiversity arise via the type of use and modifications the existing agriculture landscape is subjected to. The net impacts on biodiversity could be either positive or negative.

The growth in the world's population will place increased pressure on available **water** supplies, even in the absence of climate change. Water stress is an increasing risk, particularly in developing countries. By 2030, it is projected that 47% of the world's population will live in areas with severe water stress, compared to 35% in 2005. The growth in demand for water for non-agricultural uses seems likely to place considerable stress on the availability of water for agriculture in such countries as China and India and could constrain their ability to increase food production. Studies differ on whether total water use in the sector will actually increase but it seems likely that there will be considerable pressure to improve the efficiency of water use in agriculture (OECD, 2010c). Box 3.2 provides examples of two countries where progress is being made on improving water use efficiency through technological approaches.

Agriculture's use of **energy** is roughly in line with its contribution to GDP in OECD countries – around 2%. However, the OECD food system as a whole is a more substantial contributor to both GDP and energy use. An examination of changes in energy use in the US food system concludes that while per capita energy use declined by 1.8% between 1997 and 2002, per capita food-related energy use increased by 16.4% (Canning *et al.*, 2010). When population growth over the period is taken into account, total US food-related energy use increased by 22.4%. These calculations take into account the energy involved in the manufacture of agricultural inputs, the production of crop and livestock products, food processing and packaging, the running of refrigeration and disposal equipment in food retailing and foodservice establishments, and the equipment in home kitchens.

Box 3.2. More efficient water use in agriculture

Efficient water management has been a key to much of the success in agriculture in arid, semi-arid and dry sub-humid zones. In the Mediterranean regions, agriculture accounts for more than 60% of total consumption of water. The most conspicuous technology in this regard is drip irrigation. This technology attempts to increase water use efficiency through lowering runoff and evaporation losses and reducing leaching of water and contaminants below the root zone. The success of drip irrigation lies in the provision of optimum conditions for plant uptake of water and nutrients. Drip systems also facilitate the more efficient agronomic use of saline, brackish and marginal water.

Israel

Developed in Israel during the 1960s, and initially marketed in 1965 by the kibbutz based Netafim Corporation, drip irrigation held limited interest and was not without problems, such as pipe clogging and breakage. This changed in the 1980s with further refinements to drip systems, including developments towards the next generation of drip technology including, for example, computerised systems, fertigation by applying fertilisers directly to the plant roots, and pressurised drippers which enable stable distribution of water.

In Israel over half the irrigated area is now under drip irrigation, and has played a major role in improving water use efficiency. Drip irrigation technology forms a major part of Israeli water technology exports which totalled ILS 5.0 billion (USD 1.4 billion) in 2008, double the amount in 2005 according to the Israel Export and International Cooperation Institute. It is projected that Israeli exports of water technologies will reach ILS 36 billion (USD 10 billion at 2008 exchange rate) by 2017, with Israeli companies controlling about 50% of the global market in drip irrigation technology.

A more recent development has been sub-surface drip irrigation (SDI), with about 5%-10% of the irrigated area now under SDI systems. These systems are positioned within the soil to: conserve water; control weeds; minimise runoff and evaporation (reducing evaporation by up to 20%); increase longevity of piping and emitters; ease use of heavy equipment in the field; and prevent human contact with low-quality water. Additional motivation for SDI comes in the form of savings of the extensive labour involved with seasonal installation and collection of surface drip system piping. SDI provides the opportunity to manipulate root distribution and soil conditions in arid climates in order to better manage environmental variables including nutrients, salinity, oxygen and temperature.

Italy

Since the early 1960s, the Ministry of Agriculture has developed a programme of investment in irrigation infrastructure in southern Italy through the creation of a series of "irrigation districts". This has resulted in an evolution from subsistence agriculture to a more advanced system. The investments were based on technologies existing at that time, mainly represented by open channels for the distribution of irrigation water from dams or rivers to the farm gate. This resulted over time in unsustainable increased water demand by farmers and a significant reduction in the availability of overall water resources.

To meet the objective of improving water use efficiency, investment in publicly-financed irrigation systems have been recently promoted. Old open irrigation networks have been replaced with piped networks, which have greatly reduced losses due to evaporation. This has also permitted farmers to adopt advanced irrigation systems with water saving technologies (such as drip-irrigation) to replace traditional gravity based methods (such as flooding), thus achieving reductions in water usage ranging from 30 to 40%.

Additional investments to save water include monitoring of irrigation networks using equipment capable of detecting network losses, and using automated systems with real time accounting of water usage by individual farmers using electronic cards. These systems have further benefits, including: equitable sharing of water resources; exact matching of water charged to each user with their withdrawals; and precise reduction of volumes to each user in the event of water shortages. These technologies permit farmers to more closely match water use with actual crop requirements. In addition, the resulting reduction in the depletion of groundwater lowers the risk of soil salinisation, particularly in coastal areas.

Source: OECD (2010), OECD Review of Agricultural Policies: Israel; National Institute of Agricultural Economics (INEA), Italy.

The principal reason for the expanded use of energy in the sector is the search for convenience by consumers, in particular by consuming more prepared foods and a larger amount of food outside the home. While future increases in energy demand generated by agriculture per se may be relatively modest, further changes in lifestyles and food consumption patterns across the world could impose greater demands on global energy supplies. Reardon and Timmer (2007) document the transformation of the food system in developing countries, arguing that a profound retail revolution has occurred in the past decade that is transforming food markets in much the same way as has already occurred in OECD countries. This transformation will have important implications for the energy intensity of the food system in developing countries and globally.

In recent years there has been a substantial growth of interest in production methods that can be termed "conservation" or "integrated agriculture". These are methods that try as far as possible to only use the amount of inputs that will produce commodities in ways that are respectful of the environment. Such methods apply to conventional agriculture, as well as to alternatives such as organic production; both approaches can improve environmental performance.[9]

There is a debate between the proponents of conventional and organic agriculture on the potential for these systems to sustainably feed the world. Consumer demand, particularly in wealthier countries, is likely to continue to support the development of certified organic systems. However, the world will continue to rely on the use of non-organic inputs such as chemical fertilizer if the expanding demand for food is to be satisfied. In other words, a wide range of production systems will continue to co-exist. There is certainly scope for the transfer of integrated and conservation production methods to conventional agriculture in order to reduce its environmental footprint. Examples include the greater use of organic fertilizers and composted materials,[10] reductions in the use of pesticides through natural pest management approaches, reduced or no-tillage techniques together with greater use of crop rotations to maintain soil quality and reduce disease risk (FAO, 2010). Irrespective of the production system chosen, the challenge facing agriculture is to adopt more sustainable production practices while maintaining increases in productivity.

Finally, it is important to note that while farmers in many parts of the world are highly skilled in managing their resources – and have always adapted to changing circumstances – substantial potential exists for increasing efficiency under existing technologies. Fischer *et al.* (2009) examine the "yield gap" for grains, i.e. the gap between maximum yield under current technology and actual yield in 20 important producing regions around the world. They conclude that while the yield gap has been declining in many countries it remains substantial. They estimate that the average yield gaps for wheat and rice are 40% and 75%, respectively. For example, current maize yields in sub-Saharan Africa are roughly one third of those that are technically possible. The authors believe that a gap of 25% would be consistent with sustainable production but this can only be achieved if a range of issues are addressed, including infrastructural and institutional deficiencies affecting the use of inputs, farm management skills, and technical constraints, particularly in developing countries.

In fisheries**,** growing demand will be met by increased aquaculture production (Box 3.3). This will put increasing pressures on fish for feed compounds and use of fresh water in inland water aquaculture systems and, at a very general level, will increase competition for space, both on land and at sea. In this context appropriate spatial planning (both land and marine) is important. One of aquacultures main environmental impacts is on marine capture fisheries through demand for wild fish for feed. Feed is the biggest cost factor in carnivorous aquaculture and also one of the most criticised areas in terms of sustainability. It is therefore important that aquaculture pays particular attention to the efficient use of feeds and the inclusion of responsibly sourced ingredients. In this regard further research is important to switch towards plant proteins in feed compounds.

Box 3.3. Aquaculture

In 2007, aquaculture overtook capture fisheries and supplied more than 50% of aquatic products for direct food consumption. Although climate change and other factors might constrain developments, there are powerful drivers for expansion, including population and income growth fuelling demand for aquatic foods, coupled with supply limitations from capture fisheries. Global output from aquaculture may need to increase from 52 million tonnes in 2007 to 80 million tonnes or more by 2030 to meet demand. Success is not guaranteed though and the sector will have to manage biological risks such as disease; system risks such as equipment failures and water problems; economic and market risks such as price volatility of inputs and products, changing consumer preferences due to dietary considerations and perceptions about aquaculture products; and political risks affecting for example the legal context for production or trade.

Source: Chair's Summary in *Advancing the Aquaculture Agenda: Workshop Proceedings (*OECD 2010*).*

Overall, the food and agriculture system will face challenges in meeting future consumer demands, while simultaneously economising on the use of increasingly scarce resources whose prices have gone up and moving towards a low-carbon economy. But these challenges can be met, with the right policy, market incentives, regulations and institutions in place.[11]

Renewable energy

The food and agriculture sector can contribute renewable energy to final energy markets in the following ways:

- Production of conventional agricultural crops (grains, sugar beet and sugar cane, oilseeds) which are then transformed into biofuels, or into biogas (via anaerobic digestion).
- Production of dedicated (non-food) energy crops (any ligno-cellulosic crop). This route leads to the production of second-generation biofuels, biogas and the energies derived from primary solid biomass.
- Agricultural wastes and residues, whether of crop or animal origin, and forest residues. This is currently severely under-exploited as a source of renewable energy relative to the enormous potential.
- Wind and solar energy used for electricity generation. Although these outputs do not rely on any biological transformation process, they can fall within the decision-making sphere of the farmer, contribute to farm income and may have implications for the farm's fixed resources.
- Organic waste produced in the agrifood chain downstream from farming can also be a source of renewable energy, including first- and second-generation biofuels, heat and electricity from primary solid biomass conversion, and biogas.

The competition for land between the first two, food crops and bioenergy feedstocks, raises the possibility of higher food prices and deepening food security concerns. In fact, land diverted from food production will have to be replaced by net additions to cropped land elsewhere unless recently abandoned agricultural land can be reclaimed for cropping and growth rates for crop yields accelerate to much higher levels than observed in past years.[12] However, when land lost from food crop production is replaced by bringing new areas under cultivation (so-called indirect land use change), there may be damaging consequences in terms of green house gas emissions if this land formerly stocked more carbon than is typically stocked by an annual food crop.[13]

Other sources of energy, such as wind and solar, require relatively fewer land resources than bioenergy crops. Waste products are "free" energy resources and do not have implications for land use. Nevertheless, most of the renewable energy options are in competition from non-energy market or societal demands for the same resource, indicating that whilst greener energy is technically available, it generally has an opportunity cost and choices will have to be made. To what extent markets can, and should be allowed to, make these choices is a policy issue.

All major energy markets (transport fuel, electricity, heat and natural gas) can be supplied by renewable energies originating in the food supply chain. Renewable energies must compete with energy from all sources on these final markets, since in general specialized markets restricted to renewable energies as such do not exist unless created artificially by policy measures. This means that renewable energies would have to be accepted by final consumers as equivalent to their non-renewable substitutes, and that there has to be demand for these energies at their supply price on final markets. Any efforts further back up the chain to incentivise their production will fail if sufficient final demand is not present. Indeed, the scope for switching from fossil fuels to cleaner energies will ultimately be limited by the extent of its penetration of end-use markets. A key issue for policy makers concerns the relative merits of stimulating final demand by, on the one hand, assisting renewable energy to compete in price with non-renewables on final energy markets, and on the other, of imposing mandatory targets for their use by final consumers. An important consideration here is whether the benefits of stimulating renewable energy production/use outweigh the market distorting effects of such policies.

A successful strategy for rebasing economic growth on green energy requires policy makers to be aware of the entire supply chain for each form of energy, from the supply of raw energy resources by primary sectors right through to the supply of usable energy onto markets for final energy consumption, and to the interactions – competitive or complementary – between these supply chains. Stimulating bioenergy production will heighten the trade-offs with other market demands and societal goals, and may risk distorting or disrupting a number of other markets. When reviewing agriculture's potential contribution to green energy production, these competing claims on potential energy resources and on the land used to produce them, have to be kept in view.

Innovation

Technological change has been the major driving force behind increased agricultural productivity around the world. In the past agricultural technologies were designed and adopted with the primary aims of increasing production, productivity and farm incomes. Today, however, the challenges before agriculture are much more complex. Global issues such as food insecurity, climate change, biodiversity and associated ecosystem service loss need to be addressed simultaneously, which means that agricultural innovation must necessarily emerge out of a complex decision-making process that weighs immediate concerns of feeding the world against future concerns of sustainability.

Therefore, a holistic and strategic approach to linking knowledge with action is required. Key elements of this are greater interactions between decision-makers and researchers in all sectors, greater collaboration among environment (including both climate and biodiversity), agriculture and food security communities, and consideration of interdependencies across whole food systems and landscapes.

While post-World War II agriculture can be viewed as driven primarily by goals of increasing production, productivity, incomes and reducing labour costs and inputs, concerns over the negative environmental impacts of farming systems began to find a voice in the 1960s and 1970s (Welch and Graham, 1999). With growing evidence of the negative effects of the Asian Green Revolution (a package of intensive agricultural practices that used high-yielding varieties to boost food production in Asia) in the 1980s — due to heightened worries about pesticide poisoning and fertiliser pollution (Conway and Pretty, 1991) and the increasing popularity of studies of agro-ecosystems analysis (Conway, 1985) and agro-ecological approaches (Altieri, 1996) — ideas around sustainable agriculture began to gain ground, ultimately finding voice in policy in the 1990's. Concerns about environmental costs and risks and a greater consideration of the benefits of alternative approaches to agricultural production and development are not new, but are accorded increasing importance. The case of the Dutch agricultural system is illustrative of the way concerns about sustainability and the environment led to system-wide changes in the way farming systems were organized (Box 3.4).

Box 3.4. Dutch agriculture and environmental sustainability

The Netherlands has one of the most intensive farming systems in the world, with high output levels supported by a considerable use of agrochemicals. As one of the smallest countries in the European Union, constraints on the availability of agricultural land have contributed to conditions and incentives to increase the intensity of agricultural production over time, leading to the country figuring in the top three agricultural exporting nations in the world. In addition, the Common Market has also contributed to free internal trade within the European Union and has provided incentives to increase production in regions where competitive advantages existed — and the Netherlands, with its favourable soil conditions and proximity to several countries in the EU has considerable comparative advantages.

Dutch policy-makers and researchers have long been concerned over issues of environmental sustainability as a result of agricultural intensification (pollution of groundwater, ammonia emissions and their impact on the acidification of soils and water, negative effects of pesticide use, biodiversity and landscape issues, etc.) and the country was among the first to make system-wide changes to address these concerns in the early 1990's.

The Netherlands has the longest history of policy development to restrict pesticide use and to encourage the development of more environmentally sustainable chemicals, often in advance of EU-level policies. Its Multi Year Crop Protection Plan (1991-2000) has significantly reduced pesticide use. Dutch researchers also advocated a move to a more preventive approach to crop protection and sustainable production, from the current 'end of pipe approach', through intermediate preventive strategies within companies and ultimately to prevention on a higher system level, while recognizing that chemical crop protection methods will remain indispensable. Most Dutch farmers are now seen as being in transition from the first to the second stage. The country also brought into effect sectoral policies to improve the efficiency of energy consumption in agriculture.

The incentives to increase environmental production methods are not provided solely by public policies. Market initiatives also stimulate the environmental awareness of producers. Several sectors have responded in a pro-active manner to requirements by policy regulation as well as consumer preferences to environmentally friendly products. The Horticulture Environmental Programme, for example, stimulates environmental awareness in the cultivation of flowers, plants, bulbs and nursery stock products. The programme essentially requires producers to keep records on their use of crop protection products, fertilizers and energy. In addition, retailers increasingly demand the use of environmentally-friendly conditions in production methods used in primary production.

Government policy thus aims to promote a market-oriented approach to agriculture at national and EU levels, with the parallel aim, based largely on self-regulation, that it should remain ecologically sound. Dutch agriculture has limited natural advantages and the Ministry of Agriculture emphasizes that the sector has to increase profits by marketing new products and solving problems (environment, animal welfare) better and earlier than competitors. The sector thus depends on innovation to maintain its competitive edge.

Adapted from OECD (2002).

Ikerd (1993) defined sustainable agriculture as "capable of maintaining its productivity and usefulness to society indefinitely. Such an agriculture must use farming systems that conserve resources, protect the environment, produce efficiently, compete commercially and enhance the quality of life for farmers and society overall."

What is increasingly clear is that no one farming system can be identified as sustainable, and there is no single path to sustainability. All farming systems — from intensive conventional farming to organic farming to something that falls between the two extremes — have the potential to be environmentally-sustainable (OECD, 2001).

Developing an environment favouring innovation can contribute to green growth in food and agriculture. Notable examples of innovation include:

- *New science and generic technologies with green potential*: Specific technologies and generic platform technologies that may have significant transformation potential. Biotechnology, Information and computing technology and bioproduction are examples in this mode.
- *Farming systems innovations*: Farming systems innovations with green potential - different ways of organizing agricultural production -may involve the use of one or more specific technological innovations as defining characteristics, or it may be purely to do with how production and marketing is organized, or a combination of the two. Organic farming, Integrated Pest Management and the Systems of Rice Intensification are example of this.
- *Integrated national green regimes*: Specific technologies or agricultural production systems operate as part of national (or regional) green agenda. Examples include bio-fuels in Brazil, organic states in India, agritourism, and the potential for renewable energies in agriculture.
- *Post farm innovations:* Technologies that reduce food waste, improve transport and handling logistics, improved packaging and shelf-life.
- *Cross-cutting approaches*: Which market or policy-driven mechanisms are most suited to driving innovation in pursuit of a green agenda, and under what circumstances. It is generally left to public policy to put forth rules, property rights and other market signals that correct for market imperfections. However, in the realm of environmental sustainability — perhaps in the absence of adequate policy measures in place for the same — market-led, voluntary sustainability standards and initiatives are emerging which act as multi-actor, rules-based systems with public-good sustainable development objectives. These initiatives play a role similar to public sustainable development policy. In fisheries new gear technology with reduced ecosystem impact minimizes damage to biodiversity, for example by reducing by-catch.

It is important to note that some of the innovations offer win-win potential: production benefits and environmental benefits. For example "green technologies," such as Integrated Pest Management, conservation tillage and precision farming can increase productivity and farm profitability, all the while reducing environmental degradation and conserving natural resources. While there continues to be public concern about GM crops, these issues need to be debated on the basis of available scientific evidence. Precision agriculture similarly can reduce adverse environmental impacts by using advanced technologies, such as the global positioning system (GPS), to collect data at exact locations, and geographical information systems, to map more precisely fertiliser and pesticide requirements across a field.

Another important innovation relates to the wide range of biomaterials (renewable industrial inputs) that can be obtained from agricultural biomass. These include fibres, industrial oils used to make paints and inks, starch used for producing polymers and detergents, and a variety of high-value, low-volume products used in the production of cosmetics, flavourings and healthcare products. All products that currently result from the processing of petrochemicals can, in theory, be produced from biomass feedstocks (OECD, 2004). With higher prices for fossil fuels and/or carbon emission prices, there is likely to be more pressure to switch to biomass for producing a very wide range of non-energy industrial products.

In the aquaculture sector innovation is an important driver for enhanced production and reduced reliance on wild fish stocks for feed compounds. The recent management of the complete life cycle of bluefin tuna, a highly priced product in some markets, is one example of the potential for future reduction of the fishing pressures on wild stocks.

Notes

1. The United Kingdom Foresight report (2011) states that it is necessary to "work on the assumption that there is little new land for agriculture". This is a point also raised in Thompson (2011) in a report for Nestlé where he notes "there is only about 10% more potentially arable land that is not forested, highly erodible or subject to desertification. Expansion beyond this would involve massive destruction of forests and, with them, wildlife habitat, biodiversity and carbon sequestration capacity, which would accelerate global warming. Most of the potentially arable land is inferior to that already in production and is located in remote areas of sub-Saharan Africa and South America where infrastructure is minimal".

2. Thompson (2011) points out that "Whereas farmers may have to double the average productivity of the land already in agricultural production, they may have to triple the "crop per drop", the output per unit of fresh water they use".

3. An international conference was held in The Hague in November 2010 (*www.afcconference.com*). The conference stressed that agriculture, food security, and climate change should be at the heart of sustainable development and poverty eradication efforts.

4. It should be noted that in many countries greenhouse gas emissions have decreased the last two decades (OECD, 2008a).

5. The amount of fish added to the exploitable stock each year due to growth and/or migration into the fishing area.

6. There is on-going debate on the future date of "peak phosphorus," after which globally extractible supplies would fall, along the same lines as "peak oil". The availability of usable phosphorus also depends on the presence of contaminants such as uranium and cadmium.

7. In poorer developing countries (especially in Africa) the problem is often that few farmers can afford to buy fertilizers needed to boost crop production, yet world production of potash fertilizers needs to probably double to balance off-takes (Manning, 2010a and 2010b).

8. In China the overuse of fertilizers is estimated to be between 20% and 50% (OECD, 2006a).

9. The basic principles of organic agriculture include a minimal use of off-farm inputs and a management system that relies on techniques such as crop rotation, green manure, composting and biological pest control to maintain soil productivity and to control pests. Many countries have or are currently developing organic farming certification for standards, information, labelling to aid consumer choice.

10. This would require careful application to avoid water contamination.

11. An assessment of the environmental footprint – in particular GHG emissions and water use- throughout the food supply chain from input suppliers to final consumers (e.g. based on life-cycle analysis) will help guide decisions by government and business in identifying opportunities to improve resource use efficiency. The FAO High Level Expert Forum in October 2009 pointed out that it is feasible to meet

future food needs by 2050 with the available natural resources on the planet (*www.fao.org/wsfs/forum2050/wsfs-forum/en/*).

12. Dedicated energy crops can produce more biofuel per hectare than first-generation biofuel technologies because the entire plant is used as fuel feedstock. Typically, there is no food demand for these feedstocks to compete with demand for them as an energy resource; on the supply side, however, second-generation feedstocks compete with food crops for land unless they can be grown on marginal land that would normally not be used for food production.

13. If previously uncropped land (especially carbon-rich rainforest, peatland or permanent pasture) is used for these dedicated energy crops, the immediate impact on GHG emissions is significant and may outweigh any emission-saving from the renewable energy for a number of years (see, for example, Searchinger *et al*., 2008; European Commission, 2010).

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Chapter 4

The role of policy in contributing to green growth in agriculture and food

A key role for government is to find cost-effective ways to account for environmental externalities that are not factored into producer and consumer decisions. This means reforming existing policies, enforcing the polluter pays principle, and finding incentives for producers to generate environmental services while increasing food production.

There can be a wide range of government intervention – taxes, regulations, financial support, service provision, and information and training for individual producers and the sector as a whole; competition and zoning policies; certification and consumer policies – that influence the productive efficiency and environmental performance of agriculture and fisheries. Caution is needed in making broad generalizations about preferred approaches, as priorities and time paths will vary across countries.

Governments have at their disposal a wide range of potential policies which are outlined in Table 4.1 below.

Table 4.1. Green growth policies for food and agriculture

	Potential green growth policies
Environmental regulations and standards	Enact/enforce controls on excessive use of agrochemicals and fertilisers in production Strengthen rules and standards for water, soil quality, and land management Improve enforcement of environmental regulations and standards/certification from the farm-gate to the retail sector
Support measures	Decouple farm support from commodity production levels and prices Remunerate provision of environmental public goods (such as biodiversity, carbon sequestration, and flood/drought control) beyond reference level[1] Target environmental outcomes where feasible, otherwise target production practices favourable to the environment Target public investments in green technologies
Economic instruments	Price inputs to reflect scarcity value of natural resources Impose charges/taxes on use of environmentally-damaging inputs Implement trading schemes for water rights and carbon emissions Facilitate private investments in green technologies and green management Address policy constraints (conflict, governance, etc.) in less developed economies
Trade measures	Lower tariff and non-tariff barriers on food and agriculture product bearing in mind the potential impact on environmental concerns such as biodiversity and sustainable resource use. Eliminate export subsidies and restrictions on agricultural products Support, well-functioning input and output markets
Research and development	Increase public research on sustainable food and agricultural systems Promote private agricultural R&D through grants and tax credits Undertake public/private partnerships for green agricultural research
Development assistance	Allocate more development aid for environmentally sustainable initiatives, in food and agriculture Raise profile of agriculture in Poverty Reduction Strategies (PRS) Allocate more funding for agriculture in Aid for Trade projects
Information, education, training and advice	Increase public awareness for more sustainable patterns of consumption such as via eco-labelling and certification Incorporate sustainable approaches in training, education and advice programmes throughout the entire food chain

Box 4.1 provides information on support to agriculture and fisheries due to government policies. Support based on commodity production and unconstrained variable input use has the strongest impact on production and input use, encouraging production through higher levels of fertilizer and pesticide inputs with adverse effects on the environment, soil quality and biodiversity. However, increasingly support is linked to adherence to environmental regulations, is targeted to agricultural practices that are intended to improve environmental performance, or targeted to environmental outcomes

(Annex Table A.2). Some support is linked to production that is associated with the conservation of specific landscape or natural habitat features in some countries.

Some policies that will contribute to achieving a greener growth pathway for food and agriculture apply to the economy as a whole while some apply specifically to food and agriculture. A comprehensive framework for assessing green growth policies in the economy has been developed by de Serres *et al.* (OECD, 2010).

Government policies have for a considerable time provided transfers (or support)[2] directly or indirectly to the agriculture and fisheries sectors in OECD – and increasingly in emerging economies. This is in addition to a wide array of regulations – especially when looking at the whole food chain – some of which are economy-wide, some being more specific to the sector.

The relationship between transfers and green growth is complex. This is because the production sector both depends and impacts on natural resources (land, biodiversity, carbon, and water), there is a wide diversity of resource endowments and environmental absorptive capacities, and the impacts can differ in the short and long run and at different scales of production. The sector, in brief, thus generates both environmental harm and provides environmental benefits. Moreover, there is a wide range of transfers that influence the productive efficiency and environmental performance of food and agriculture. Caution is needed in making broad generalisations, but there are lessons from OECD work that can help to identify effective policy practices that can contribute to green growth. Not all government transfers are harmful to growth and the environment; not all environmentally motivated subsidies are good for the environment; and the presence or absence of transfers is no guarantee that environmental performance will be achieved.

The policy challenge is to find cost-effective ways to account for environmental externalities that are not factored into producer and consumer decisions. That implies addressing at least three policy sets: removing those transfers that distort production decisions and trade flows, and harm the environment (or cause extra pressure on natural resources) not only in the country implementing them but also, via trade, other countries; enforcing the polluter pays principle; and finding ways to incentivise producers to generate economic and environmental services (benefits). Striking the best balance between requiring producers to account for the environmental harm that they cause and incentivising them to generate environmental benefits is not an easy task – it involves issues of property rights, environmental targets and transaction costs, all of which are embedded in the variety of diverse institutional, legal and cultural systems. And removing transfers that are environmentally harmful can involve trade-offs between economic efficiency, environmental protection, social equity and employment.

Which types of transfer measures are likely to create the greatest barriers to improving economic efficiency (and thus potential for growth) and improved environmental performance – and thus should be prime targets for policy reform to enhance green growth? They are dominated by those transfers that are closely linked to commodity production in terms of generating outputs or using inputs with no environmental or other constraining conditions attached – and where there is a relatively low absorptive capacity of the environment and few if any environmental services generated as a result of production.

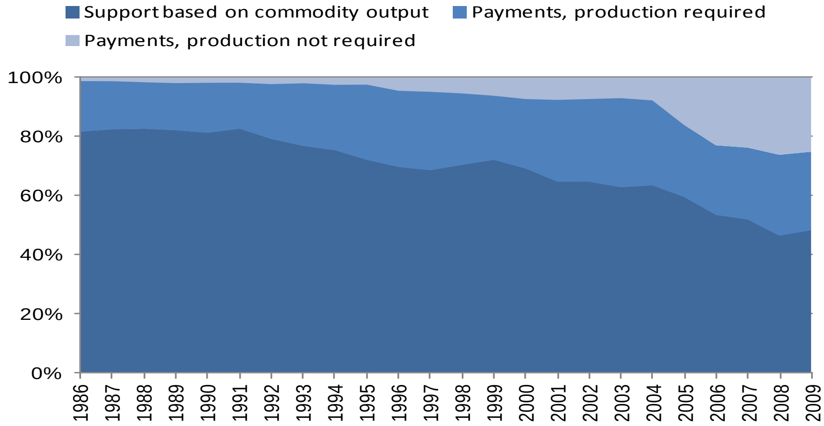
Box 4.1. Support to agriculture and fisheries

Since the mid-1980s, support to agricultural producers as measured by the Producer Support Estimate (PSE) has decreased gradually, although with significant differences across countries in the level and rate of decrease. However, OECD countries have made a concerted effort to reduce producer support based on prices and output levels – which declined from almost 70% of the total in 2001 to 48% in 2009.

Support to agriculture has been prevalent in OECD countries for a considerable period of time. The OECD's PSE, Consumer Support Estimate and General Services Support Estimate track transfers in OECD and emerging economies using a common methodology. The overall level of support (Total Support Estimate) provides a broad indication of the transfers from the rest of the economy to agriculture – currently overall support accounts for nearly 1% of total OECD GDP, and while this share has fallen over the last 25 years, it varies significantly across countries. But of perhaps more significance for green growth is the changing composition of support to producers. Over the same period as shown in the figure below, there has been a decrease in the share of support that is linked to commodity production (such as market price support and associated trade barriers, direct production support based on output of specific commodities, or input subsidies not associated with environmental and other constraints on their use) and an increase in support measures that either do not require production or require some production but are not based on outputs of specific commodities, or support based on provision of non-commodity outputs, including resource retirement and provision of specific environmental services. Similarly, these developments have also varied widely across countries.

Share of support in the OECD

As measured by the Producer Support Estimate, 1986-2009



These categories are: (1) transfers based on commodity output and unconstrained input use (support based on commodity output); (2) transfers based on current production parameters other than commodity outputs – area, animal numbers, farm receipts, or income – (payments, production required); and (3) transfers not based on current production, including resource retirement and non-commodity outputs, which include the provision of environmental services (payments, production not required).

Source: OECD PSE Database.

Government financial transfers (GFTs) to the fishing industry in OECD countries have been slightly reduced over the last ten years, from USD 6.8 billion in 1996 to USD 6.4 billion in 2006. GFTs in OECD countries represented around 19% of the value of the total catch from capture fisheries in 2006. The majority of GFTs are categorized as general services, accounting for 75% of the total GFTs in 2006. Specifically, OECD governments spent USD 1.6 billion for management and enforcement while USD 736 million were used to conduct fisheries research. Other GFTs under the general services category included harbour construction and maintenance as well as stock enhancement and habitat conservation. However, significant GFTs for general services (USD 2.1 billion out of 5.3 billion) fell into the "programs not specified" category because several countries have not reported details. In the meantime, direct payments represented 19% of total GFTs. USD 185 million were dedicated to vessel reduction schemes in 2006 while USD 32 million were used to construct or modernize fishing vessels. Other GFTs included unemployment insurance (USD 223 million) and disaster relief (USD 188 million). The third category, cost reducing transfers, accounted for 6% of the total GFTs.

Source: OECD (2009) Review of Fisheries.

On the other hand, which types of transfer measures are likely to facilitate the greatest economic efficiency and environmental benefits – and thus be high priorities for contributing to green growth? They are dominated by those transfers that are targeted as closely as possible to those farmers delivering specific environmental outcomes (or farming practices that can be expected to lead to such outcomes), provide an enabling framework to improve economic efficiency (such as through the application and transfer of knowledge, new technology, improved infrastructure and enforceable property rights), and facilitate structural adjustment to changing market conditions while providing safety nets for extreme and non-insurable risk.

It should be stressed that a given level and type of transfer measures implemented in different countries or regions will not be likely to deliver the same economic and environmental impacts. Moreover, the wider regulatory and macro-economic context and the mix of policy measures – whether specifically targeted towards for the economic and environmental performance of these sectors or impacting on them – will also play an important role.

The impact of Government Financial Transfers (GFTs) to fisheries is closely associated with the type of fisheries management system that is in place. The effectiveness of the management regime and its enforcement is critical in determining the effects of transfer programmes. Anything less than complete enforcement will generally result in adverse economic, environmental and social impacts and under all management regimes. Whether these adverse impacts lead to a net welfare loss as a result of the transfer policy is an open empirical question which will vary according to the conditions applicable in different fisheries settings. However, there are some types of management regimes which tend to be more robust than others. For example, management regimes which are characterized by stronger access rights will tend to be more self-enforcing as the industry has a greater incentive to cooperate with enforcement measures. A higher degree of stakeholder participation is likely to reinforce this incentive (OECD, 2006).

Policies for increasing productivity

As noted earlier, technological change and improvements in productivity have played a central role in helping agriculture to contribute to growth in the economy as a whole, while meeting expanding demands for food and agricultural raw materials, and improving the well-being of consumers. Research and development (R&D) and further increases in productivity will continue to play a vital role in helping agriculture to continue to achieve these outcomes, and in dealing with new challenges such as climate change. There is a pressing need to obtain more from existing resources (particularly land and water) within a sustainable and robust food and agricultural system. A fundamental requirement for green growth in agriculture is that suitable technologies are available to farmers and they have the knowledge and skills to use them (OECD, 2001). An important part of this is knowledge and technology transfer programmes.

A comprehensive review of trends in R&D expenditures in agriculture has been carried out under the auspices of the Consultative Group on International Agricultural Research (CGIAR). Estimates of total expenditure on agricultural research and development (public and private) at the beginning of the current millennium (Science Council CGIAR, 2005) was around USD 37 billion (2000 values, purchasing power parity basis) (Annex Table A.5). Public expenditures accounted for 63% of the total and the top ten countries in terms of public sector spending (in decreasing order) were the United States, China, India, Japan, Brazil, Germany, Australia, South Korea, United Kingdom and Canada. Over 90% of the roughly USD 14 billion in private sector expenditures was concentrated in developed countries. Global public investment in agricultural research increased by roughly 50% in inflation-adjusted terms during the period from 1981-2000, although total expenditure in developed countries declined by roughly 4% from 1991-2000. Public research expenditures are heavily concentrated in a few countries. The United States, Japan, France and Germany – accounted for two-thirds of the total in developed countries in 2000; five developing countries – China, India, Brazil, Thailand and South Africa – accounted for over half of the developing world's total.

R&D expenditures in those developing countries that are expected to experience strong pressure on food supplies, such as Sub-Saharan Africa, displayed very little growth. Msangi *et al.* (2009) estimate that public sector expenditure on agricultural R&D in developing countries was equivalent to just 0.55% of agricultural GDP in 2000, compared to 2.35% in developed countries. They estimate that if developing countries are to feed their growing populations and respond to the challenges created by climate change, total research expenditures will have to be one third higher to 2050 than without climate change.

Given the numerous and increasing demands upon public finances in many countries it may prove difficult to mobilize adequate public resources to address the productivity and environmental challenges in agriculture. As noted earlier, the private sector plays an important role in R&D in developed countries, but only a minor role in developing countries. This can be attributed to several factors, including higher returns to the development of new technologies in developed countries, the greater protection of intellectual property rights, or to a more favourable environment for private sector investment. The precise causes of low private investment in specific developing countries warrant further analysis, in order to identify appropriate remedial actions that could be taken to attract increased flows of investment from the private sector.

One particularly contentious area of innovation is the role of new technologies, in particular GM technologies, in addressing future food needs. In 2005, public R&D expenditures in the OECD area for all types of biotechnology were USD 28.7 billion, and expenditures by the private sector in 2003 were USD 21.5 billion (OECD, 2009b). With the sequencing of the genome for major food crops close to completion, there is considerable potential for these technologies to contribute to increases in productivity. There is a debate between those who argue that conventional plant breeding techniques are sufficient to address such challenges as increasing drought and disease resistance and those who argue that these issues can be addressed more efficiently and more rapidly by using alternative technologies. In any event, the transfer of existing technologies and management practices is necessary to improve resource use efficiency.

The future potential of new technologies to address productivity and environmental issues is being actively evaluated in the agricultural research community (CGIAR, 2005). As noted earlier, a range of policy issues are involved, including the allocation and use of public funds for research and the legal framework for the protection of intellectual property. While it is not possible to reach definitive conclusions on how these policies will affect future innovation in the sector or indeed what the future direction of policies in these areas should be, it is clear that the implications for the ability of the sector to meet future food demands while achieving green growth will have to be evaluated.

Finally, the results of research on new technologies and production methods are of little use to farmers unless they know how to apply these. Public sector support for the diffusion of new knowledge through training and advice (extension) has been a feature of productivity growth in agriculture around the world. For example, Rosegrant and Evanson (1992) demonstrate that such expenditures played a significant role in the growth of total factor productivity in agriculture in South Asia. In India, for example, the rate of return to investment in extension services over the period 1956-87 was 52%, which compares very favourably to the 63% rate of return to research. While many of the advisory services that were previously provided through public funds are increasingly being provided by the private sector in developed countries, it seems likely that the public sector will need to play an important role in the provision of extension services in developing countries for the foreseeable future. Those countries with severely constrained public funds may find it difficult to supply needed extension services.

Policies oriented towards internalising the cost of negative externalities

One of the central issues in achieving green growth is to ensure that all the costs (public and private) associated with economic activity are reflected in production and consumption decisions (i.e. are internalized). In terms of market-based instruments two major approaches have been identified – one based on the use of taxes and subsidies (Pigou, 1932) and a second based on the assignment of property rights (Coase, 1960). An alternative approach is to use various non-market instruments, including regulations. No one approach is universally superior: each is context-specific and has advantages and disadvantages.[3] In fact, it is likely that a mix of market-based instruments and regulations will be needed. Effectiveness and efficiency depend on a range of factors including the nature of the issue to be addressed, the institutional environment, and the technical limitations and constraints to be faced in the use of particular policy instruments. Some of these issues in the context of sectoral approaches for agriculture are discussed below.

An important category of policies consists of those that could serve to internalise the costs of the environmental damage created by agricultural production. As noted earlier, agriculture can contribute negatively to environmental quality, for example, through nutrient discharges to water, climate change through GHG emissions, and through other effects, such as reduced biodiversity. The climate change issue, in particular, may be addressed through both economy-wide and sector-specific policies.

Economy-wide policies that seek to internalise the environmental costs of using fossil fuels are likely to increase the cost of fuel, as well as chemicals and other purchased inputs to agriculture. Thus a carbon tax applied to fossil fuels or a cap-and-trade scheme introduced to internalise the costs of environmental damage will lead to higher input prices. Farmers will generally respond by trying to economise on the use of inputs. A reduction in input use generated by this approach would not only reduce GHG emissions, but could also have other environmental benefits, such as less contamination of water by pesticides or residues from chemical fertilisers. The internalisation of environmental costs in fossil fuel (and other natural resource) prices could have an impact on costs and prices and thus on resource efficiency throughout the food chain.

Taxes could also be used to address the pollution generated by agricultural production. Applying such taxes directly to the source of pollution is challenging since it is often difficult to monitor, for example, the amount of methane produced by ruminant animals on a given farm. In theory, a tax could be applied per unit of output to reflect the contribution of production of a particular product to GHG emissions. If levied on the basis of sales of products the calculation of the tax would not be straightforward. GHG taxes levied on agricultural output have the disadvantage that there is no incentive for farmers to reduce the level of emissions in the production process, e.g. by changing cultivation practices to reduce nitrous oxide emissions or by adjusting feeding rations for ruminants to reduce the production of methane. Much more analysis is needed on the impact of implementing such taxes. Moreover, there are important questions regarding the feasibility of implementation, particularly in the context of some developing countries.

Another issue is that the application of taxes designed to reduce GHG emissions in agriculture could conflict with other environmental objectives. For example, there may be a desire to maintain grazing animals in order to preserve certain types of landscapes and grazing-dependent ecosystems. If a GHG tax causes farmers to abandon livestock or to reduce stocking rates this could have a negative effect on that ecosystem. While there could also be a conflict with other types of policies, for example, the provision of payments under agri-environmental programmes to encourage certain types of land-use systems, by having the right mix of policies that penalise environmental bads and encourage environmental goods, this would allow farmers to make more fully informed decisions when managing their land.

An alternative approach to taxing at the point of production would be to tax at the point of consumption. However, given normal variations in consumer prices the size or incidence of such a tax might actually bear little relationship to the estimated costs of the environmental damage implied by the production/consumption of the products concerned. The use of consumption taxes to internalise externalities may be technically difficult. Other approaches to induce voluntary changes in consumption patterns could also be considered. There are many efforts underway to create such systems. Private enterprises are supporting efforts such as the Sustainable Agriculture Initiative (SAI) Platform and Carbon Trust, which are responding to consumer demand for increased environmental and social responsibility.

More generally, taxes and cap and trade schemes are difficult to apply when non-point-source pollution is involved and this tends to be the case in much of agriculture. Concerning water quality, for example, it can often be difficult to determine the source of the pollution of water bodies – specifically how much a particular farm contributes to the problem (OECD, 2011a). Where the amount of nutrients generated can be monitored – for example, in concentrated feeding operations – it is somewhat easier to monitor the externality and to address it. Moreover, in some countries farmers receive “payments by results” from private utility companies for cleaner water.

Policies designed to increase positive externalities and the provision of public goods

There has been an increasing emphasis in OECD countries on measures designed to stimulate positive externalities in agriculture and the provision of public goods. These include measures that are specifically targeted to the protection of environmental quality, as well as other policy measures. The former category includes payments under a range of environmental schemes; the latter category includes the imposition of environmental conditions linked to the receipt of support payments (cross-compliance).

Other things being equal, with respect to furthering environmental objectives, measures targeted to the environmental outcome desired (or, as a proxy, farm management practices that can be expected to lead to such outcomes) are likely to be more efficient and cost effective in achieving specific environmental aims. The distribution of income support payments is unlikely to correspond to the distribution of environmental costs or benefits of agricultural production. Such payments are typically linked to current or historical production, whereas it is often the case that the volume of production from farms in areas of high environmental value is relatively low. In that case, high levels of payments to farms in relatively productive areas under cross-compliance conditions are likely to generate relatively modest environmental returns per unit of expenditure. However, cross-compliance is preferable to measures that provide support to farmers *without* any environmental conditions attached.

Price support that is directly linked to current output is likely to increase input use, which may work against the aim of reducing the stress that farming places on the environment. This might not always be the case but, *"while commodity output and input linked support measures can contribute to maintaining farm systems providing environmental services such as biodiversity, flood control, carbon sinks, and landscape, such support is not targeted at these non-commodity outputs and their effects must be weighed against the environmental damage and other distortions in resource allocation which are also generated"* (OECD, 2004). Given the likelihood that public funds will be increasingly scarce in the future there is a strong argument for shifting expenditure from relatively untargeted measures for improving environmental quality to more targeted measures, such as those under environmental programmes.

Payments under agri-environmental programmes can be used to reduce negative externalities from agricultural activities or/and to increase positive externalities, and to promote the supply of public goods. (Box 4.2 gives one example in developing countries). Applying the argument used above with respect to internalising negative externalities the polluter pays principle (PPP) should apply in this regard, i.e. the externality should be taxed so that the socially optimal level of production can be generated, rather than trying to address the problem by using payments. The PPP can be difficult to apply where there are non-point sources of pollution. In many countries there is considerable reluctance to imposing taxes on agriculture – it is far more popular among farmers and their supporters, and often politically easier, particularly in more wealthy countries, to use payments to pursue environmental aims.[4] This is not to imply that the tax versus subsidy issue is clear cut in this area, and this will differ from country to country. For example, where significant capital costs are involved in the adoption of technologies to reduce pollution, public funds might be used to stimulate adoption, for example, through cost sharing.

There may be a high environmental payoff in terms of reduced pollution in helping to overcome a financial barrier to the adoption of a beneficial technology. In reality many environmental programmes are composed of a mixture of measures – implicit taxes imposed by rules and regulations and subsidies – designed to reduce negative externalities, such as water pollution, and measures designed to increase positive externalities, such as an increase in wildlife populations. The advantage of such programmes is that if designed appropriately they can address environmental issues at a much more disaggregated geographical scale than other programmes, can be targeted to achieving specific environmental outcomes, and can achieve these outcomes at lower cost than through untargeted measures.

As with taxes, the use of payments to achieve environmental aims can confront problems of conflicting objectives. For example, in order to maintain a particular wildlife ecosystem (e.g. one created by the grazing of hill land by cattle or sheep) there may be a trade-off in terms in providing an incentive for the maintenance of particular production systems. While grazing animals may increase the nutrient loading in water supplies and add to GHG emissions, they may at the same time protect wildlife habitat. Some agricultural support policies have broader social goals and seek to maintain the viability of rural areas. However, this can also be achieved with non-sectoral policies. As a choice may have to be made between ecosystem preservation and other environmental objectives, it will be necessary to weigh up the costs and benefits of different policies. Again, a number of countries deal with multiple objectives by linking the provision of support to meeting environmental requirements (cross-compliance).

Box 4.2. The silvopastoral approach

Silvopasture is the practice of combining forestry and grazing of domesticated animals in a mutually beneficial way. Advantages of a properly managed silvopasture operation are: enhanced soil protection and increased long-term income due to the simultaneous production of trees and grazing animals. The Regional Integrated Silvopastoral Approaches to Ecosystem Management Project was an initiative funded by the UN Global Environmental Facility and involving the Tropical Agricultural Center for Research and Education (CATIE), FAO and other partners. The project's objective was to assess silvopastoral (forest grazing) systems to rehabilitate degraded pastures to protect soils, store carbon, and foster biodiversity. It also aimed at developing incentives and mechanisms for payment for ecosystem services, which would result in benefits for farmers and communities and distil lessons for policy-making on land use, environmental services and socio-economic development.

From 2003 to 2006, cattle farmers, from Colombia, Costa Rica and Nicaragua, participating in the project received between USD 2 000 and USD 2 400 per farm, representing 10 to 15% of net income to implement the program. This resulted in a 60% reduction in degraded pastures 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% increase in carbon sequestration, increases in bird, bat and butterfly species and a moderate increase in forested area. Milk production and farm income also increased by more than 10 and 115% respectively. Herbicide use dropped by 60%, and the practice of using fire to manage pasture is now less frequent. Other demonstrated environmental benefits of Silvopastoral systems included the improvement of water infiltration; soil retention; soil productivity; land rehabilitation, and the reduction of fossil fuel dependence (e.g. substitution of inorganic fertilizer with nitrogen fixing plants). The project has successfully demonstrated the effectiveness of introducing payment incentives to farmers and in increasing the awareness of the potential of integrated ecosystem management for providing critical environmental services including the restoration of degraded pasture.

Source: Adapted from FAO (2010).

Designing policies that hold farmers to account for environmental damage and remunerate them for the provision of environmental public goods over and above those emanating from production that is already paid for through the market is challenging. It involves issues of property rights, transactions costs, identifying non-point sources of environmental pollution or provision, and measurement of non-priced environmental outputs. Moreover, it often takes a long time for the desired environmental outcome to appear. And such policies cannot be disassociated from the existing set of agricultural policies, natural resource pricing policies, and trade policies. Finally, the actual impact of financial incentives depends on farmer preferences and behaviour (Box 4.3).

Box 4.3. Farmer behaviour and management

Examining the broad range of factors driving farm management decisions is important, because it could help identifying policy options that would contribute to a sustainable agricultural sector. For example, some actions are both profitable to farmers and to the environment in reducing greenhouse gas emissions (such as fertilizer managements and animal breeding), yet are not implemented. Identifying the reasons for this, and how farmers' behaviour could be influenced to encourage greater uptake of a sustainable management, is needed in order to inform and clarify potentially cost-effective measures.

There is a large body of literature which has tried to understand the primary determinants of farmers' behavioural change. Knowler and Bradshaw (2007) synthesised recent research on farmers' adaption of conservation agriculture to identify independent variables that regularly explain adoption behaviour based on the results of 31 recent empirical analyses. This frequency analysis is useful for policy makers seeking to find any universal relationship across the several studies in relation to policy prescription. Household characteristics will be important in influencing the adoption decision for conservation agricultural managements. "Farm size" correlated positively with the adoption of conservation agricultural practices in six previous studies, but two negative correlations were also observed.

Regarding the "education" level of the farmer, several studies showed a positive correlation with the adoption of conservation practices, however, some analysis also found a negative correlation and insignificance. Similarly, the age of the farmer does not demonstrate a clear relationship. With respect to biophysical characteristics, it is not necessarily the case that larger farmers are willing to adopt conservation practices, and negative correlations and insignificance are also found. In addition, difference between owned land and leased land are not clear. Regarding the geographical differences between North America and Africa, Knowler and Bradshaw (2007) found that studies from North America tend to show a more positive significant effect of "education", "land tenure" and "farm size" on adoption than do studies in African regions.

The main finding is that there are few variables that universally explain the adoption of conservation agriculture across past analyses. Knowler and Bradshaw (2007) conclude that efforts to promote conservation agriculture will have to be tailored to reflect the particular conditions of individual locations. There is no simple formula to explain which factors may be the most important in a given case, suggesting that understanding local conditions are key.

In addition to conventional field surveys which try to find possible universal socio-economic variables that explain farm management behaviour, drivers of and barriers to behavioural change could be considered in more depth by applying theory and recent findings of behavioural economics (i.e. enriching economic theory by applying findings from the psychology literature). It is widely considered that actual (not hypothesized) human behaviour needs to be taken into consideration to tackle with policy objectives, and incentives should be thus adapted as appropriate.

Source: OECD (2011b).

Other policies affecting agricultural production

In addition to policies that can be directly oriented to influencing externalities in agriculture there are others that are part of a green growth strategy. The environmental impact of price and income support policies for agriculture has been noted earlier. However, in addition to those polices input subsidies are sometimes used to try to improve the net income of farmers. In terms of their potential negative environmental impact the most notable types of subsidies are those for fertilizer, agro-chemicals and fuel, and incentives for land clearing or drainage of wetlands. From an environmental perspective there is little justification for continuing to use subsidies of this type. However, an area in which explicit or implicit input subsidization is a more complex issue is in the use of water. The provision of investment aids to improve irrigation systems, reducing water loss and increasing irrigation efficiency, can make a positive environmental contribution, in addition to helping to "climate proof" agriculture. On the other hand farmers are often provided with irrigation water at less than full cost. The under-pricing of water and energy may result in over-use and inefficiency. The use of appropriate pricing mechanisms for water and energy is often highly sensitive politically and socially, but especially where water stress is a serious issue, addressing this will be a key part of helping to manage increasingly scarce water resources and non renewable energy in the future.

The production of feedstock for biofuels has been expanding in OECD countries in recent years, driven largely by policy support. There is a continuing debate on the magnitude of the net contribution of first generation biofuels to reduce GHG emissions, but it is clear that there are significant implications for food prices and resource use (land and water) in agriculture.

Other policies affecting the food industry

In order the address environmental issues many manufacturing companies in OECD countries are beginning to focus on *eco-innovation*, i.e. innovation that results in a reduction of the environmental impact of producing and delivering products to consumers, regardless of whether or not that effect is intended. An important feature of such innovation is that it shifts the emphasis from “end-of-pipe” pollution control to a focus on product life cycles and integrated environmental strategies and management systems (OECD, 2009a). There are many examples in food and agriculture where such an approach is important. A considerable amount of “waste” can be generated in the food and agricultural system, which not only adds to pressure on the land and water resources used by the system but also represents an untapped resource. The food and agricultural system has become increasingly energy intensive. The growth in the production of “convenience” foods and changes in the presentation of foods to consumers (e.g. sales of washed and packaged vegetables rather than in their relatively unprocessed state) incurs energy usage and generates a waste stream in the form of packaging. The standards set by retailers (e.g. requirements on the size and appearance of fruit and vegetables) can also add to the amount of material entering the waste stream as products that do not meet those requirements may be unable to find a market. Much of the food product waste which used to be fed to livestock (which is prohibited on food safety grounds) now ends up in landfill sites, which could be used instead for bioenergy production. Nevertheless, in some countries investment in facilities to produce biogas from food waste (and slurry) is underway – with investment subsidies.

Green growth in agriculture and the food system will require an examination of product life cycles and for governments to evaluate what they can do to help reduce energy usage and product waste. This is already beginning to happen. For example, food retailers in some OECD countries are beginning to reduce the amount of plastic packaging[5] they use. Various initiatives are being taken to promote the recycling of packaging materials. Many of the supply side initiatives involve the creation of networks, platforms or partnerships with participation by industry and other stakeholders. Pressure from the general public for the “greening” of the food system can be an important part of the process. Governments can assist through the use of conventional measures, such as funding research, education and demonstrations of green technologies. They can also aid the process by modifying existing regulations, e.g. on product standards or the use of waste products in feeding livestock, to promote greater efficiency in the use of energy and the food and raw material production in the sector. They can also facilitate the development of new uses for “waste” in the system, e.g. composting to produce soil-conditioning products or the use of waste for the production of bioenergy. Demand-side measures such as green public procurement are also receiving increasing attention, as governments acknowledge that insufficiently developed markets are often the key constraint for eco-innovation. Many governments or local authorities are substantial purchasers of food – for the military, the prison population, schools, public administrations, and for food assistance programmes. Such purchases can be used to promote the greening of the agricultural sector.

Policies for international trade

Growth in agricultural trade and the closer integration of national agricultural markets has been a significant feature of overall growth in recent years. The growth in world trade in agricultural products has typically been more rapid than that for world agricultural production or GDP. For the period 2000-08 world exports of agricultural products grew at an average annual rate of 5%, compared to a 2.5% rate for agricultural production and 3% for GDP (WTO, 2009). In the future, international trade will continue to play a key role in meeting world food needs and in buffering the world food economy against shocks due to climatic events. However, trade restrictions can contribute to "thinness" in international markets and accentuate international price volatility (OECD, 2008a). Volatility can be further accentuated by emergency measures taken to restrict exports when changes in the international supply/demand balance threaten to cause increases in domestic prices.[6]

Since the late 1980s, the degree of border protection in OECD countries has been significantly reduced through international trade negotiations. Starting with the Uruguay Round Agreement on Agriculture, negotiated in 1986-94 and phased in over six years from 1995, trade-distorting agricultural subsidies and tariffs have been subject to multilateral rules. However, *bound tariffs* (i.e. those at a globally-agreed maximum level) on agricultural products remain high in comparison with other sectors, averaging 35%-50% of product value. *Applied tariffs* (i.e. those set by individual countries) are much lower averaging 17% for bulk agricultural commodities and 20% for processed foods.[7]

Agricultural export subsidies have also been reduced significantly. The UR Agreement on Agriculture prohibits export subsidies for agricultural products unless they are specified in a member's lists of commitments and these must be reduced in terms of the monetary level and the quantities of exports that receive subsidies.

Restrictions on agricultural imports by non-tariff measures have been largely replaced by tariff-rate quotas which are more transparent. Among the prohibited non-tariff measures are quantitative import restrictions, variable import levies, and discretionary import licensing procedures, voluntary export restraint agreements, minimum import prices and non-tariff measures maintained through state-trading enterprises. However, the Agreement on Agriculture does not prevent the use of non-tariff import restrictions consistent with other WTO agreements such as those maintained under the Agreement on the Application of Sanitary and Phytosanitary Measures (health and safety regulations) and the Agreement on Technical Barriers to Trade (technical regulations and product standards including rules of origin). These measures can prove problematic for developing country producers.

More open agricultural markets will provide incentives for countries to produce goods and services more in line with each country's comparative advantage. Taking into consideration environmental and social costs and benefits has the potential to facilitate the sharing of technologies and innovations supportive of Green Growth. Barriers to trade in environmental goods and services can be important obstacles to the diffusion of cleaner technologies in agriculture and other sectors. Trade in environmentally-friendly technologies faces different rates of applied tariffs. In addition, non-tariff measures, such as quantitative import restrictions, customs procedures and foreign investment controls, can act as barriers to technology trade and transfer.

Demonstrating the various environmental effects of agricultural trade liberalisation is a difficult task. However, available evidence (OECD, 2004) suggests that it has resulted in some shift in production from higher to lower cost farming systems. It has reduced production intensity in countries with historically high levels of fertiliser and pesticide application, relieving environmental stresses in these areas, but has contributed to environmental pressure in those countries where production has increased. Thus it is important that the consequences of trade liberalization on environmental outcomes – and the trade consequences of environmental policies – are recognized (OECD, 2005). In this regard, the meeting of Agriculture Ministers in OECD in 2010 noted that "*care needs to be taken to avoid all forms of protectionism*". A balanced and comprehensive conclusion of the Doha Development Agenda is a necessary but not a sufficient condition to improving the environmental performance of agriculture. Implementing policy measures to address environmental externalities are also necessary.

In fisheries, international trade has increased substantially over the past decades. There is an important trade flow from developing countries to the OECD countries that constitute the principal market for fish. Many different species and products are traded, but the main share of international trade is made up of groundfish, tuna and shrimp. Fish products are from both capture fisheries and aquaculture origins with aquaculture increasing in relative importance as many fish stocks have reached or exceeded their maximum sustainable yields.

The tariff rates and structures applied by OECD countries in fish and fish products are complex and range from very low to very high levels. There is an extensive use of preferential tariff arrangements. In the trade in fish and fish products technical import requirements and sanitary regulations are in place, and in some cases a number of non-tariff barriers are applied. In the meantime, the full benefits of market liberalisation will only be achieved, without compromising sustainability, if proper fisheries management regimes are in place and thoroughly enforced. To maximise welfare gains policies should target market liberalisation and improvements in fisheries management concurrently (OECD, 2003).

International co-ordination

Much of the policy focus on achieving green growth will inevitably be domestic in nature. Each country will need to evaluate what will contribute to green growth in its food and agriculture sector and how the domestic policy environment can help to achieve that aim. However, there is also an important role for international collaboration. As already noted, unilateral actions in the face of stresses and strains in the food system, such as those generated by extreme weather events, can intensify problems in the food system for other countries. There is a need to avoid such unilateral actions if the stability of the global food system is to be assured in the future. Multilateral actions to reduce the use of harmful subsidies and incentives that promote negative environmental effects and international co-ordination in the use of measures to promote positive environmental outcomes could also play an important role in achieving green growth objectives. Since much of the future emphasis in meeting food needs will be on increasing productivity in developing countries, it is important that developed countries do not hamper opportunities for development by imposing restrictive trade policies, and that developing countries do not adopt inappropriate policies to subsidise the use of inputs or output that are inconsistent with achieving green growth objectives globally.

Beyond this, however, there is a role for proactive international action in several areas to contribute to green growth objectives. The sharing of the results of R&D and new knowledge that contributes to the greening of agriculture is important (Box 4.4). There is considerable potential for taking advantage of spillovers at the international level from the development of new production methods in agriculture (CGIAR, 2005). International co-ordination in the face of weather induced disasters affecting agriculture, which is already a feature of the activities of several international agencies, will also become more important. Although recent experience in the area of climate change policy suggests that it will not be easy to reconcile the sometimes competing needs and objectives of countries, an ongoing international dialogue will be needed if successful approaches to achieving green growth in world agriculture and the global economy as a whole are to be found.

Box 4.4. Global research alliance on agricultural greenhouse gases

The Global Research Alliance on Agricultural Greenhouse Gases was launched in December 2009 in the margins of the UN climate change conference in Copenhagen, Denmark. Instigated by New Zealand, the Alliance now has more than 30 Member countries from all regions of the world.

The Alliance provides a framework for voluntary action to increase cooperation and investment in research activities to help reduce the emissions intensity of agricultural production systems and increase their potential for soil carbon sequestration. It aims to do so in a way that will help improve the efficiency, productivity, resilience and adaptive capacity of agricultural systems, thereby contributing in a sustainable way to overall mitigation efforts, while still helping meet food security objectives.

The Alliance is founded on the voluntary, collaborative efforts of countries. Members of the Alliance aim to deepen and broaden existing mitigation research efforts across the agricultural sub-sectors of paddy rice, cropping and livestock, and the cross-cutting issues of carbon and nitrogen cycling and measurement, including by conducting an annual stock take of research activities to guide the development of their research activities.

The Alliance promotes an active exchange of data, people and research to help improve the way agricultural greenhouse gas research is conducted and to enhance participating countries' scientific capability.

Alliance Members will work with farmers and farmer organisations, the private sector, international and regional research institutions, foundations and non-governmental organizations to improve the sharing of research results, technologies and good practices, get these out on the ground.

The Alliance is an opportunity for countries to be part of an initiative that will bring together the world's best expertise to tackle the challenges of agriculture greenhouse gases and food security to grow more food, greener. It is expected that the Alliance will accelerate the international agriculture mitigation research effort for the benefit of all countries.

The Alliance will be officially launched at a ministerial summit and signing ceremony in Rome in June 2011. The Alliance research groups plan to hold their next meetings in November 2011 to review progress on their action plans and plan future work.

Source: *www.globalresearchalliance.org*

Towards a green growth strategy

A green growth strategy seeks to realize more sustainable growth and development through articulating a policy framework integrating economic efficiency, environmental integrity and social equity objectives. While policies should seek to internalize agricultural externalities (positive or negative) to the extent possible, green growth approaches must be tailored to the unique nature of the agricultural sector. The choice, design and implementation of policies will differ across countries depending on local environmental and agricultural conditions and political economy factors. Table 4.2

outlines linkages between selected policy tools and effects that can constitute a way to think about developing a green growth policy framework. It is illustrative and not exhaustive and – given the important role of technology and innovation in the green growth strategy for food and agriculture – separately identifies science and technology policy tools and technical impacts.

Table 4.2. Linkages between selected policy tools and impacts

	Economic tools	Environmental tools	Social tools	Science and technology tools
Economic impacts	**Cost-benefit assessments**	Environmental regulations to internalize costs	Green poverty reduction strategies (PRS) in agriculture	Public research to promote eco-efficient agriculture
Environmental impacts	Payments for environmental services (PES)	**Environmental cross-compliance mechanisms**	Provision of social infrastructure in rural areas	Research and development of agricultural biotechnology
Social impacts	Support to farm incomes	Production of environmental goods and services	**Structural adjustment measures**	Skills training in green agricultural practices
Technical impacts	R&D tax credits for agricultural research	Water charges and trading systems	Rural green extension programmes	**Alternative farm systems**

Source: OECD Secretariat based on Stevens (2011).

The transition to a greener food and agricultural sector implies structural changes. At the macro-level, greener economic growth could prompt a shift in financial and labour resources from agriculture to other sectors, particularly services. However, some sustainable agricultural practices such as integrated pest or nutrient management involve increased expertise and time, while others involve new on-farm activities to manage biomass (such as anaerobic digesters) or wind turbines, which could incur a shift of resources into agriculture. It is an empirical question as to the direction of change. At the micro-level, the implementation of green growth policies will likely induce changes in traditional farming practices and entail employment and distributional effects. The development of new green services, technologies and industries offers opportunities to the agricultural sector but also requires careful management of the potential job losses from more environmentally-damaging activities. Structural adjustment measures to facilitate the transition to green growth may include temporary income support, rural diversification, and training. Addressing these challenges will have implications for institutions, particularly greater co-ordination between agriculture and environment ministries in order to identify synergies and trade-offs. One example of an approach to green growth in the agricultural sector in Korea is shown in Box 4.5.

Box 4.5. Green growth policies in Korea

Korea has been a pioneer in implementing green growth through policies in all major sectors of their economy. In the food and agricultural sector, notable examples include reduction in the use of chemical fertilizers, energy savings, promotion of organic agriculture, and expansion of financial investment in the area of agricultural green technology.

In 2010, Korean farmers reduced the use of fertilizers by 8.8% between 2009 and 2010. This was achieved through better utilization of bulk blending fertilizers matched to soil characteristics.

Significant energy savings (and GHG emissions reductions) can be achieved by introducing geothermal heating system in greenhouses. The government aims to increase geothermal heating to an area covering 13 000 ha (about 1% of total agricultural land) by 2020 thus reducing oil consumption by 1.14 million kl, thereby reducing GHG emissions by 7.9 million tons of CO_2-equivalents (about 4% reduction of GHGs emission in the agricultural sector).

The Ministry for Food, Agriculture, Forestry and Fisheries has designated organic agriculture and food industries as core green industries and has outlined specific measures to develop these activities. The Ministry has also established a regular policy review process as demonstrated by the 3rd Five Year Plan on Environment-Friendly Agricultural Industry announced in November 2010.

In rural areas, the government has been managing 27 regional environmentally-friendly agricultural enterprises of 1 000 ha since 2010. In addition, the Ministry has increased the financial investment on green technology in its overall R&D budget on agricultural and fishery products to WON 251.9 billion (USD 223 million) by 2010 (one third of the total green growth R&D investment in agriculture).

The Ministry expects many jobs (about 5% of total employment in agriculture and food) will be created through significant investments (KRW 11 71.1 billion, USD 1.04 billion) promoting green growth in agriculture and fisheries.

Sources: Kim *et al.* (2010), Korean Ministry for Food, Agriculture, Forestry and Fisheries (2010).

An important component of a green growth strategy is further reforming and decoupling agricultural support from output and input levels. Such reform can potentially mitigate negative environmental impacts and provides an opportunity to target environmental public goods. In some countries, support is conditional on farmers respecting good environmental practices. Successful reform will depend on policy design, policy mix and timing as well as possible compensation and assistance for those that are adversely affected.

Payments can be designed to promote structural adjustment, for example through investment aids which assist the financial or physical restructuring of farm operations in response to demonstrated structural disadvantages. They have been used in some countries to promote rationalization and restructuring of farming and livestock operations and to support the processing and marketing of agricultural products. However, such investment aids should be limited in both amount and time and not be linked to the type or volume of agricultural production.

As part of the transition to green growth, governments can promote rural development based on ecosystem services, conservation agriculture practices, diversification of farming activities from commodity production to the processing of agricultural and forest products, eco-tourism and craft-related enterprises. Where environmentally and economically viable, land can be converted to biomass production including for bio-fuels.

Increasing the engagement of farm households in the broader rural economy includes the development of eco-tourism on farms. Rural economic diversification can be promoted through micro-credit and business development schemes. Gender-based programmes are useful as it is often women in farm households who initiate and engage in economic activities as an alternative to production agriculture.

In agriculture as in other sectors, active labour market policies including skills training are essential for helping workers make structural transitions. The adaptive capacity of labour markets in agriculture may be more limited than in other sectors owing to the narrower focus of farming and also location-specific factors. Safety nets for farmers and farm workers should be in place. Public initiatives to train rural workers in green skills such as retro-fitting buildings, landscape and habitat preservation, and renewable energy production are needed. Farmers will generally benefit from vocational training and gaining basic business skills in human resource management, networking and market development.

In the fisheries sector, government efforts to facilitate adjustment have tended to focus on short-term efforts to finance alternative employment for redundant workers. These are generally introduced as an adjunct to capacity adjustment programmes given that vessel reduction is usually the main focus of policy reform. A longer-term issue is to ensure that governments develop broader and coherent set of policy signals for fishing communities so that adjustment occurs smoothly and largely autonomously in the future. Such policies are an essential complement to ensuring that the adaptability and resilience of fishing communities are strengthened over time. The management arrangements for fisheries will also play a major role in ensuring the resilience of the fishing sector as it is essential that fisheries management policy and labour market policies are mutually supportive.

Notes

1. Reference levels define the minimum level of environmental quality that farmers are obliged to provide at their own expense and differ from country to country depending on property rights and legal systems (OECD 2010d).
2. The OECD indicator of support to agricultural producers due to policies is the Producer Support Estimate. The indicator of support to the agricultural sector due to policies is the General Services Support Estimate. The OECD also provides indicators of Government Financial Transfers to the fisheries sector. In this report the terms "support" and "transfers" are used interchangeably, to cover both agriculture and fisheries.
3. For further details of the strengths and weaknesses of non-sector specific taxes and trading schemes and non-price instruments, readers are invited to consult the *Green Growth Strategy Synthesis Report* (Tables A4 and A5).
4. In fact, tax concessions are often applied in agriculture. A particular example with negative environmental consequences is the tax concession often applied to fuel used in agriculture (OECD, 2003).
5. Since 2007, Carrefour in France has stopped using plastic bags.
6. Commodity price and income volatility also results from weather and climate related events (droughts, floods, crop and livestock diseases) and is of high public concern. More attention is now being paid to risk management strategies and policies.
7. Ongoing multilateral trade negotiations on agriculture in the World Trade Organization (WTO), which are part of the Doha Development Agenda launched in 2001, have not yet yielded agreement although talks continue on further reducing tariff and non-tariff barriers and export subsidies.

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Chapter 5

Measuring progress towards green growth in food and agriculture

A green growth strategy needs measurement tools to help policy makers evaluate the effectiveness and efficiency of their policies and the extent to which they are shifting economic activity onto a greener path. It is necessary to identify measurable green growth policy targets related to food production and consumption, economic efficiency, resource use, environmental impact, and social welfare. There is a need to develop indicators for the food and agriculture sector that together can track progress towards green growth.

A green growth strategy needs to use measurement tools to help policy makers evaluate the efficiency of their policies and measure the extent to which they are shifting economic activity onto a greener path. The aim is to broaden the range of existing economic and resource productivity indicators to allow for more comprehensive comparative analyses and benchmarking of countries on green growth.

In order to assess progress in food and agriculture several steps need to be taken. First, it is necessary to identify measurable green growth policy targets related to food production and consumption, economic efficiency, resource use and social welfare. Second, the policy targets should determine the set of indicators needed to measure economic efficiency, environmental and resource use impacts, and social welfare. Third, analytical tools and case studies are needed to assess whether policies are meeting the green growth targets in the agriculture, fisheries, and food chain.

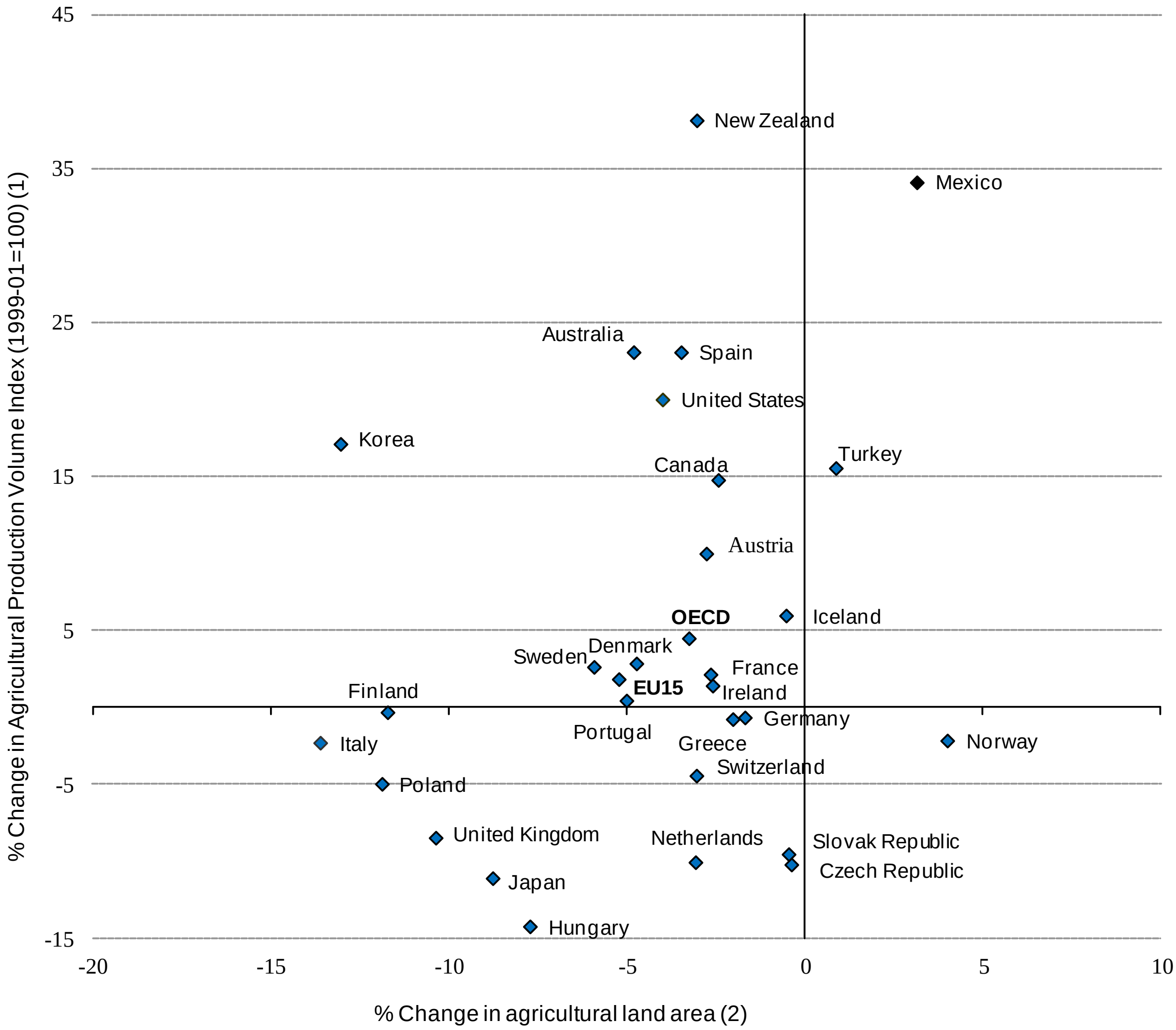
Given the specific nature of many environmental issues, the varying preferences constituting green growth across countries, the multiple factors that determine environmental outcomes in agriculture and fisheries, the lack of objective valuations of environmental externalities and public goods will make it difficult to establish quantitative assessments of the cause and effect linkages between policies and green growth performance, and any comparisons across countries would need to be undertaken with great caution. That being said, comparison of trends over time offer more promise.

There are no existing indicators for the food and agriculture sector that taken together can track progress towards green growth. Economic, agri-environmental, natural resource stocks and social indicators exist, but are at various stages of development. In particular for agri-environmental and natural resource stocks, there are methodological, measurement and data availability problems. However, there are indicators that can illustrate particular issues such as: the relationship between agriculture production and land area (Figure 5.1); use of irrigated water in agriculture (Figure 5.2); greenhouse gas emissions in relation to agriculture production (Figure 5.3); and nutrient balances (nitrogen and phosphorous) in relation to agriculture production (Figures 5.4 and 5.5). It should be stressed that all of these indicators are national averages which often encompass wide variations within the country and that weather and natural factors (such as soil status) affect the relationship between changes in agricultural production and environmental outcomes. What is needed in the long run is the development of a set of *resource intensity indicators* at different stages of production, and the *valuation of environmental externalities*, which would be helpful in assessing progress towards green growth in food and agriculture.[1]

1. The OECD regularly produces a set of agri-environmental indicators which cover the whole range of environmental media (*Environmental Performance of Agriculture: At a Glance*, 2nd edition, *forthcoming*).

Figure 5.1. Agricultural production volume index and agricultural land area

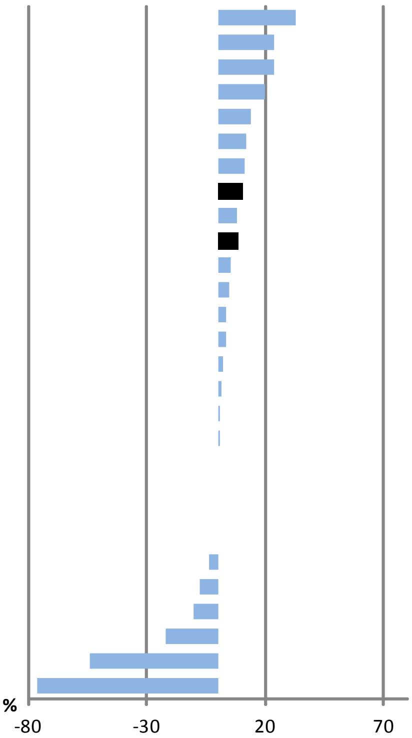
1990-92 to 2002-04



1. Agricultural production index is a volume index of total crop and livestock production, see definition in Figure 5.2. The data included in the figure are averages for 2002-04, with 1999-01 as the base period = 100.
   Czech Republic and Slovak Republic: Average 1990-92 = Average 1993-95.
   Belgium and Luxembourg are excluded as data are available only from 2000 to 2004.
2. Percentage change in the total national agricultural land area expressed in thousand hectares, 1990-92 to 2002-04.

Source: This figure is taken from OECD (2008), *Environmental Performance of Agriculture in OECD countries since 1990*, Figure 1.1.5, p. 46.

Figure 5.2. Irrigated area, irrigation water use and irrigation water application rates



	Irrigated area (1)		Change in irrigated area	Irrigation water application rates		
	'000 hectares		%	Megalitres per hectare of irrigated land		
	1990-92	2002-04	1990-92 to 2002-04	1990-92	2002-04	% change
Turkey	3 933	5 215	33	4.8	6.6	39
Greece	1 195	1 482	24	4.8	5.1	8
France	2 107	2 611	24	2.3	1.9	-17
Canada (2, 3)	900	1 076	20	3.5	3.6	1
New Zealand (2)	250	285	14	..	..	..
Spain	3 388	3 787	12	7.0	6.4	-9
Sweden (2, 4)	48	54	12	2.1	1.7	-19
EU-15 (5)	11 791	12 994	10	3.6	3.4	-6
United States (2, 6)	20 900	22 543	8	9.0	8.4	-7
OECD (7)	50 827	54 808	8	8.0	7.5	-7
Belgium	24	25	6	0.5	1.5	189
Australia (2)	2 380	2 497	5	7.5	4.1	-45
Denmark	433	448	3	0.6	0.4	-35
United Kingdom	165	170	3	1.0	0.6	-46
Mexico	6 170	6 313	2	9.9	8.7	-12
Netherlands	557	565	1	0.3	0.2	-51
Germany	482	485	1	3.3	2.4	-29
Poland	100	100	0	3.7	0.9	-77
Austria	4	4	0	12.5	20.5	64
Finland (2)	64	64	0	0.3	0.6	100
Switzerland	25	25	0	..	..	..
Italy (8)	2 698	2 698	0	..	7.7	..
Portugal (2, 9)	626	601	-4	8.9	8.6	-3
Japan	2 846	2 624	-8	20.6	21.4	4
Korea	977	879	-10	14.3	17.4	22
Hungary	213	166	-22	2.3	1.0	-55
Czech Republic (2)	43	20	-54	0.7	1.2	64
Slovak Republic (2)	299	70	-76	0.5	0.7	31

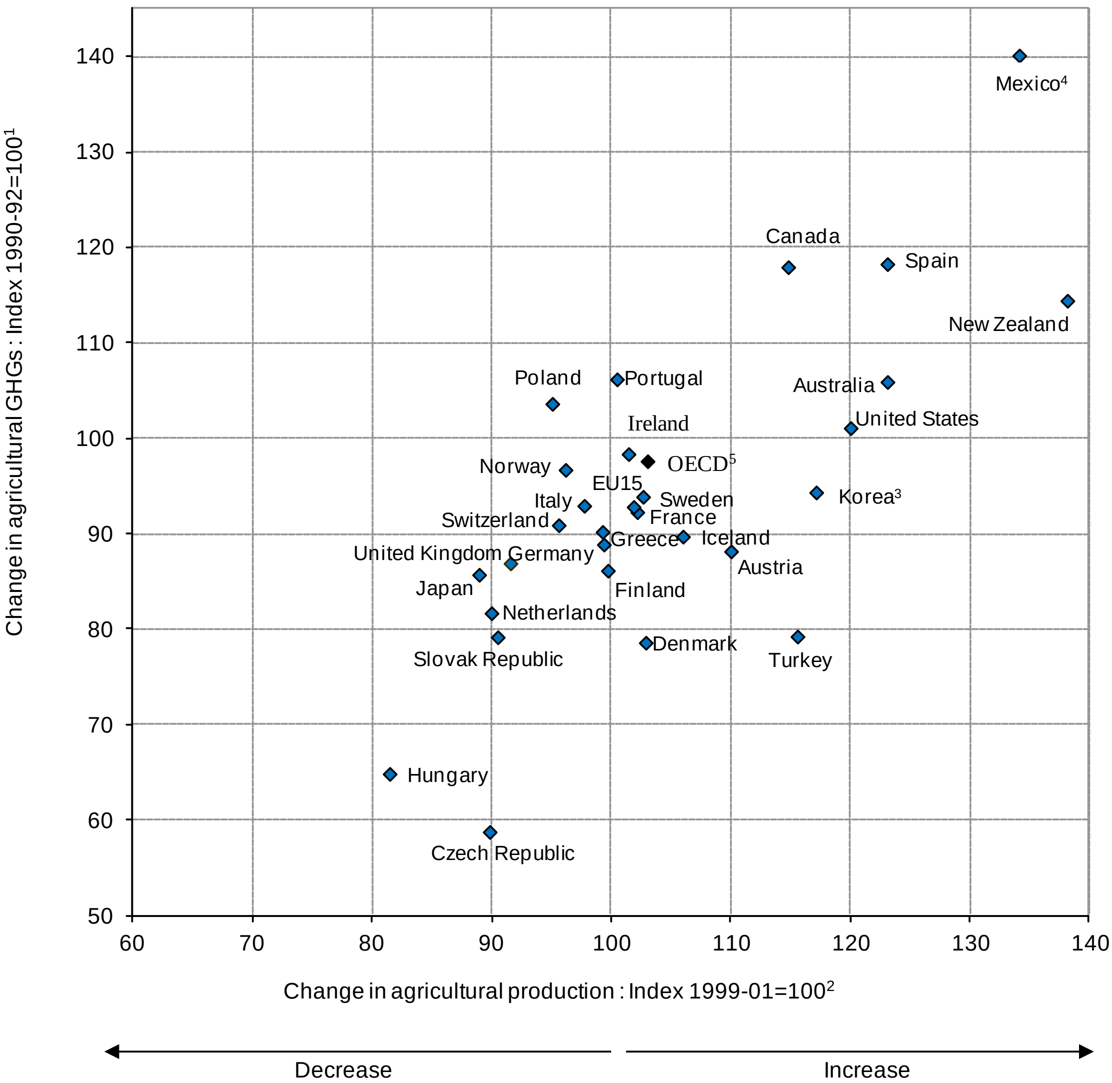
.. = not available.

1. Covers area irrigated and not irrigable area (i.e. area with irrigation infrastructure but not necessarily irrigated.) To be consistent, the years used for the average calculations are the same for irrigation water use and total agricultural water use, irrigated area and total agricultural area.
2. For some countries, data in brackets below are used to replace the average due to missing data: Australia: 1990-92 (1997), Canada: 1990-92 (1988), 2002-04 (2003). Czech Republic: 1990-92 (1994), 2002-04 (2003). Finland: 2002-04 (2001). New Zealand: 1990-92 (1985), 2002-04 (2003).
   Portugal 1990-92 (1989), 2002-04 (1999). Slovak Republic: 1990-92 (1993), Sweden: 1990-92 (1985), 2002-04 (2003). United States: 1990-92 (1990), 2002-04 (2000).
3. For Canada, the source is the OECD questionnaire at *www.oecd.org/water*.
4. For Sweden, the source is the OECD questionnaire at *www.oecd.org/water*.
5. EU15 excludes: Ireland, Luxembourg.
6. For the United States, the source is the Census of Agriculture.
7. OECD excludes: Iceland, Ireland, Luxembourg, Norway, Switzerland.
8. For Italy, share of irrigation water in total agriculture water use, for 1998.
9. For Portugal, the area irrigated is that equipped for irrigation and not the actual area irrigated which was 453 540 hectares for 2002-04.

Source: Updated from OECD (2010), *Sustainable Management of Water Resources in Agriculture*, Figure 2.2., p. 47.

Figure 5.3. Agricultural production and agricultural greenhouse gas emissions

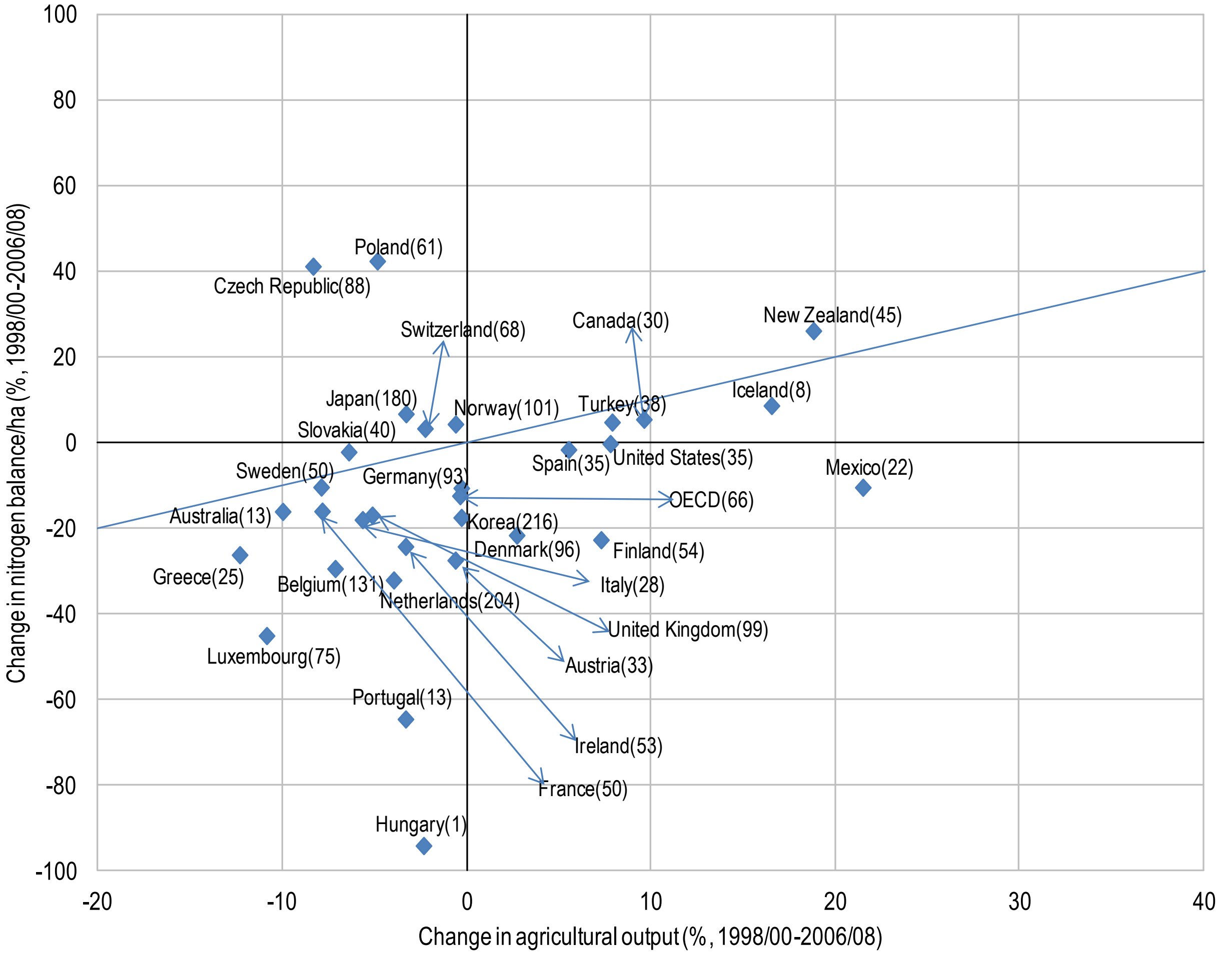
Change in index 1990-92 to 2002-04



1. See notes in Figure 5.1.
2. The Agricultural Production Index is a volume index of total crop and livestock production. The data included in this figure are averages for 2002-04, with 1999-01 as the base period = 100.
3. Data for the period 2001-03 refer to the year 1999-01 for agricultural greenhouse gas emissions.
4. Data for the period 1990-92 and 2001-03 refer to the year 1990 and 1998 for agricultural greenhouse gas emissions.
5. For OECD, Belgium and Luxembourg are not included, because data are not available on the Agricultural Production Index and, for Korea and Mexico, on agricultural greenhouse gases.

Sources: This figure is taken from OECD (2008), *Environmental Performance of Agriculture in OECD countries since 1990*, Figure 1.7.10, p. 128.

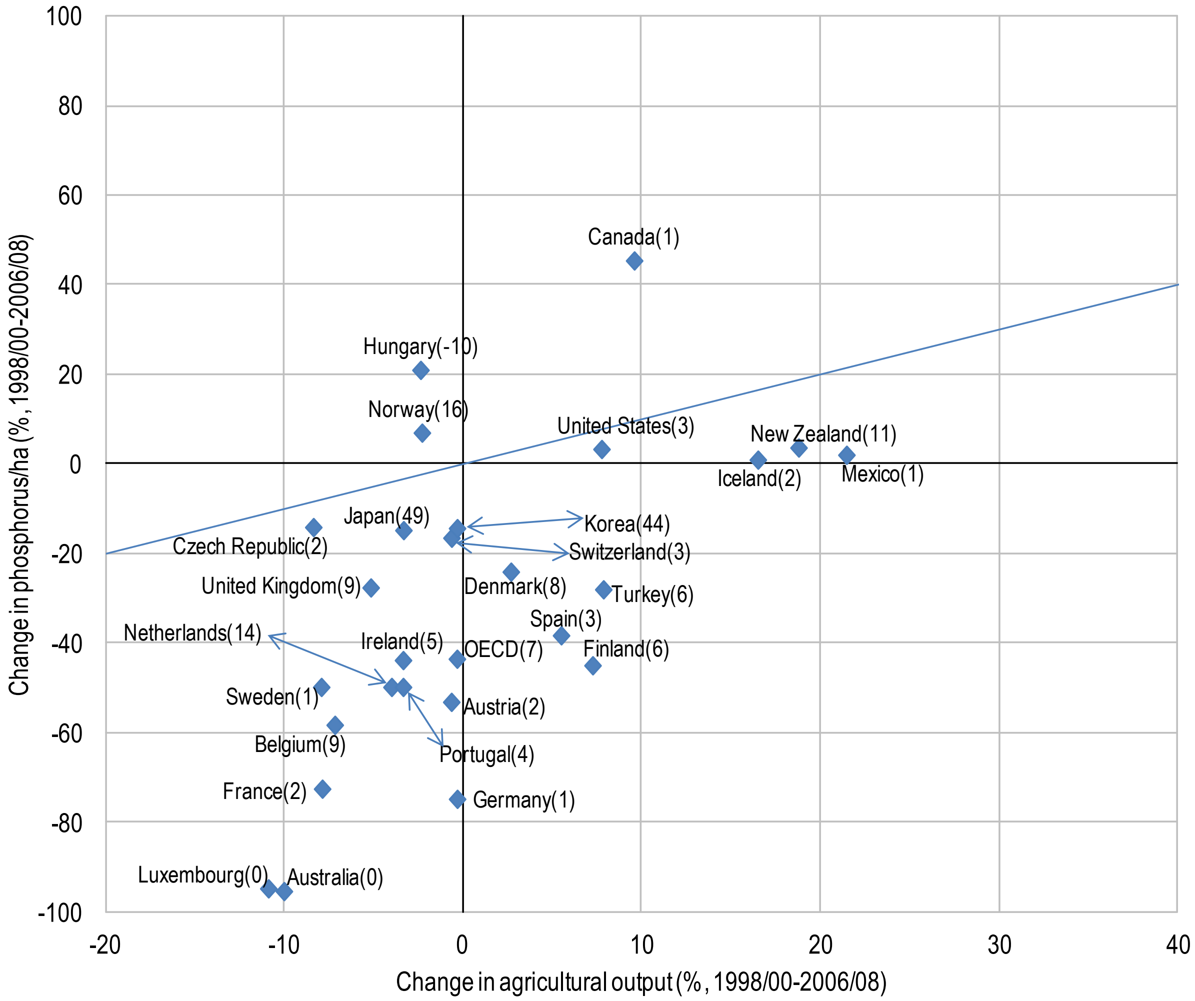
Figure 5.4. Nitrogen balance and agricultural output, 1998-00/2006-08)



The values in brackets indicate the average nitrogen balance (kg/ha) in 2006-08. A three-year average is considered to smooth the influence of natural events (such as drought and floods) on agricultural production over time.

Source: Drawing on OECD (2008), *Environmental Performance of Agriculture in OECD countries since 1990.*

Figure 5.5. Phosphorous balance and agricultural output, 1998-00/2006-08



The values in brackets indicate the average phosphorous balance (kg/ha) in 2006-08. A three-year average is considered to smooth the influence of natural events (such as drought and floods) on agricultural production over time.

Source: Drawing on OECD (2008), *Environmental Performance of Agriculture in OECD countries since 1990.*

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Chapter 6

Delivering green growth in food and agriculture

A green growth strategy for food and agriculture requires a well targeted, co-ordinated and coherent response to the economic, environmental and social challenges in the coming decades. This will involve a wide range of policy measures, some sector specific, some economy-wide. Actions to promote green growth should not only complement existing priorities but also, where necessary, change priorities in order to take advantage of beneficial overlaps (finding win-win solutions) where possible.

Moving towards green growth in the food and agriculture sector will involve a wide range of policy measures, some of which are sector specific, some economy-wide. Actions taken to promote green growth should not only complement existing priorities, but also consider changing priorities where necessary, taking advantage of beneficial overlaps where possible in order to be most cost-effective in attenuating environmental pressures, while providing for future demands for food, fibre and the provision of ecosystem services.

This report highlights key issues in developing a green growth strategy for food and agriculture, focused mainly on OECD countries. Some of the analysis and messages are also relevant to emerging and developing economies. Other international government organisations are also addressing many of the same issues, for example the FAO's *Greening the Economy with Agriculture* (GEA) project focused mainly on developing countries, and which will be an input into the Rio+20 Conference in Brazil in 2012. The OECD is working closely with the FAO, bringing together the particular strengths of each organisation (Box 6.1).

A green growth strategy for food and agriculture requires a well targeted, co-ordinated and coherent response to the economic, environmental and social challenges in the coming decades (OECD, 2007). Such a strategy ideally involves five key stages with respect to policy actions.[1]

- Outlining business as usual projections with respect to economic, environmental and social trends relevant to the food and agriculture sector (establishing baselines);
- Developing a long-term vision of the economic, environmental and social goals for agriculture and food (setting measureable targets);
- Identifying policy priorities and cost-effective policy instruments (to achieve targets);
- Implementing policies, including involvement of stakeholders, public-private partnerships, and co-ordination among different ministries (to ensure coherent policy implementation); and
- Monitoring progress towards green growth (indicators and policy reviews).

The political economy thus has to be right with a supportive overall policy environment, good governance, and ownership and buy-in from stakeholders, policy makers and the general public.

Putting the food and agricultural sector on a greener growth pathway implies change and adjustment, sequencing and timing of policies both in the short and long term. Who shoulders the costs or reaps the benefits – not only in terms of income flows but stocks of wealth – has social and distributional consequences. This means there will be winners and losers. Opening or facilitating alternative opportunities for those adversely affected will help smooth the transition. In the short run some form of compensation is often associated with significant reform. But ensuring that such compensation for adjustment is both targeted and temporary is difficult, especially in the agriculture and fisheries sector that already receives significant public support. However, moving to green growth offers opportunities to, for example, further reorient support to improve environmental performance, enhance the capacity of farmers and fishers to become more efficient and productive, and facilitate the diversification of their activities. In this context, economy-wide social welfare and rural development policies have a role to play. But here is neither a silver bullet nor a unique "one-size-fits-all" policy solution.

Box 6.1. The FAO's *Greening the Economy with Agriculture* project

The Food and Agriculture Organisation (FAO) is exploring how the food and agriculture sector can contribute to greening the economy, with a particular focus on developing countries where agriculture, forestry and fisheries account for a major part of the economy and employment and have significant impacts on natural resources. The overall objective of the FAO initiative, Greening the Economy with Agriculture (GEA), is to contribute to the definition and implementation of the green economy in the context of sustainable development, food security and poverty alleviation through the mobilization of the food and agriculture sector. The project will be a contribution to the UN Conference on Sustainable Development (UNCSD, or Rio+20) in Rio de Janeiro, Brazil, in June 2012.

Considering the importance of agriculture, forestry and fisheries in alleviating poverty and the great impact of its management on natural resources, this sector is an essential part any green economy strategy. A green economy needs a dual effort in increasing food and agriculture productivity, while improving both ecological and economic efficiency in the use of resources throughout the food chain: from the resources used and recycled during production, through waste minimization during post-harvest handling, processing, retailing and consumption, to fair trading.

The cost-effectiveness of greening agriculture in developing countries is likely to be far higher than a similar effort in other sectors and could, at the same time, help alleviate poverty and hunger, improve human health and nutrition and lower adverse ecological impacts, such as biodiversity loss, soil erosion, water stress and greenhouse gas emissions.

Through action at technical, policy and civil society involvement levels, GEA seeks to:

- Assess how the green economy translates into the food and agriculture sector, including opportunities and constraints;
- Seek the endorsement of the constituencies in agriculture, forestry and fisheries for a GEA strategy;
- Promote food and agriculture stakeholders' participation into the Rio+20 process.

By taking a proactive role in international, regional and national debates for Rio+20 and beyond, the GEA initiative would create bridges among different stakeholders and between constituencies, notably between agriculture and environment, while strengthening the overall resilience of countries to exogenous shocks (macroeconomic and ecological).

FAO seeks to team-up with international partners on the GEA initiative, including collaboration with the OECD. FAO plans to work through several international and national partners in analyzing existing information and developing possible GEA scenarios for the future, from evaluating sustainability progress and gaps in the food supply chain to projecting supply and demand towards 2050. It also plans to develop international guidelines for assessing sustainability throughout the food chain. The consultation will be launched with a joint FAO-OECD international expert meeting in September 2011.

In brief, a green growth strategy should establish productivity and environmental performance priorities for food and agriculture, address constraints to delivering improvements, and foster policies and management practices that can achieve green growth objectives. At the core of green growth is the presence of unpriced public goods and externalities that drive a gap between private returns to economic activities and overall benefits to society. Green growth strategies should attempt to close this gap.

Overcoming obstacles to achieving green growth

Poorly functioning markets, inappropriate policies, weak governance structures and ineffective regulations can all hinder green growth. Moreover, climate change and extreme weather events are important factors affecting food production. Markets often do not adequately price natural resources (e.g. carbon, water, biodiversity), deal with pollution or reward public goods associated with agriculture, or common pool resources like fisheries (Box 6.2) and air quality. Moreover, market outcomes can lead to welfare and distributional outcomes that can conflict with norms of social equity. When farmers and fishers do not have incentives to take into account externalities, natural resources may be over-exploited, too much pollution may be produced, and not enough of the environmentally beneficial services desired by society may be provided, unless appropriate regulations are implemented and enforced. This is as much about critically reviewing existing policies as it is about developing and implementing new ones. Throughout the food supply chain, vested interests, the reluctance to reform long-standing policy measures and the uncertainty of change can be tackled by providing the right incentives and information on alternative opportunities for participants, involvement of a wider range of stakeholders in the policy debate, and learning from the experiences of others.

Box 6.2. Individual Transferable Quota in New Zealand Fisheries

New Zealand has adopted (from 1986) a market-based system for the allocation of limited fisheries resources. This provides indicators of resource values through Individual Transferable Quota (stock) and Annual Catch Entitlement (flow) prices in markets for these access rights. The market prices signal values among potential users who make the allocation decisions by buying or selling rights.

The collection of sale price data allows the market value of resource access to be tracked over time. These indicate an annual net economic surplus of around NZD 350 m for commercial fisheries. The total GDP contribution of New Zealand commercial fisheries is around NZD 900 m per annum.

The Ministry of Fisheries has commissioned economic studies of the functioning of the management system under rights-based allocation that have demonstrated the efficiency of quota market operations. Studies of quota systems elsewhere have shown empirically a range of positive impacts including productive efficiency, increased economic value, and reduced negative impacts on fish stocks and the environment.

Source: New Zealand Ministry of Fisheries.

One of the main green growth principles is policy integration, to avoid conflicting policy signals. For example, it would not be cost-effective to implement a regulation to control nutrient run off from farms while subsidies are given for fertilizer use or for production linked support, which encourages overuse of nutrients.

Dealing with market imperfections, internalizing external environmental effects or pricing resources to reflect their scarcity should also be a high priority. However, even where there are overall benefits to society, where there are increased costs in the short run, this can present obstacles to implementation. Similarly, the cost-effectiveness of policies (or business initiatives) to facilitate research, development and innovation to enhance resource productivity is difficult to assess when the time period for payoff is over decades rather than years.

Many farmers and fishers are not aware of alternative, better management practices, or lack the technical know-how to deploy them. They may be concerned that adopting, for example, conservation tillage, lower stocking rates, better management of nutrients, pests and irrigation water will increase their costs and not result in win-win solutions for both profitability and environmental performance. Further, even in the case of win-win solutions in the long term, there may be a case for financial assistance to facilitate transition costs in short term. There is also a role for education, training, information and sharing experiences ("demonstration effect"). In a broader perspective, where farms are family owned and property is transmitted through generations, there is an incentive for farmers to use responsible practices and conserve natural resources.

Connecting natural resource use and environmental outcomes to social preferences is an important part of a green growth strategy. If consumers cannot transmit their preferences regarding the nature of the food they eat to producers up the supply chain, then an important market signal is lost. Both businesses and public agencies have moved to fill this gap by providing certification of the characteristics of products through eco-labelling. By providing the consumer with information that enables them to choose the product with the characteristics they desire, producers are given the incentive to respond to social preferences in a way that is compatible with the market. Good transmission of information along the food supply chain will help achieve green growth.

At low levels of development, lack of infrastructure, under investment in human capital and poor institutional quality can mean heavy reliance on resource extraction and little incentive for improved natural resource use such as better fisheries and forest management. This involves issues of investment, market openness, and property rights. Capacity building and private investment can work together to establish the view of the resource base as a foundation for sustainable long term growth.

Establishing priorities

The motivation for green growth is that long-term growth is maximised by paying attention now to resource limits and constraints. This raises questions of trade-offs (or synergies) over time as it implies in many cases that changes in resource use that could have negative short-term impacts on economic growth will enable improved progress in the long term. In the case of food, this is complicated by the constraint that the world must produce enough food to satisfy the nutritional requirements of a growing population, it must do so continually, and it must preserve the resource base required to do so in the face of growing competing demands and need to mitigate and adapt to climate change.

The FAO has estimated that food production must grow by 70% by 2050 to match global population trends. Food production could be increased using current technologies, but it would require cutting down a large proportion of remaining forests, mostly in developing countries. But investments in technology could reduce the amount of new land required considerably

In some places, the state of environmental resources is already serious. For example, the FAO estimates that more than half of current fish stock groups are fully exploited and cannot support more fishing. 25% of fish stock groups could support additional fishing, and 25% are already overexploited, collapsed, or recovering from collapse. At the same time, for many developing countries, fish is the major (if not only) source of animal protein and is central to hunger and food security (Love, 2010). For developed countries, fishing is typically a small part of the economy and food supply. These differences will drive different priorities, but in all cases the system must be put on a sustainable footing before irreversible resource depletion occurs.

Constructing policy packages

A range of policy options are available to advance a green growth strategy. Best approaches are those where economic and environmental objectives are attained. But even in those cases where the objectives are not always *complementary*, ensuring that the different elements of the policy package do not *conflict* is an essential part of any approach to green growth.

Many environmental challenges such as climate change or preserving biodiversity[2] are global in nature, and globalisation will continue to deepen the connection between economies. This means that applying green growth principles in the domestic policy framework alone is not sufficient; trans-boundary and multilateral measures need to also be considered. This includes policies impacting on trade, investment, knowledge transfer and multilateral environmental agreements. It means ensuring compatibility between green growth policies, trade and environmental regulations.

In all countries there is an extensive policy tool-kit to draw on, and that includes market based instruments and regulations. For example, tradable quotas in fisheries provide market incentives for conservation, but a total allowable catch is also set, along with gear restrictions, season limits and other rules that govern fisheries. Water rights can be well defined and water pricing put in place, but regulations governing water trade and use also exist, which is important for allocating water in agriculture (OECD, 2010h). Together with performance standards, property rights, and legal systems, the challenge is not just how to choose between policy instruments, but how to ensure that the policy package as a whole works well.

Another dimension of constructing policy packages is the often multiple levels of governments that are involved. Local governments can offer the knowledge required to make policies work "on the ground" where the trade-offs between economic and environmental concerns are most strongly experienced. National-level policies can undermine the regional level when there is a lack of information about the existence of conflicting rules or practices. On the other hand, regional initiatives that focus on stand-alone projects without regard to where these projects fit within national policy frameworks risk falling short of their promise.

Achieving green growth is about taking a broader view—both exploring the cost-effectiveness of different policy measures in meeting a range of objectives, and identifying the synergies between policies. A good green growth policy package will: maximise policy coherence; identify and implement a balanced set of market-based and regulatory policy tools; facilitate longer-term structural adjustment, including through public and private innovation and investment; take into account both the whole food supply chain (vertical connections) and the linkages outside the food chain (horizontal connections); and avoid as far as possible unintended consequences.

Notes

1. Actions taken by the various business enterprises in the entire food chain are also crucial to achieving green growth, and are closely linked to the prevailing policy environment.
2. The preservation of biodiversity and resilient ecosystems is a precondition for the capacity of agriculture to provide food and fibre.

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Chapter 7

Conclusions

The food and agriculture sector is crucially important in the green growth context because it is the major user of land, water and marine resources and has important linkages with biodiversity. While the sector can cause environmental harm, it also provides valued ecosystem services. This is true notwithstanding the fact that it typically accounts for a small share of employment and GDP in most OECD countries, though much larger shares in many developing countries.

The food and agriculture sector has been largely successful in meeting the demands of a world population that continues to grow in size and prosperity. Productivity growth has been strong, exceeding the population growth rate. Many farmers and fishers are aware of the importance of their economic dependence on conserving natural resources and ecosystems, and governments have started to re-orientate their policy priorities to take account of the environmental consequences of food and agriculture production, which has led to some improvements in environmental performance.

Nevertheless, progress has been uneven and the future holds many new challenges. In some countries and regions productivity growth in agriculture and fisheries has been low and there is an increasing awareness that some growth has not been sustainable. Pressure on land, water, marine ecosystems, forests, and the biodiversity resources that are fundamental to sustainable food production is already critical in some areas and is likely to grow. Agriculture and fisheries are particularly vulnerable to climate change and will need to adapt to changing patterns of precipitation, temperature and extreme weather events.

Pursuing green growth cuts across many of the traditional categories governments use to organise their actions. Green growth implies that the whole set of policies becomes more coherent and compatible with respect to their growth and sustainability objectives.

More integrated and coherent policy approaches are beginning to take shape, involving a combination of policy instruments. This is evident with climate change, for example, as many countries have started to coordinate and integrate the previously separated policy domains of water, flood and drought control and the environment. For example, support has been provided for the restoration of land in flood plains by planting trees, which has helped to reduce impacts of floods, improved water quality, and led to co-benefits such as restoring biodiversity and sequestering greenhouse gases.

Tracking and measuring progress towards green growth in the food and agriculture sectors will not be easy. Not only are the links between the biophysical, economic and social relationships imperfectly understood, information on the state of the environment is difficult to collect and interpret. There is no single overarching indicator of environmental (or social) performance. While some indicators are available, the challenge will be to develop indicators that cover the food chain as a whole.

From the analysis three priority areas for policy attention stand out: increasing productivity in a sustainable manner, in particular by according a higher priority to research, development, innovation, education, extension services and information; ensuring that well functioning markets provide the right signals, and in particular that prices reflect the scarcity value of natural resources as well as the positive and negative environmental impacts of their use; and establishing and enforcing well defined property rights, so as to ensure sustainable resource use.

Moving beyond these general guidelines to more concrete policy proposals that illustrate – without prescribing – how alternative policy sets can contribute to a greener growth model for food and agriculture will require further consideration. In this context, particular attention will need to be paid – in collaboration with FAO – to the specific circumstances of developing countries. Ultimately, the objective would be to institute an ongoing process of policy monitoring and evaluation. Over time, this could become a tool to increase collective knowledge about how policies contribute to green growth. It would be a way for countries to measure their own progress relative to others and learn from the experience of others. Most importantly it would be a step towards reframing growth to better account for natural assets and the environmental risks that could ultimately undermine economic growth and development.

ANNEX A

TABLES

Table A.1. Summary of environmental trends in OECD agriculture

Factor	Summary of trends	Explanatory notes
Soil	Improvement or stability in soil erosion from both water and wind. Increase in the share of agricultural land in the tolerable erosion risk class and reduction in areas with moderate to severe erosion risk	Areas of agricultural land affected in terms of different classes of erosion, i.e. tolerable, low, moderate, high, severe.
Water	Agricultural water use rose by 2% compared to no change for all users from 1990-92 to 2001-03. Increase in irrigated area was 8% compared to a reduction in total agricultural area of 3%. Limited data indicate that an increasing share of supplies are being drawn from aquifers – agriculture's share in total groundwater utilisation was over 30% in one third of OECD countries in 2002.	Agricultural water use accounted for 44% of total water use in OECD countries in 2001-03.
Air	Farming accounted for 22% of total OECD acidifying emissions, 8% of the use of potential ozone depleting substances, and 8% of greenhouse gases in 2002-04. Total ammonia emissions grew by 1% from 1990-92 to 2001-03, but there was a reduction in overall acidifying emissions. GHG emission decreased in most countries but there were in increases of over 5% in some countries.	Agriculture accounts for over 90% of anthropogenic ammonia emissions; nearly 75% of methyl bromide use, 70% of nitrous oxide, and over 40% of methane emissions.
Nutrients	Decline in nutrient balance surplus of 4% for nitrogen and 19% for phosphorous between 1990-92 and 2002-04. Use of inorganic nitrogen fertilizer rose by 3%, but that of inorganic phosphate declined by 10%	Measure relates to gross nutrient balance, i.e. the difference between the quantity of nutrients entering and leaving the agricultural system.
Pesticides	Total pesticide use declined by 5% between 1990-92 and 2001-03 with marked variations across countries.	Measured in terms of pesticide use (or sales) in terms of tonnes of active ingredients.
Energy	On-farm energy consumption increased by 3% between 1990-02 and 2002-04 compared to 19% for all sectors.	Share of farming in total OECD energy consumption was around 2% in 2002-04.
Biodiversity	Increasing diversity of crop varieties and livestock breeds in production (1990-2002). Decline in farmland bird populations from 1991-2004, but less pronounced than in the 1980s.	

Source: OECD (2008).

Table A.2. Matrix of environmental regulations in agriculture

Regulation	Purpose	Form
Water quality	Maintain chemical, physical and biological integrity of water by addressing point and non-point sources of pollution.	Groundwater controls Pollutant discharge permits Animal feeding restrictions Irrigation rules
Air quality	Maintain and improve the quality of air to protect human health and the environment by controlling emissions.	Emission standards for air pollutants, *e.g.* nitrous oxide Standards for particulate matter Air quality permits
Land use	Preserve quality of land through limiting production intensity and overuse of chemicals.	Chemical use permits Limits on waste disposal Soil removal and placement rules
Pesticides	Control use of chemicals which may pose a risk to human health and the environment.	Pesticide registration and labelling Pesticide use restrictions Food and feed residue limits.
Natural habitats	Maintain or restore the natural habitats and populations of species of wild fauna and flora.	Land development restrictions Endangered species protections Agricultural habitat rules
Machinery and equipment	Maintain farm machinery and equipment in good working order and prevent environmental damage.	Emissions controls Noise limitations Diesel fuel restrictions
Food safety and quality	Safeguard the health and well-being of consumers.	Animal welfare provisions Storage and handling rules Food labelling requirements

Source: OECD Secretariat.

Table A.3. Recent trends in productivity growth in world agriculture

	1961-1990	1990-2007 (a)	1990-2007 rate minus 1961-1990 rate
	Average annual increase %		
Yields			
Maize	2.20	1.77	-0.43
Rice	2.19	0.96	-1.23
Soya beans	1.79	1.08	-0.71
Wheat	2.95	0.52	-2.43
Output per unit			
Land	2.03	1.82	-0.21
Labour	1.12	1.36	0.24

(a) Averages for land and labour are for 1990-2005.

Source: Alston *et al.* (2009).

Table A.4. Projected impact of climate change on agriculture

Outcome	Level of confidence
Increase in crop yields in mid-to high latitude regions with temperature increases of 1-3°C but lower yields in low-latitude regions (also higher forestry productivity). Increases in temperatures above 3°C to have a negative impact on yields in all regions	Medium
Changes in the frequency and severity of extreme climate events have significant consequences for food (and forestry) production and for food insecurity	High
Increasing benefits of adaptation to climate change with low to moderate warming	Medium
Adaptation to place stress on water and other resources	Low
Smallholders and subsistence farmers and pastoralists to suffer complex, localised impacts	High
International trade in food and forest products projected to increase, with increased dependence on food imports for most developing countries	Medium to low

Source: Parry *et al.* (2007).

Table A.5. Estimated annual private and public expenditures on agricultural research and development

	Total expenditure (billion 2000 US PPP dollars)			**Shares** (%)	
	Public	Private	Total	Share of world R&D expenditure	Public share of regional/all countries totals
Developing countries	12.8	0.9	13.7	38	94
Developed countries	10.2	12.6	22.8	62	45
All countries	23.0	13.5	36.5	100	63

Based on data from 28 developed countries and 139 developing countries in current local currency units, deflated to 2000 constant currency units, and converted to internationally comparable values using purchasing power parity (PPP) exchange rates.

Source: Science Council of the Consultative Group on International Agricultural Research (2005).

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