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GREEN economy

Agriculture

Investing in natural capital

Acknowledgements

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Contents

List of acronyms **35**

Key messages **36**

1 Introduction **38**
1.1 General background 38
1.2 Conventional/industrial agriculture 40
1.3 Traditional/small farm/subsistence agriculture 41
1.4 The greening of agriculture 42

2 Challenges and opportunities **44**
2.1 Challenges 44
2.2 Opportunities 48

3 The case for greening agriculture **50**
3.1 The cost of environmental degradation resulting from agriculture 50
3.2 Investment priorities for greening agriculture 51
3.3 The benefits of greening agriculture 57
3.4 Modelling: Future scenarios for green agriculture 61

4 Getting there: Enabling conditions **64**
4.1 Global policies 64
4.2 National policies 65
4.3 Economic instruments 66
4.4 Capacity building and awareness-raising 66

5 Conclusions **68**

References **70**

List of figures

Figure 1: Total average contribution to poverty reduction from growth of agricultural, remittance and non-farm incomes in selected countries . . . 39
Figure 2: Contribution of agriculture to GDP and public expenditure on agriculture as a proportion of agricultural GDP . . . 39
Figure 3: Global trends in cereal and meat production, nitrogen and phosphorus fertiliser use, irrigation and pesticide production . . . 40
Figure 4: Regional distribution of small farms . . . 41
Figure 5: Distribution of population by age in more developed and less developed regions (1950-2300) . . . 44
Figure 6: Urban and rural population trends in developing regions . . . 45
Figure 7: Trends in food commodity prices, compared with trends in crude oil prices . . . 45
Figure 8: Percentage of country populations that will be water stressed in the future . . . 46
Figure 9a-b: The makeup of total food waste . . . 47
Figure 10: Expected future food insecurity . . . 48
Figure 11: Share of overseas development assistance for agriculture (1979–2007) . . . 48
Figure 12: Global trade in organic food and drinks (1999-2007) . . . 49
Figure 13: Estimated producer support by country (as a percentage of total farmer income) . . . 65

List of tables

Table 1: Potential indicators for measuring progress towards green agriculture . . . 43
Table 2: Selected evidence on benefits and costs of plant and animal health management . . . 52
Table 3: Selected evidence on benefits and costs of soil management strategies . . . 55
Table 4: Selected evidence on benefits and costs of water management strategies . . . 56
Table 5: Selected evidence on benefits and costs of agricultural diversification . . . 58
Table 6: Incremental annual agricultural investment figures by region needed to counteract climate-change impacts on child malnutrition . . . 60
Table 7: Results from the simulation model . . . 62

List of boxes

Box 1: Agriculture at a crossroads . . . 41
Box 2: Opportunities for improved sanitation systems and organic nutrient recycling . . . 46
Box 3: Innovations in the agricultural supply chain increase shareholder and societal value . . . 49
Box 4: Cost of training smallholder farmers in green agriculture practices . . . 52
Box 5: Simple storage: low investment, high returns . . . 54
Box 6: Investment in sustainable agriculture – case study . . . 57
Box 7: Innovative sustainable and social capital investment initiatives . . . 59
Box 8: Organic versus conventional cotton production . . . 59

List of acronyms

ADB	Asian Development Bank
AKST	Agricultural knowledge, science and technology
BAU	Business-as-usual
BCI	Better Cotton Initiative
BSI	Better Sugar Initiative
CAADP	Comprehensive Africa Agriculture Development Programme
CGIAR	Consultative Group on International Agricultural Research
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
DEFRA	Department for Environment, Food and Rural Affairs (UK)
EU	European Union
FAO	Food and Agriculture Organisation of the United Nations
FAOSTAT	Food and Agriculture Organisation Statistical Databases
FiBL	German Research Institute of Organic Agriculture
G8	Group of Eight
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
GHG	Greenhouse gas
GMO	Genetically modified organism
GRID	Global Resource Information Database
HICs	High Income Countries
IAASTD	International Assessment of Agricultural Knowledge, Science and Technology for Development
ICARDA	International Centre for Agricultural Research in the Dry Areas
IDH	Dutch Sustainable Trade Initiative
IEA	International Energy Agency
IFAD	International Fund for Agricultural Development
IFOAM	International Federation of Organic Agriculture Movements
IFPRI	International Food Policy Research Institute
ILO	International Labour Organisation
IMF	International Monetary Fund
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
ITC	International Trade Centre
LICs	Low Income Countries
LMICs	Lower Middle Income Countries
MDG	Millennium Development Goal
MSCI	Morgan Stanley Capital International
NCAR	National Centre for Atmospheric Research
NGO	Non-governmental organisation
ODA	Oversees Development Assistance
OECD	Organisation for Economic Co-operation and Development
PAHM	Plant and animal health management
PES	Payment for Ecosystem Services
PICS	Purdue Improved Cowpea Storage
R&D	Research and development
ROI	Return on investment
RSPO	Roundtable on Sustainable Palm Oil
RTRS	Round Table on Responsible Soy
SAM	Sustainable Asset Management AG
SOM	Soil organic matter
SRI	System Rice Intensive
SWFs	Sovereign wealth funds
UMICs	Upper Middle Income Countries
UNCTAD	United Nations Conference on Trade and Development
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESC ECA	United Nations Economic and Social Council, Economic Commission for Africa
WDR	World Development Report
WIPO	World Intellectual Property Organisation
WTO	World Trade Organisation
WWAP	World Water Assessment Programme

Key messages

1. Feeding an expanding and more demanding world population in the first half of this century, while attending to the needs of nearly one billion people who are presently undernourished and addressing climate change, will need managed transitions away from "business-as-usual" (BAU) in both conventional[1] and traditional[2] farming. In different ways and in varying degrees, current farming systems deplete natural capital and produce significant quantities of global greenhouse gases (GHG) and other pollutants, which disproportionately affect the poor. The continued demand for land-use changes is often responsible for deforestation and loss of biodiversity. The economic cost of agricultural externalities amounts to billions of US dollars per year and is still increasing. A package of investments and policy reforms aimed at greening agriculture[3] will offer opportunities to diversify economies, reduce poverty through increased yields and creation of new and more productive green jobs – especially in rural areas, ensure food security on a sustainable basis, and significantly reduce the environmental and economic costs associated with today's industrial farming practices.

2. Green agriculture is capable of nourishing a growing and more demanding world population at higher nutritional levels up to 2050. It is estimated that an increase, from today's 2,800 Kcal availability per person per day to around 3,200 Kcal by 2050, is possible with the use of green agricultural practices and technologies. It is possible to gain significant nutritional improvements from increased quantity and diversity of food (especially non-cereal) products. During the transition to a greener agriculture, food production in high-input industrial farming may experience a modest decline, while triggering significant positive responses in more traditional systems run by small farmers in the developing world, and producing the majority of stable crops needed to feed the world population. Public, private and civil initiatives for food production and social equity will be needed for an efficient transition at farm level and to assure sufficient quality nutrition for all during this period.

3. Green agriculture will reduce poverty. Environmental degradation and poverty can be simultaneously addressed by applying green agricultural practices. There are approximately 2.6 billion people who depend on agriculture for livelihood, a vast majority of them living on small farms and in rural areas on less than US$1 per day. Increasing farm yields and return on labour, while improving ecosystem services (on which the poor depend most directly for food and livelihoods) will be key to achieving these goals. For example, estimates suggest that for every 10 per cent increase in farm yields, there has been a 7 per cent reduction in poverty in Africa, and more than 5 per cent in Asia. Evidence shows that the application of green farming practices has increased yields, especially on small farms, between 54 and 179 per cent.

4. Reducing waste and inefficiency is an important part of the green agriculture paradigm. Crop losses due to pests and hazards, combined with food waste in storage, distribution, marketing and at the household level, account for nearly 50 per cent of the human edible calories that are produced. Currently, total production is around 4,600 Kcal/person/day, but what is available for human consumption is around 2,000 Kcal/person/day. The Food and Agriculture Organisation (FAO) suggests that a 50 per cent reduction of losses and wastage in the production and consumption chain is a

1. Refer to section 1.2 for more details about what this report categorises as conventional or industrial agriculture.
2. Refer to section 1.3 for detailed information about what this report considers traditional, smallholder and subsistence farming.
3. Refer to section 1.4 for detailed information about a green agriculture paradigm.
4. For details, refer to the Modelling Chapter of this report.

necessary and achievable goal. Addressing some of these inefficiencies – especially crop and storage losses – offers opportunities that require small investments in simple farm and storage technology on small farms, where it makes the most material difference to smallholder farmers. The FAO reports that although reducing post-harvest losses could be achieved relatively quickly, less than 5 per cent of worldwide agricultural research and extension funding currently targets this problem.

5. Greening agriculture requires investment, research and capacity building. This is needed in the following key areas: soil fertility management, more efficient and sustainable water use, crop and livestock diversification, biological plant and animal health management, an appropriate level of mechanisation, improving storage facilities especially for small farms and building upstream and downstream supply chains for businesses and trade. Capacity building efforts include expanding green agricultural extension services and facilitating improved market access for smallholder farmers and cooperatives. The aggregate global cost of investments and policy interventions required for the transition towards green agriculture is estimated to be US$ 198 billion per year from 2011 to 2050.[4] The value added in agricultural production increases by 9 per cent, compared with the projected BAU scenario. Studies suggest that "Return on investments (ROI) in agricultural knowledge, science and technology across commodities, countries and regions on average are high (40-50 per cent) and have not declined over time. They are higher than the rate at which most governments can borrow money". In terms of social gains, the Asian Development Bank Institute concluded that investment needed to move a household out of poverty, in parts of Asia, through engaging farmers in organic agriculture, could be as little as US$ 32 to US$ 38 per capita.

6. Green agriculture has the potential to be a net creator of jobs that provides higher return on labour inputs than conventional agriculture. Additionally, facilities for ensuring food safety and higher quality of food processing in rural areas are projected to create new better quality jobs in the food production chain. Modelled scenarios suggest that investments aimed at greening agriculture could create 47 million additional jobs in the next 40 years, compared with the BAU scenario.

7. A transition to green agriculture has significant environmental benefits. Green agriculture has the potential to: rebuild natural capital by restoring and maintaining soil fertility; reduce soil erosion and inorganic agro-chemical pollution; increase water-use efficiency; decrease deforestation, biodiversity loss and other land use impacts; and significantly reduce agricultural GHG emissions. Importantly, greening agriculture could transform agriculture from being a major emitter of GHG to one that is net neutral, and possibly even be a GHG sink, while reducing deforestation and freshwater use by 55 per cent and 35 per cent, respectively.

8. Green agriculture will also require national and international policy reforms and innovations. Such policy changes should focus particularly on reforming environmentally harmful subsidies that artificially lower the costs of some agricultural inputs and lead to their inefficient and excessive use. In addition, they should promote policy measures that reward farmers for using environmentally-friendly agricultural inputs and farming practices and creating positive externalities such as improved ecosystem services. Changes in trade policies that increase access of green agricultural exports, originating in developing countries to markets in high income countries, are also required, along with reforms of trade-distorting production and export subsidies. These will facilitate greater participation by smallholder farmers, cooperatives and local food processing enterprises in food production value chains.

1 Introduction

This chapter makes a case for investing in greening the agriculture[5] sector, emphasising the potential global benefits of making this transition. It provides evidence to inspire policymakers to support increased green investment and guidance on how to enable this transformation, which aims to enhance food security, reduce poverty, improve nutrition and health, create rural jobs, and reduce pressure on the environment, including reducing GHG emissions.

The chapter begins with a brief overview of agriculture at the global level, followed by a discussion on conceptual issues including two predominant farming-practice paradigms, i.e. conventional (industrialised) agriculture systems and traditional (subsistence) smallholder agriculture. The section ends with a brief description of key characteristics of the green agriculture paradigm. Section 2 presents the major challenges and opportunities related to the greening the agriculture sector and Section 3 discusses a wide range of sustainable agriculture practices, mostly using examples and evidence from the organic sector, which is relatively rich in data. The section starts with an overview of the cost of degradation resulting from current agricultural practices and benefits of greening the sector. It is followed by an outline of some of the priorities for investment. The section ends with a discussion on the results of an economic modelling exercise, which presents future scenarios for green agriculture and business-as-usual (BAU). Section 4 shows how global and national policy as well as capacity building and awareness raising can facilitate necessary investments and encourage changes in agricultural practices. Section 5 concludes the discussion.

1.1 General background

Agriculture is a major occupational sector in many developing countries and is an important source of income for the poor. World Bank statistics (2010) show agricultural value-added as a percentage of GDP to be 3 per cent for the world as a whole, and 25 per cent for low income countries (LICs), 14 per cent for lower middle income countries (LMICs), 6 per cent for upper middle income countries (UMICs) and 1 per cent for high income countries (HICs).[6] Approximately 2.6 billion people rely on agricultural production systems – farming, pastoralism, forestry or fisheries – for their livelihoods (FAOSTAT 2004).

To date, global agricultural productivity has more than kept up with population growth (FAO 2009; IAASTD 2009). However, agricultural productivity per worker and per land unit varies a great deal across countries. Agricultural productivity per worker in 2003-05 was 95 times higher in HICs than in LICs, and this difference increased compared with 1990-1992, when it was 72 times higher. Industrial agriculture mostly practiced in developed countries, continues to generate high levels of production – more than 50 per cent of the world value added in agriculture and food processing – but it also accounts for proportionally more adverse environmental impacts than lower-yield traditional farming (World Bank 2010). Agriculture in developing countries is becoming more productive. Over the above period, aggregate agricultural productivity per worker in developed countries increased by 21 per cent, albeit from a very low base.

Despite the increasing productivity of agriculture, nearly 1 billion people remain malnourished. Between 2000 and 2007, over a quarter (27.8 per cent) of children under the age of five in LICs were malnourished (World Bank 2010). Moreover, over half of food-insecure families are rural households, often in countries such as India that have food surpluses. A transition in the agricultural paradigm must also assist in meeting this challenge.

Agriculture also has tremendous potential to alleviate poverty. A large proportion of the rural population and labour force in developing countries is employed in agriculture. On average, the contribution of agriculture to raising the incomes of the poorest is estimated to be at least 2.5 times higher than that of non-agriculture sectors in developing countries. Underscoring the relationship between increasing yields and return on labour with poverty, Irz et al. (2001) estimate that for every 10 per cent increase in farm yields, there was a 7 per cent reduction in poverty in Africa and more than a 5 per cent poverty-reduction effect for Asia. Growth in manufacturing and services do not show a comparable impact on poverty reduction. The World Bank (2010) reported that an increase in overall GDP derived from agricultural labour productivity was, on average, 2.9 times more effective in raising the incomes of the poorest quintile in developing countries than an equivalent increase in GDP derived

5. In this report agriculture includes only crop and animal husbandry unless clearly indicated otherwise. Forestry and fisheries are covered in separate chapters.

6. World Bank Classification: Low-income economies (US$ 1,005 or less), Lower-middle-income economies (US$ 1,006 to US$ 3,975), Upper-middle-income economies (US$ 3,976 to US$ 12,275), High-income economies (US$ 12,276 or more); Available at: http://data.worldbank.org/about/country-classifications/country-and-lending-groups.

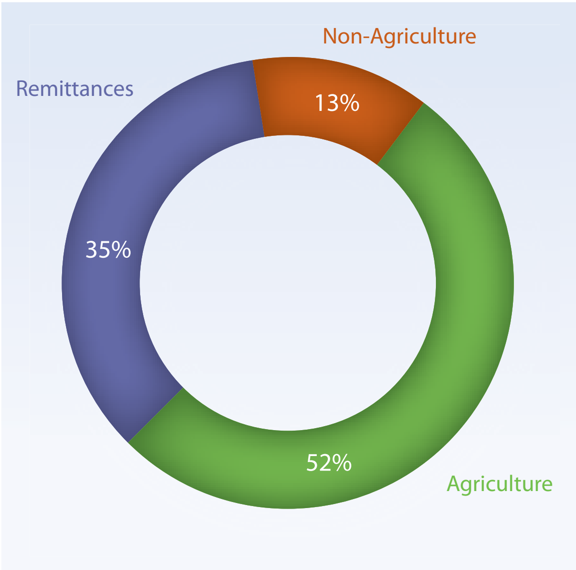


Figure 1: Total average contribution to poverty reduction from growth of agricultural, remittance and non-farm incomes in selected countries
Source: OECD calculations based on data from Povcalnet (2009); WDI (2009)

from non-agricultural labour productivity. Using cross-country regressions per region, Hasan and Quibriam (2004) found greater effects from agricultural growth on poverty (defined as less than US$ 2 per day per person) reduction in sub-Saharan Africa and South Asia. (This trend was not seen in East Asia and Latin America where there were greater poverty-reducing effects of growth originating in non-agriculture sectors).

Despite the potential contribution of agriculture to poverty alleviation, mainly owing to the urban bias of many national government policies (Lipton 1977), rural sectors in most developing countries have not received the levels of public investment required to support the development of a thriving agriculture sector. Government expenditure on agriculture in developing countries dropped from 11 per cent in the 1980s to 5.5 per cent in 2005, with the same downward trend observed in official development assistance going to the agriculture sector, which fell from 13 per cent in the early 1980s to 2.9 per cent in 2005 (UN-DESA Policy Brief 8, October, 2008). In Africa, governments publicly committed in the Maputo Declaration of 2000 to spending 10 per cent of their GDP on agriculture, including rural infrastructure spending (UNESC ECA 2007). However, only eight countries had reached the agreed level by 2009 (CAADP 2009).

Between 1980 and 2000, an inverse association was noted between the contribution of agriculture to GDP and public spending on agriculture as a percentage of agricultural GDP as shown in Figure 2, which distinguishes between agriculture-based, transforming and urbanised countries.[7]

The result of this long-term neglect of the agriculture sector in developing countries is that rural poverty rates consistently exceed those in urban areas, with more than 75 per cent of the world's most impoverished people living in rural areas, and many seeking ways to migrate to cities (IFAD 2003). We note that in this scenario, poverty can result in environment-related economic consequences if crop production is based upon unsustainable land use, which in turn results in the depletion of soil nutrients and cultivation of unsuitable, marginal land that can lead to soil erosion, degradation of ecosystems and the reduction of natural habitats[8] for biodiversity.

In the following paragraphs, we discuss particular attributes of conventional and small-scale agricultural practices that have exacerbated these trends.

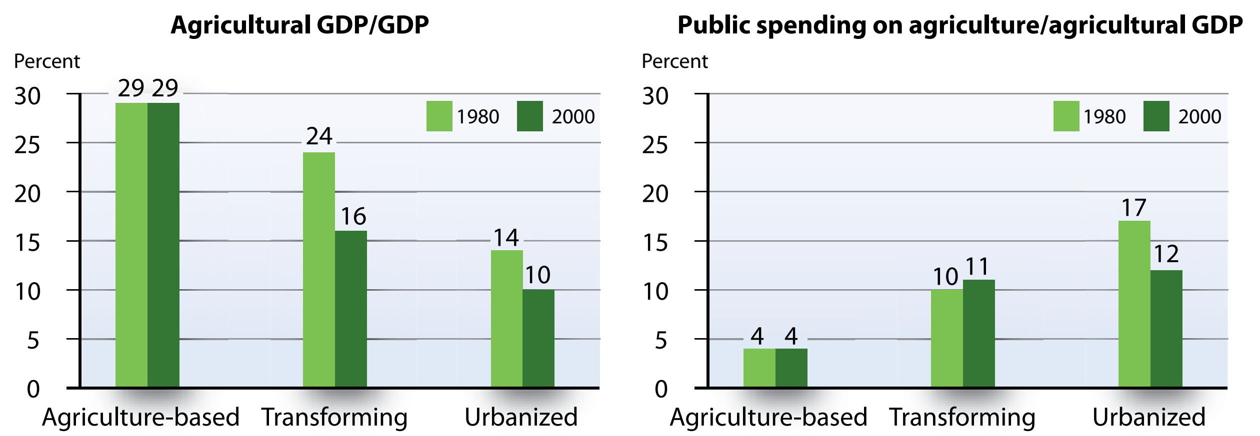


Figure 2: Contribution of agriculture to GDP and public expenditure on agriculture as a proportion of agricultural GDP
Source: EarthTrends, based on year 2000 data obtained from WDR Overview. Available at: http://siteresources.worldbank.org/INTWDR2008/Resources/2795087-1192112387976/WDR08_01_Overview.pdf

7. Agriculture based = developing, Transforming = new industrialised, Urbanised = developed countries.

8. This poverty-environment nexus is a well researched area. For a framework and review, see Opschoor (2007).

1.2 Conventional/industrial agriculture

Conventional (industrial) agriculture is characterised by farming practices that rely on use of external farming inputs. Most of the large scale industrial farming is considered energy-intensive (using 10 calories of energy for every calorie of food produced), whose high productivity (kg/ha) relies on the extensive use of chemical fertilisers, herbicides, pesticides, fuel, water, and continuous new investment (e.g. in advanced seed varieties and machinery).

The impressive productivity gains of the Green Revolution of the last few decades took place mainly in conventional agriculture. These productivity gains were triggered by investment in agricultural research and expansion in public-sector extension services.[9] The productivity increases of the Green Revolution relied primarily on the development of higher-yield varieties of major cereal crops (i.e. wheat, rice and corn/maize), a significant increase in the use of irrigation, inorganic fertilisers, pesticide/herbicide use and fossil fuel-based farm machinery.

9. For an overview refer to Ruttan (1977), and for a critique refer to Shiva (1989).

Despite substantial gains in total crop production, the consequences of the revolution have not been entirely positive. Production gains have been highly correlated with increased use of non-renewable resource inputs, and have often entailed significant environmental costs due to their overuse (Figure 3). Industrial agriculture consumes on average 10 exosomatic energy calories (derived from fossil fuel energy resources) for every food endosomatic energy calorie (derived from human metabolism of food) that is produced and delivered to the consumer (Giampietro and Pimentel 1994). This energy-intensity, in many cases, is encouraged by subsidising inorganic fertiliser, fuel and electric power used on farms. In addition, biodiversity losses have resulted from production subsidies targeted at a limited number of crops. Industrial agriculture has also resulted in shrinking the agricultural labour force even as farm outputs have dramatically increased, a trend intensified to some extent by subsidies for farm mechanisation. (Lyson 2005; Dimitri et al. 2005; Knudsen et al. 2005; ILO 2008).

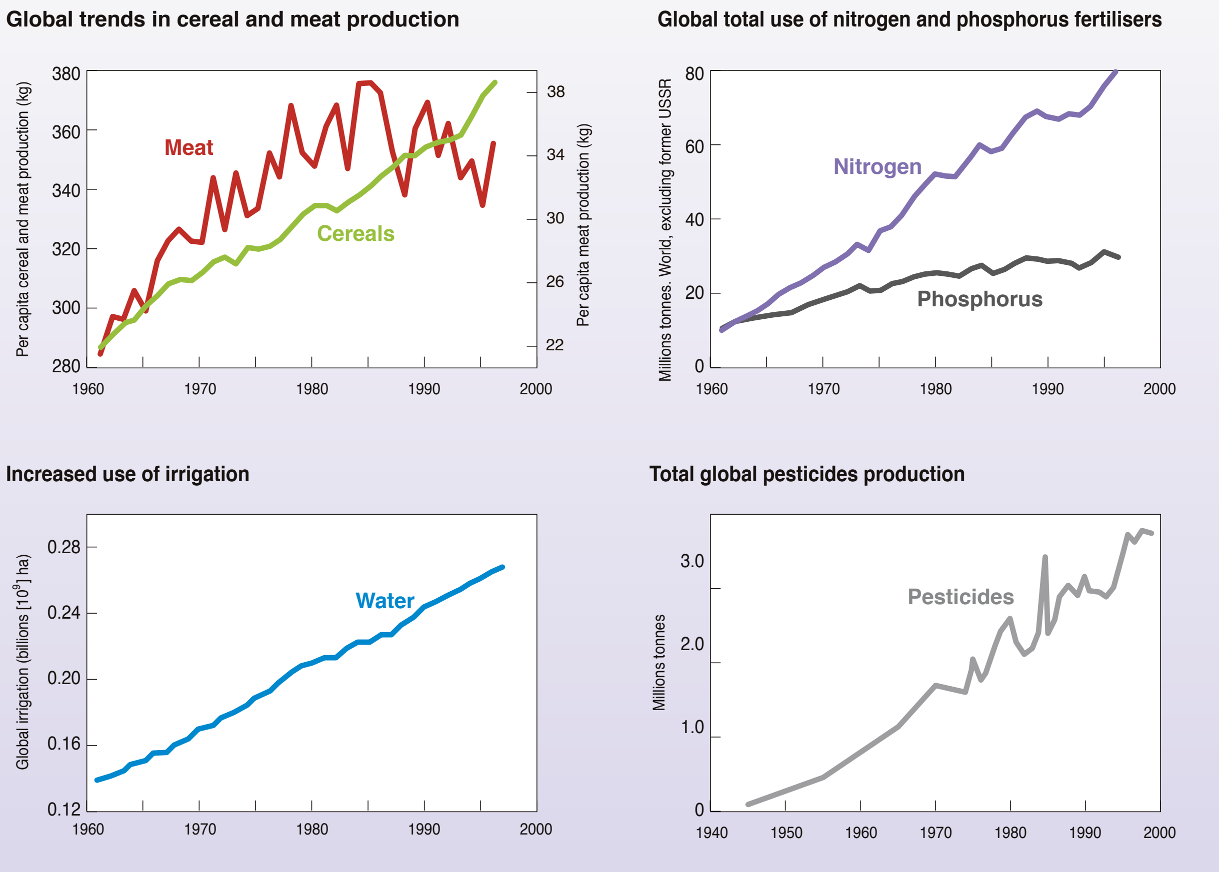


Figure 3: Global trends in cereal and meat production, nitrogen and phosphorus fertiliser use, irrigation and pesticide production

Source: Tilman et al. (2002) and IAASTD/Ketill Berger, UNEP/GRID-Arendal (2008). Available at: http://maps.grida.no/go/graphic/global-trends-in-cereal-and-meat-production-total-use-of-nitrogen-and-phosphorus-fertilisers-increas

1.3 Traditional/small farm/ subsistence agriculture

Traditional (subsistence) smallholder agriculture typically relies on indigenous and traditional knowledge that is based on farming practices used for several generations, has limited or no use of off-farm inputs, and results in low-productivity, low value added per worker and primarily reliant on extracting soil nutrients with insufficient replenishment by either organic or inorganic fertilisers. Generally, it is susceptible to yield losses due to erratic rainfall, pest and weed infestations and other production-related risks. It can trap already poor farmers in a downward spiral of growing poverty and social marginalisation.

Traditional agriculture has limited scope for capital intensive farm mechanisation and intensive use of external agrochemical inputs. Many smallholders' plots, overarchingly located in developing countries, are too small to realise the economies of scale required for most of the available commercial farm machinery. In addition, the high cost of purchased inputs, such as chemical fertilisers, pesticides and seeds, generally require that at least some portion of the crops produced must be sold to recover costs. Failure to modernise land tenure systems, which can facilitate distribution, consolidation, and the use of land as security for bank loans are important barriers to the commercialisation of small-scale agriculture in many developing countries. Commercialisation is further limited by inadequate road transportation linking food-producing areas to large urban centres. For these reasons, value added per worker in developing countries is far below that of industrialised economies. Whereas the average value added per agricultural worker in OECD countries in 2003 was US$ 23,081 (which grew at 4.4 per cent per year between 1992 and 2003, in Africa, the figures were only US$ 327 and 1.4 per cent, respectively (IAASTD 2009b).

Worldwide, there are 525 million small farms, 404 million of which operate on less than two hectares of land (Nagayets 2005). These small farmers in the developing world produce the majority of staple crops needed to feed the planet's population (Altieri 2008). Their highest share is in Africa where about 90 per cent of all agricultural production is estimated to be derived from small farms, (Spencer 2002). In many instances their contribution is growing at the national level. While the issue is contested, there is substantial evidence that smaller farms have higher yields than large farms (Banerjee 2000; Rosset 1999; Faruqee and Carey 1997; Tomich et al. 1995; Barrett 1993; Ellis 1993; Cornia 1985 and Feder 1985). In Kenya, the share of national agricultural production contributed by smallholders increased from 4 per cent in 1965 to 49 per cent in 1985 (Lele and Agarwal 1989). In India, smallholders contributed over 40 per cent of food grain production in 1990-91, compared with only a third of

Box 1: Agriculture at a crossroads

The key message of the Assessment of Agricultural Knowledge, Science and Technology for Development, published in 2009 is: "The way the world grows its food will have to change radically to better serve the poor and hungry if the world is to cope with a growing population and climate change while avoiding social breakdown and environmental collapse." The Assessment calls for a fundamental shift in agricultural knowledge, science and technology (AKST) to successfully meet development and sustainability objectives. Such a shift should emphasise the importance of the multi-functionality of agriculture, accounting for the complexity of agricultural systems within diverse social and ecological contexts and recognising farming communities, farm households, and farmers as producers and managers of ecosystems. Innovative institutional and organisational arrangements to promote an integrated approach to the development and deployment of AKST are required as well. Incentives along the value chain should internalise as many negative externalities as possible, to account for the full cost of agricultural production to society. Policy and institutional changes should focus on those least served in the current AKST approaches, including resource-poor farmers, women and ethnic minorities. It emphasises that small-scale farms across diverse ecosystems need realistic opportunities to increase productivity and access markets.

Source: IAASTD (2009)

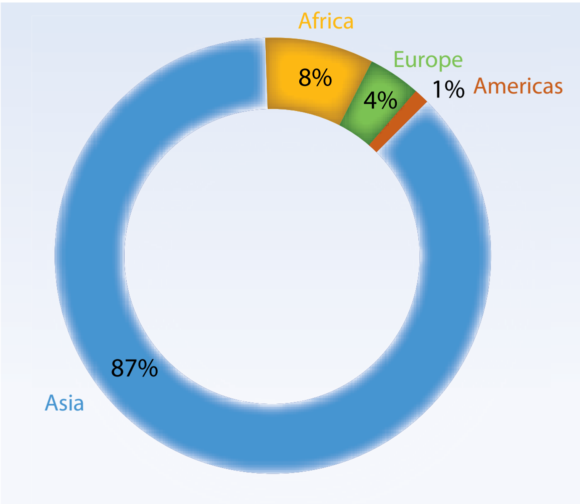


Figure 4: Regional distribution of small farms

Source: Nagayets (2005), based on FAO 2001c and 2004c and national statistical agencies.

Note: Small-scale farms are defined as those of less than 2 hectares. The total number of small-scale farms is 404 million.

the total in 1980. As of the late 1990s, they also owned the majority of livestock and dominated the dairy sector (Narayanan and Gulati 2002).

Despite their higher output per hectare and the significant contribution they make to food production, however, small farmers are often very poor. In a survey of smallholder households, 55 per cent in Kenya and 75 per cent in Ethiopia, respectively, fell below the poverty line (Jayne et al. 2003). Low prices, unfair business practices and lack of transportation, storage and processing infrastructure contribute to this situation. Half of all undernourished people, three-quarters of malnourished African children and the majority of people living in absolute poverty are found on small farms (Millennium Project Task Force on Hunger 2004; IFAD 2001). In the majority of countries, poor rural people are both sellers of food commodities and buyers of foodstuffs, at different times of the year. Typically, they sell immediately after harvest, usually at very low prices, to meet their immediate cash requirements, and buy food in the months prior to the following harvest, usually at higher prices, to meet their food needs (IFAD 2010b).

It is expected that expanding smallholder production through green agricultural practices and greater commercialisation and integrating them into supply chains will create more better rewarding jobs in rural areas. As farmers get wealthier, they are likely to withdraw from occasional labour (Wiggins 2009). Wealthier farmers are also likely to spend more on locally-produced goods and services leading to multiplier effects. Rural linkage models in Africa have estimated multiplier effects ranging from 1.31 to 4.62 for Burkina Faso, Niger, Senegal and Zambia (Delgado et al. 1994).

1.4 The greening of agriculture

The greening of agriculture refers to the increasing use of farming practices and technologies that simultaneously:

- maintain and increase farm productivity and profitability while ensuring the provision of food and ecosystem services on a sustainable basis;
- reduce negative externalities and gradually lead to positive ones; and
- rebuild ecological resources (i.e. soil, water, air and biodiversity natural capital assets) by reducing pollution and using resources more efficiently.

A diverse, locally adaptable set of agricultural techniques, practices and market branding certifications such as Good Agricultural Practices (GAP), Organic/Biodynamic Agriculture, Fair Trade, Ecological Agriculture, Conservation Agriculture and related techniques and food supply protocols exemplify the varying shades of green agriculture.

Farming practices and technologies that are instrumental in greening agriculture include:

- restoring and enhancing soil fertility through the increased use of naturally and sustainably produced nutrient inputs; diversified crop rotations; and livestock and crop integration;
- reducing soil erosion and improving the efficiency of water use by applying minimum tillage and cover crop cultivation techniques;
- reducing chemical pesticide and herbicide use by implementing integrated and other environmental friendly biological pest and weed management practices; and
- reducing food spoilage and loss by expanding the use of post-harvest storage and processing facilities.

The greening of agriculture does not imply ruling out technologies or practices on ideological grounds. If a technology works to improve productivity for farmers, and does not cause undue harm to society and the environment, then it is very much part of the efforts for greening of agriculture. Although natural methods of pest and weed management and organic sources of fertiliser and seed are at one end of a green agriculture spectrum, the highly efficient and precise use of inorganic fertilisers, pest controls and technological solutions may also be included in the broad spectrum of sustainable farming practices. The Foresight Report (2011) presents resembling ideas given the need for the global food system to deliver much more than just food, and food security in the future. So greening of high input dependent agriculture, which has a high ecological footprint, could start by making the use of inputs most precise and efficient, gradually moving toward farming practices that have low or no ecological footprint.

To be able to measure success in moving towards the objectives of greening agriculture, two categories of indicators are proposed in Table 1.

Action indicators	Outcome indicators
Number of enacted and implemented policy measures and officially approved plans that promote sustainable agriculture (including trade and export policy measures, payment for ecosystem services through agriculture, etc.)	Percentage and amount of land under different forms of green agriculture (organic, GAP-good agriculture practices, conservation, etc.)
Level of governmental support to encourage farmers to invest in conversion to green agriculture and get the farm and the product certified	Decline in use of agro-chemicals as a result of conversion to green agriculture; and the number and percentage of farmers converting to green agriculture
Percentage of agricultural budget that is earmarked for environmental objectives	Increasing proportion of Payments for Environmental Services as a percentage of total farm income
Proportion of available producer support utilised for environmental objectives as a percentage of total agricultural producer support	Number of agriculture extension officers trained in green agriculture practices
Approved measures that reduce or eliminate barriers to trade in technologies and services needed for a transition to a green agriculture.	Number of enterprises set up in rural areas, especially those that produce local natural agricultural inputs, to offer off-farm employment opportunities.

Table 1: Potential indicators for measuring progress towards green agriculture

2 Challenges and opportunities

Today, agriculture stands at a crossroads. There are calls for changing the way food is produced and distributed if the poor and hungry are to be served better and if the world is to cope with a growing population and climate change. This section presents some major challenges and opportunities in transitioning to a green agriculture.

2.1 Challenges

Agriculture is facing a multitude of challenges on both the demand and supply side. On the demand side, these include food security, population growth, changing pattern of demand driven by increased income, and the growing pressure from biofuels. On the supply side, limited availability of land, water, mineral inputs and rural labour as well as the increasing vulnerability of agriculture to climate change and pre-harvest and post-harvest losses are the main challenges.

Increasing demand for food

The most significant factors contributing to the increasing demand for food are the continued growth of the global population, especially in developing countries (Figure 5), and a rise in income levels in emerging economies. Demand for meat and processed food is rising with growing affluence. The current global population of more than 6 billion, of which 925 million are undernourished (FAO 2010), is forecast to reach 8.5-9 billion by 2050, and per capita incomes are expected to rise by as much as a factor of 20 in India and 14 in China, respectively (Goldman Sachs 2007). Figure 6 shows that rural populations are increasingly migrating to urban and peri-urban areas in developing countries. This has consequences for food demand and field-to-table supply chains because the diets of urban dwellers show an increased proportion of processed foods. The prospect of the human population expanding by almost a third by 2050, combined with an expected rise in per capita demand for meat, dairy and vegetable products, requires geographically-focused efforts and a change in agricultural production patterns.

Competing demand from biofuels

Growing interest in producing first-generation liquid biofuels to augment and replace petroleum-based transportation fuels is adding to the demand for starch, sugar and oilseed food commodities. For example,

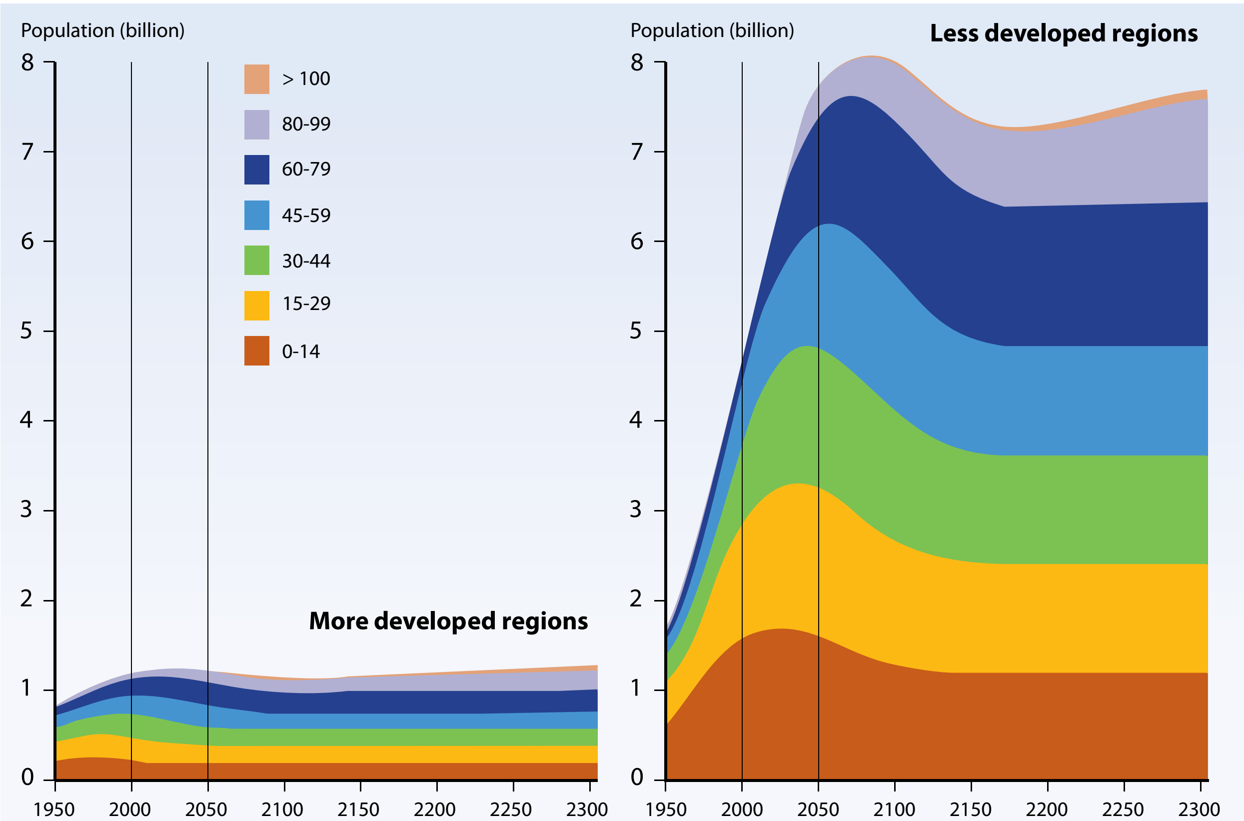


Figure 5: Distribution of population by age in more developed and less developed regions (1950-2300)

Source: UN ESA, World Population to 2300. Available at: http://www.un.org/esa/population/publications/longrange2/WorldPop2300final.pdf the production of ethanol and bio-diesel fuels are predominantly based on food commodity feed stocks such as corn, sugarcane, soy, canola, sunflower and palm oil. Despite growing ethical, environmental, and economic concerns surrounding the use of food staples for producing these biofuels, there is continued public- and private-sector interest in their development. No matter where these crops are grown, they will inevitably compete with food crops for land, water and nutrients. Figure 7 shows food prices tracking fuel prices. At present, this alignment of food and energy prices may primarily result from the cost of fossil fuels used as an input in food production. But it is expected that the pattern will become more marked because of the competition for food crops that are used to produce biofuels.

As a result, significant efforts are being made to develop technologies for second-generation biofuels, which can be produced from non-food biomass feedstock such as ligno-cellulosic wood and crop-residue wastes, perennially-grown switch grass and algae. Such technologies can potentially enable the production of biofuels to be scaled up with fewer adverse impacts on global food security. However, much more analysis is needed regarding the degree to which converting large quantities of cellulosic feedstock to biofuels would displace the recycling of organic nutrients from crop residues to arable land, pastures and forests (Balgopal et al. 2010).

Limited arable land and scarce water

Approximately 1.56 billion hectares or 12 per cent of the earth's total land surface area is arable land being used to produce crops for human and livestock consumption. In addition, some 3.4 billion hectares of pasture and woodland are now used for livestock production (Bruinsma 2009). The agricultural productivity of the available arable land is extremely varied. Crop yields in developed countries are generally far greater than the yields realised in most developing countries. These productivity differences result from different levels of natural soil fertility; fertiliser, pesticide and herbicide use; quality of cultivated plant species and seeds; availability and access to water; farmers' education and access to information, credit and risk insurance and the degree of agricultural mechanisation.

Only limited additional land can be readily brought into agricultural production through conversion or rehabilitation. Moreover, the often highly fertile arable land surrounding cities is rapidly being converted into residential and commercial development as urbanisation gathers pace (Pauchard et al. 2006). Expanding cultivated areas is no longer the obvious way to increase production (exceptions are parts of sub-Saharan Africa and Latin America where some savanna areas could be brought into production). Furthermore, over-grazing by livestock and extended drought conditions are accelerating the desertification of fragile arid and semi-arid regions. Agriculture has contributed to land degradation in all regions, but is most severe in input-intensive production systems (notably in East Asia, Latin America, North America and Europe). Agricultural activities account for around 35 per cent of severely degraded land worldwide (Marcoux 1998). Given the high risk of further deforestation, developing countries will need to meet food-supply gaps by simultaneously increasing productivity and

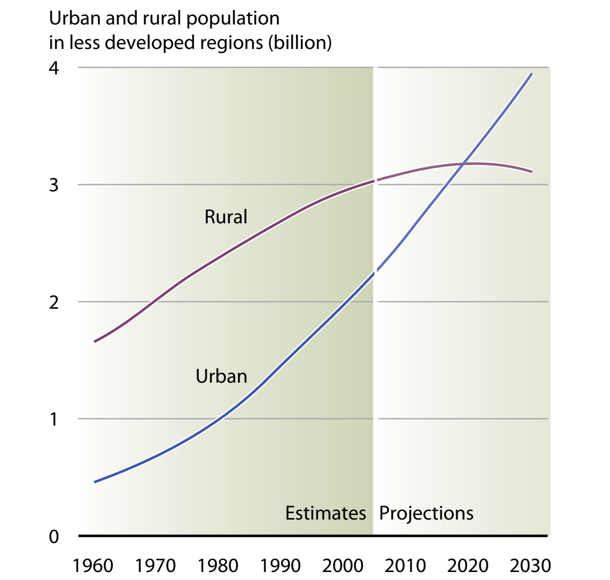


Figure 6: Urban and rural population trends in developing regions

Source: Nordpil, Ahlenius (2009); United Nations Population Division (2007); World Urbanization Prospects: The 2007 Revision Population Database, Available at: http://esa.un.org/unup/index.asp?panel=1

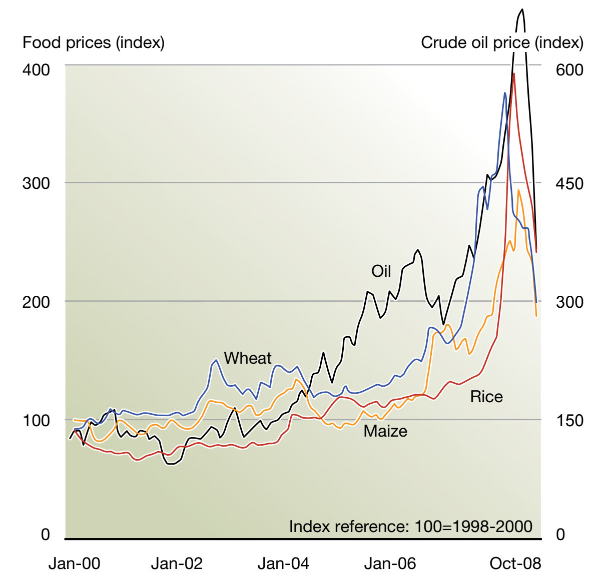


Figure 7: Trends in food commodity prices, compared with trends in crude oil prices

Source: Nordpil, Ahlenius (2009); Food and Agricultural Organisation of the United Nations (2008). International commodity prices., Available at: http://www.fao.org/es/esc/prices, IMF 2008. IMF Primary Commodity Prices, monthly data for 8 price indices and 49 actual price series, 1980 – current, Available at: http://www.imf.org/external/np/res/commod/index.asp

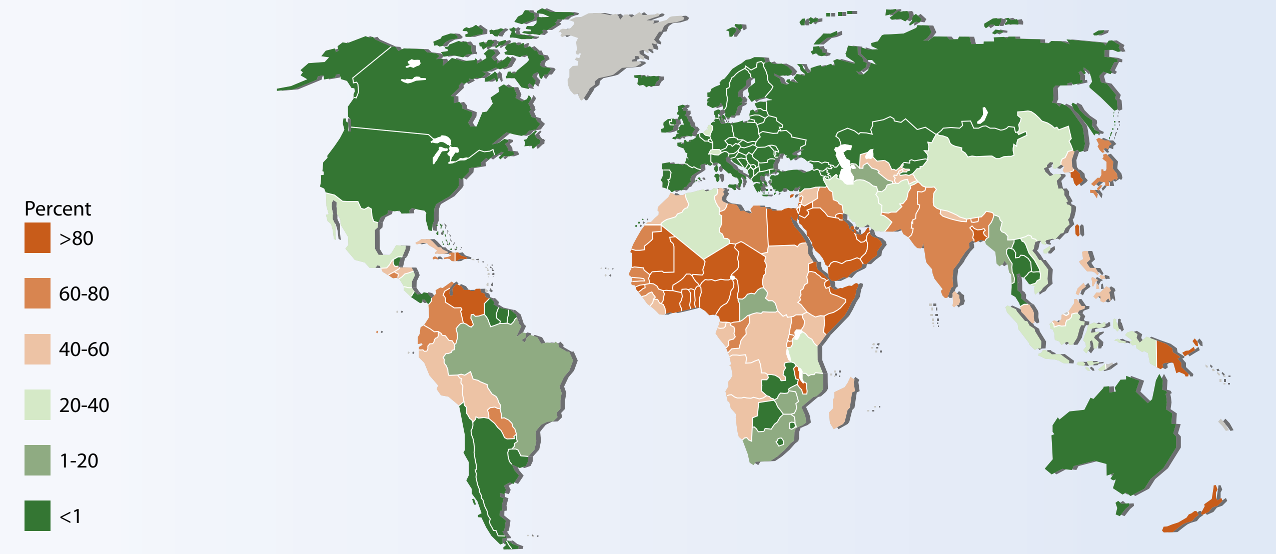


Figure 8: Percentage of country populations that will be water stressed in the future

Source: Rost et al. (2009) Water limitation of crop production in the absence of irrigation, i.e. ratio of NPP (INO simulation) and NPP (OPT simulation), 1971–2000 averages. The lower the ratio the stronger the water limiation. Available at: http://iopscience.iop.org/1748-9326/4/4/044002/fulltext

greening their agricultural practices, rather than seeking widespread expansion of arable land.

The agriculture sector is the largest consumer of fresh water, accounting for 70 per cent of global use, including rainfall run-off. A majority of crop lands are exclusively rain-fed, and only 24 per cent of arable land is cultivated with the help of irrigation from flowing surface waters or groundwater aquifers (Portmann et al. 2009). This distinction is important because irrigated fields are much more productive and produce nearly a third of all agricultural output (Falkenmark and Rockstrom 2004).

The increasing disruption of historical rainfall patterns experienced in many areas of the world is a cause for great concern since rain-fed farming is the dominant form of agriculture. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report concluded that many observed changes in extremes, such as more frequent, heavy precipitation events and longer, more intense droughts, are consistent with warming of the climate system (IPCC 2007a). While affecting rain-fed agriculture, precipitation changes also adversely affect the recharge rates of aquifers and watersheds. The continued worsening of water-stress conditions suggests that efforts to increase the use of irrigation will gradually increase agricultural production costs. Clearly, practices that increase water-use efficiencies are required to alleviate this trend.

Figure 8 shows projections for global water stress in the future. The figure also underscores the need for increased coordination in water use nationally and across borders. In this context, the Mekong River Commission, which coordinates the watershed development plans of member states, is one of several promising supra-national river basin initiatives.

Limited availability of mineral inputs

Industrial farming practices are dependent on inorganic fertilisers. In turn, the production and prices of these depend on the availability of fossil fuels, minerals and petro-chemicals. In this context, the demand for two major minerals – potassium and phosphorous – used

Box 2: Opportunities for improved sanitation systems and organic nutrient recycling

There is a critical need to recover and recycle nutrients from organic waste streams and use them as productive inputs of organic fertiliser. Enormous quantities of valuable organic nutrients could be recovered from intensive livestock farming; food processing sites; municipal green wastes; and human sewage wastes in both rural and urban communities. It is particularly important to maximise the recovery of phosphorous nutrients from organic wastes; as a mineral, phosphate is essential to agricultural productivity and it has been estimated that economically recoverable global reserves may be depleted in 100 years (Cordell et al. 2010). Technologies are under development that would eliminate pathogens and other toxic elements from these waste streams and recover commercial quantities of phosphorus (Frear et al. 2010). It is expected that the rising costs of inorganic fertilisers will help accelerate research and commercialisation of such organic nutrient-recovery technologies.

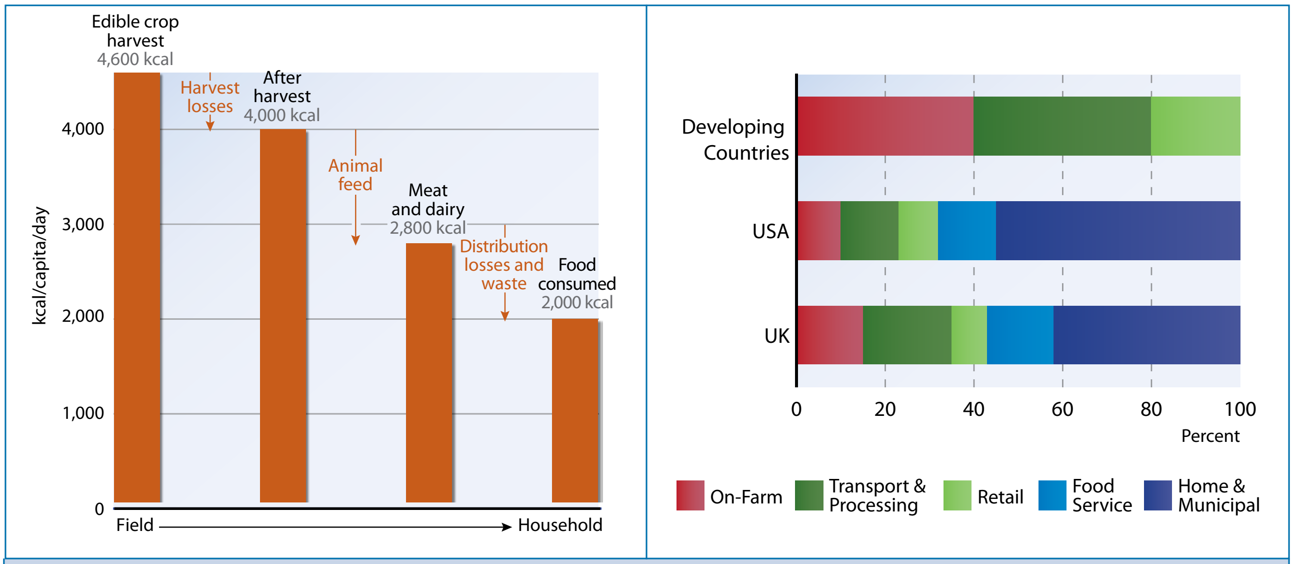


Figure 9a-b: The makeup of total food waste[10]

Source: Lundqvist et al.: SIWI (2008). Saving Water: From Field to Fork; Curbing Losses and Wastage in the Food Chain. Available at: http://maps.grida.no/go/graphic/losses-in-the-food-chain-from-field-to-household-consumption; (Godfray (2010); Food Security: The Challenge of Feeding 9 Billion People. Available at: http://www.sciencemag.org/content/327/5967/812.figures-only

in fertiliser production, has been increasing. But known supplies of readily accessible, high-grade stocks, especially phosphate rock, are falling. Estimates of the longevity of these stocks vary dramatically.[11] Nevertheless, only one-fifth of the phosphorus mined for food production actually contributes to the food we consume, while the remainder is either polluting the world's water or accumulating in soils or urban landfills (Cordell et al. 2010[12]). Although it is expected that the increasing prices of phosphates and other minerals will lead to increases in supplies, including recovery of phosphate from wastewater treatment facilities, these prices are likely to continue to put upward pressure on the cost of fertilisers and food prices, which affects the poor's access to food disproportionately.

Post-harvest spoilage

Today, the volume of food produced globally is more than sufficient to feed a healthy population. But significant amounts of food produced around the world are lost or wasted after harvesting. As Figure 9b shows, in developed countries this primarily occurs in the retail, home and municipal food-handling stages. For example in the USA, around 40 per cent of all food produced is wasted, resulting in losses of all embedded inputs such as energy (equivalent to wasting 350 million barrels of oil per year), water (equivalent to about 40 trillion litres of water every year) and huge volumes of fertilisers and pesticides (Hall et al. 2009). Losses in developed countries are often caused by factors such as retailers' rejection of produce due to poor appearance or super-sized packages leading to post-retail spoilage. The latter can account for up to 30 per cent of the food bought by retail distributors. Post-retail food losses tend to be lower in developing countries. There, they mainly result from a lack of storage facilities, on-farm pest infestations, poor food-handling and inadequate transport infrastructure. For example, rice losses in developing countries may be as high as 16 per cent of the total harvest (Mejía 2003[13]). Thus, there is ample scope for increasing food supplies and food security in developing countries through simple targeted investments in post-harvest supply chains.

Rural labour

The accelerating migration of rural populations to urban and peri-urban areas in developing regions of the world (Figure 6) has resulted in significant demographic changes in rural populations. Working-age men are likely to relocate to cities in search of employment, reducing the pool of men available for agricultural work. This rural out-migration of men has also resulted in a dominant role for women as smallholders in these regions; more than 70 per cent of smallholders in sub-Saharan Africa are women (World Bank, FAO and IFAD 2009). These demographic changes, while offering economic opportunities, have placed additional responsibilities on women, who invariably also have to care for their children and the elderly.

Increased vulnerability of agriculture due to climate change

Modelling by the IPCC suggests that crop productivity could increase slightly at mid- to high-latitudes for mean temperature increases of up to 1-3°C (depending on the crop) (Easterling et al. 2007). However, at lower latitudes, especially in the seasonally dry and tropical regions, crop

10. Retail, food service, and home and municipal are aggregated for developing countries.

11. Steén (1998) indicates that phosphate stocks will be depleted by 50-100 per cent by the end of 21st century, whereas Isherwood (2003) suggests that supplies could last between 600-1,000 years.

12. Available at: http://liu.diva-portal.org/smash/record.jsf?pid=diva2:291760.

13. Available at: http://www.fao.org/DOCREP/006/Y4751E/y4751e0o.htm.

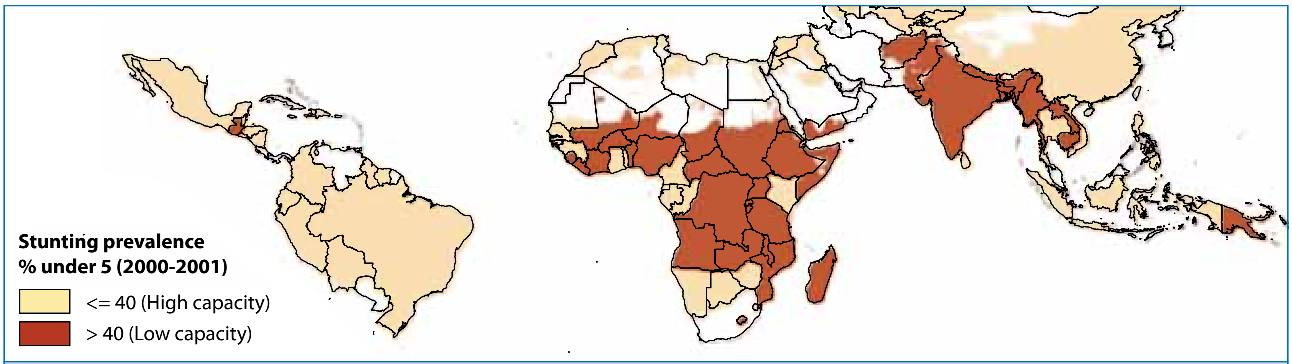


Figure 10: Expected future food insecurity

Source: CGIAR 2011. Available at: http://ccafs.cgiar.org/sites/default/files/assets/docs/ccafsreport5-climate__hotspots_advance-may2011.pdf

productivity could decrease as a result of even small local temperature increases (1-2°C).

Further warming could have increasingly negative impacts in all regions. Climate change scenarios suggest that by 2080 the number of undernourished people will increase, mostly in developing countries (see Figure 10), by up to 170 million above the current level. Intergovernmental Panel on Climate Change modelling indicates that an increased frequency of crop losses due to extreme climate events may overcome any positive effects of moderate temperature increases in temperate regions (Easterling et al. 2007).

In South Asia and sub-Saharan Africa, where some of the poorest people live and farm, the scenarios of climate change's impacts on agriculture present a dire picture. Recent studies confirm that Africa is the most vulnerable continent to climate change because of multiple abiotic and biotic stresses and the continent's low adaptive capacities (IPCC 2007b). Yields in Central and South Asia could decrease up to 30 per cent by the mid-21st century (IPCC 2007a). In drier areas of Latin America, climate change is expected to lead to salinity and desertification of some agricultural land, reducing the productivity of some important crops and animal husbandry (IPCC 2007a).

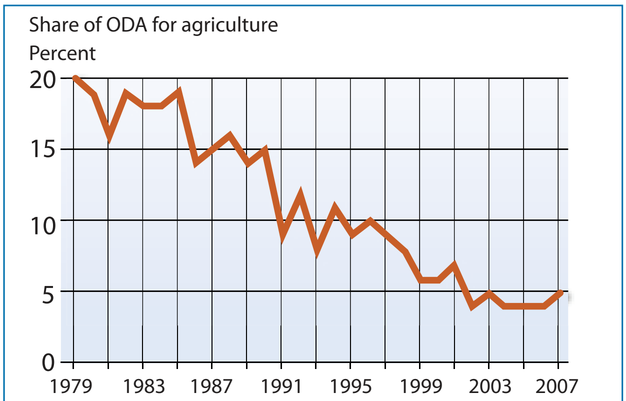


Figure 11: Share of overseas development assistance for agriculture (1979–2007)

Source: Based on OECD (2010). The agricultural sector includes forestry and fishing, although they are separately identifiable in the data from 1996 onwards. Private funding is not covered. Available at: http://www.oecd.org/dataoecd/54/38/44116307.pdf

2.2 Opportunities

Many opportunities exist for promoting green agriculture. They include increased awareness by governments, donor interest in supporting agriculture development in low income countries, growing interest of private investors in sustainable agriculture and increasing consumer demand for sustainably produced food.

Government awareness

Governments, particularly in developed countries, have become increasingly aware of the need to promote more environmentally sustainable agriculture. Since the mid-1980s, OECD countries have introduced a large number of policy measures addressing environmental issues in agriculture. Some of these are specific to the agriculture sector, including the practice of linking general support to environmental conditions; others are included in broader national environmental programmes. The result is that the environmental performance of agriculture has begun to improve in OECD countries.

The proportion of global arable land dedicated to organic crops has increased from a negligible amount in 1990 to around to 2 per cent in 2010, and as much as 6 per cent in some countries. The extent of soil erosion and the intensity of air pollution have fallen; the amount of land assigned to agriculture has decreased even as production has increased, and there have been improvements in the efficiency of input use (fertilisers, pesticides, energy, and water) since 1990. However, subsidies for farm-fuel have continued to be a disincentive to greater energy efficiency (OECD 2008).

Donor support for agriculture development

Agriculture-related Overseas Development Assistance (ODA), which has fallen steadily over the past 30 years, began to pick up in 2006 as the current food crisis escalated. In 2009, at the G8 summit in Italy, wealthy nations pledged US$ 20 billion for developing-country agriculture. However, there is a pressing need to ensure that these investments, as Ban Ki-moon put it, "breathe new life into agriculture, one which permits sustainable

Box 3: Innovations in the agricultural supply chain increase shareholder and societal value

For investors, water risk exposure is increasingly becoming material for mitigating investment risk in companies. For example, Robeco Asset Management invests in mainstream companies and encourages them, through active dialogue, to implement policies and innovative practices that mitigate risks resulting from water scarcity to their operations and reputations. In doing so, it also encourages companies to find solutions that can enhance their performance, increase shareholder value and therefore contribute in the long-term to building and sustaining a green economy.

Cotton, one of the most water-intensive crops, is the focus of a dialogue with companies in the textile industry to develop water-efficiency targets and adopt sustainable supply-chain practices. Through Better Cotton Initiative (BCI), a platform has been created for exchange of experiences on the use of efficient irrigation technologies, farmer education programmes and reduction in the use of pesticides and acceptance of transparent sourcing efforts.

Source: Based on the information from Robeco Asset Management received through Lara Yacob, Senior Engagement Specialist (2010)

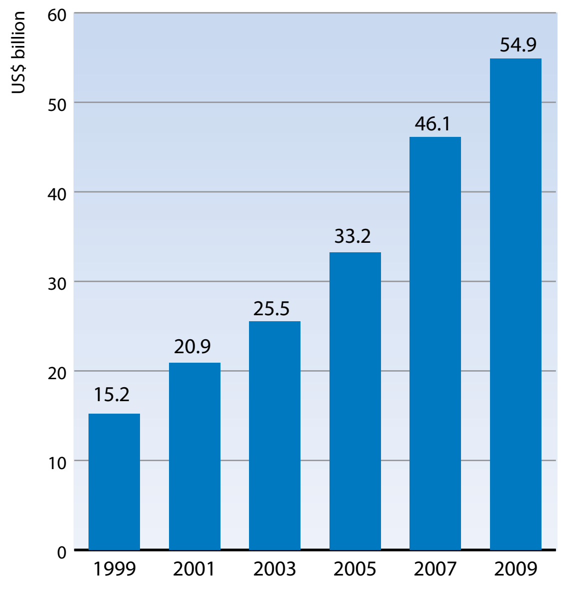


Figure 12: Global trade in organic food and drinks (1999-2009)

Source: Prepared by Asad Naqvi, Pratyancha Pardeshi based on the data from Sahota, A. (2009)

yield improvements with minimal environmental damage and contributes to sustainable development goals".[14] Recently, the Food and Agriculture Organisation (FAO), World Bank, the United Nations Conference of Trade and Development (UNCTAD) and the International Fund for Agricultural Development (IFAD) have jointly proposed Principals for Responsible Agricultural Investments.[15]

Private funding interest

Preferential access to credit and investment capital is one of the most important incentives to catalyse a transition to greener agriculture. The number, volume and rate of return of sovereign wealth funds (SWFs), pension funds, private equities and hedge funds with investment in agriculture, are increasing (McNellis 2009). Major financial institutions are expanding their green portfolios to offer investment credit to companies that manufacture and market products that enable more efficient use of agricultural inputs and introduce innovative private enterprises (see Box 3). The public sector, especially in developing countries, should support finance mechanisms (e.g. loan-guarantee funds) that can leverage larger multiples of private capital loans to smallholders who need working capital to undertake sustainable agriculture practices.

Increasing consumer demand for sustainable food

Over the last few years, consumer demand for sustainably produced food has increased rapidly. Purchasing patterns of fairtrade products have remained strong despite the global economic downturn. In 2008, global sales of fairtrade products exceeded US$ 3.5 billion. Data collected by the International Trade Centre (ITC) and the Forschungsinstitut für biologischen Landbau (FiBL) shows that the major markets for organic food and beverages expanded on average by 10 to 20 per cent per year between 2000 and 2007 and reached US$ 54.9 billion in 2009. This figure does not include markets for organic fibre, cosmetics and other luxury products. This demand has driven a similar increase in organically managed farmland. Approximately 32.2 million hectares worldwide are now farmed organically. In addition, as of 2007, organic wild products were harvested on approximately 30 million hectares.

14. Ban Ki-moon. (2010). Media coverage of his statement: available at http://www.un.org/apps/news/story.asp?NewsID=26670 , retrieved on 26 January 2011.

15. These Principles are available at: http://siteresources.worldbank.org/INTARD/214574-1111138388661/22453321/Principles_Extended.pdf

3 The case for greening agriculture

Both conventional and traditional agriculture generate substantial pressure on the environment, albeit in different ways. With very different starting positions, the pathways to green agriculture will vary substantially and will have to be sensitive to local environmental, social and economic conditions. Industrial agriculture needs to lessen its reliance on fossil fuels, water and other inputs. Both large and small farms can benefit from more on-farm recycling of nutrients by reintegrating livestock, which provide manure, and the cultivation of green manures to improve and maintain soil fertility (IAASTD 2009).

3.1 The cost of environmental degradation resulting from agriculture

Several studies have estimated the cost of externalities caused by current agricultural practices, which include those from use of inputs such as pesticides and fertilisers leading, for example, to the pollution of waterways and emissions from farm machinery and food-related transport.

Agricultural operations, excluding land use changes, produce approximately 13 per cent of anthropogenic global GHG emissions. This includes GHGs emitted by the use of inorganic fertilisers agro-chemical pesticides and herbicides; (GHG emissions resulting from production of these inputs are included in industrial emissions); and fossil fuel-energy inputs. Agriculture also produces about 58 per cent of global nitrous oxide emissions and about 47 per cent of global methane emissions. Both of these gases have a far greater global warming potential per tonne than CO_2 (298 times and 25 times respectively). Moreover, methane emissions from global livestock are projected to increase by 60 per cent by 2030 under current practices and consumption patterns (Steinfeld et al. 2006). The expansion of agricultural land at the expense of forests has been estimated to represent an additional 18 percent of total global anthropogenic GHG emissions (IAASTD 2009 and Stern 2007).

A study by Jules Pretty et al. (2001) estimated the annual costs of agricultural externalities to be US$ 2 billion in Germany and US$ 34.7 billion in the USA. This amounts to between US$ 81 and US$ 343 per hectare per year of grassland or arable land. In the UK, agriculture's total environmental externality costs, including transporting food from the farm to market and then to consumers, have been calculated to be £ 5.1 billion per year for 1999/2000, a cost greater than annual net farm income (Pretty et al. 2005). In China, the externalities of pesticides used only in rice systems have been estimated to amount to US$ 1.4 billion per year in health costs to people, and adverse effects on both on- and off-farm biodiversity (Norse et al. 2001). The national pollution census in China revealed that agriculture was a larger source of water pollution than industry, discharging 13.2 MT of pollutants (China's National Pollution Census 2007; New York Times 2010). In Ecuador, annual mortality in the remote highlands due to pesticides is among the highest reported anywhere in the world at 21 people per 100,000 people. The economic benefits of Integrated Pest Management (IPM) based systems that eliminate these effects are increasingly beneficial (Sherwood et al. 2005). Land degradation is costing ten Asian countries an economic loss of about US$ 10 billion, equivalent to 7 per cent of their combined agricultural GDP (FAO 1994).

At the same time, as a result of the poor management of fertiliser usage during the last half-century, the phosphorus content in freshwater systems has increased by at least 75 per cent, and the flow of phosphorus to the oceans has risen to approximately 10 million tonnes annually (Bennett et al. 2001; Millennium Ecosystem Assessment 2005; Rockstrom et al. 2009). The combined effects of phosphate and nitrogen water pollution, much of it linked to the use of inorganic fertilisers is the main cause of eutrophication, the human-induced augmentation of natural fertilisation processes which spurs algae growth that absorbs the dissolved oxygen required to sustain fish stocks (Smith and Schindler 2009). The estimated costs of the eutrophication in the USA alone run as high as US$ 2.2 billion annually (Dodds et al. 2009).

Not all agricultural externalities are quantified and thus the calculations above probably underestimate the total cost to society. Conventional agriculture, for example, causes millions of cases of pesticide poisoning per year, resulting in over 40,000 deaths (FAO-ILO 2009). It is important to note that most such cases remain unreported.

Farmers who use chemical/synthetic farm inputs are significantly more indebted, especially in developing countries (Eyhorn et al. 2005; Shah et al. 2005; Jalees 2008). For example, in Central India, cotton farmers bought inputs with loans at annual interest rates between 10-15 per cent (from cooperative societies) to over 30 per cent (from private money lenders). By contrast, those engaged in organic agriculture were far less likely to take loans owing to lower production costs and greater use of on-farm inputs (Eyhorn et al. 2005).

Although there is a difference of opinion on the issue, Jalees (2008) has argued that the main cause for the extremely high rate of suicide among Indian farmers is the debt-servicing obligations for working capital (e.g. fertilisers, pesticides and GM seeds) costs.

The following section presents some on- and off-farm investment strategies that will help minimise, eliminate and gradually reverse the environmental and economic costs resulting from currently predominant forms of agriculture.

3.2 Investment priorities for greening agriculture

Investments in R&D and Agribusinesses

One of the major reasons for the wide spread adoption of the Green Revolution that greatly increased agricultural productivity was the level of first public, then private-sector investment in R&D and the subsequent dissemination and commercial implementation of the results. These gains were also achieved with the introduction of irrigation and greater application of inorganic agrochemical inputs. A new wave of investment is needed to develop, deploy and diffuse resource-efficient technologies and agricultural inputs, farming practices, and seed and livestock varieties that would counter the environmental externalities that are often associated with the green revolution.

The International Assessment of Agricultural Knowledge, Science and Technology for Development noted that ROI in AKST across commodities, countries and regions on average are high (40-50 per cent) and have not declined over time. They are higher than the rate at which most governments can borrow money (Beintema and Elliott 2010). The commercial rate of return, however, should not be the only determinant of the decision to invest in R&D for greening agriculture. The social rate of return would be considerably higher if rural communities could adequately monetise the ecosystem, livelihood and socio-cultural benefits that would accrue with their adoption of greener agriculture practices and land stewardship (Perrings 1999).

Research to improve the performance of biological nitrogen fixation processes, breeding plant, livestock and aquatic species for improved yields and adaptive resilience and developing perennial cereal crops would enable significant reductions in the energy, water and fertiliser inputs needed to cultivate commodity grains. Such research may require several decades to produce commercially viable crop varieties with these beneficial attributes. However, the impacts would be significant in terms of providing options for future generations' dependency on expensive fossil fuel-based fertilisers and adapting to expected climate change.

Plant and animal health management (PAHM)

Field trials of improved PAHM practices have resulted in increased profitability of farms. Various intercropping strategies utilise selected plant species' biochemical emissions to either attract or repel different insects, nematodes and other pests. One of the most effective such techniques is known as "push-pull", which involves intercropping, for example, certain species of legumes and grasses with maize. Aromas produced by legumes planted on the perimeter of a field repel (push) maize pests, while scents produced by the grasses attract (pull) insects to lay their eggs on them rather than the maize.

The implementation of push-pull in eastern Africa has significantly increased maize yields and the combined cultivation of N-fixing forage crops has enriched the soil and has also provided farmers with feed for livestock. With increased livestock operations, the farmers are able to produce meat, milk and other dairy products and they use the manure as organic fertiliser that returns nutrients to the fields. In small-holder farming operations, the ability to support livestock for meat, milk and draft animal power is an important added benefit of this strategy (Khan et al. 2008). An economic analysis of a push-pull field trial in East Africa with 21,300 farmers revealed a benefit-cost ratio of 2.5 to 1. (Khan et al. 2008). The income returns for labour were US$ 3.7 per person/day with push-pull as opposed to US$ 1 person/day with their previous maize mono-cropping practice. The gross revenue ranges between US$ 424 and US$ 880 per hectare under push-pull and US$ 81.9 to US$ 132 per hectare in maize mono crop. Similar systems are being field-trialed for other cropping systems and it is likely that comparable rates of return will be realised.

Another example of PAHM practices is seen in Cameroon. In this case study (Dieu et al. 2006), cocoa farmers were trained in pruning, shade adjustment and phytosanitary harvesting methods that effectively maintained yields comparable to conventional practices that used multiple applications of fungicides. The farmers who practiced these techniques used 39 per cent fewer fungicides. Although labour costs increased by 14 per cent, total production costs decreased by 11 per cent relative to conventional practices. By introducing green farming, methods that relied on more knowledgeable labour inputs, a much larger share of the total costs of cocoa production was paid to workers within the local community. Imports of fungicide chemicals were also reduced, saving valuable foreign exchange. Additional benefits included reduced health costs and less environmental pollution (Velarde 2006).

Investments in PAHM should focus on research, training and investments in natural pest- management processes that defend, defeat and manage the many organisms that threaten agricultural production. While there are a

Box 4: Cost of training smallholder farmers in green agriculture practices

In a recent report on organic agriculture, the ADB concluded that the cost of transition for farmers to move from conventional agricultural practices to organic practices, including the cost of certification, was approximately US$ 77-170 per farmer for an average farm size of 1 hectare (ADB 2010). Training costs were estimated at US$ 6-14/farmer. These are fairly modest compared to the overall investment required for extricating farmers from poverty (an approximate investment of US$ 554-880, according to the World Bank (2008a). Yet there remain additional costs. These are the costs of enabling policies that allow research and development, market linkages and creating incentive systems on the demand and supply side. These costs cannot be understated and obviously require multilateral and bilateral support in the international arena.

wide range of low-cost natural bio-control practices that improve the ability of plants and livestock to resist and suppress biotic stresses and combat pests, during the past few decades there has been a substantial increase of private and, to a much lesser degree, publicly-funded efforts to develop genetically modified (GM) crops to overcome pest and weed problems. After initial success, there is growing evidence of an evolving resistance to GMO crops by many pests and weeds. The IAASTD report (2009) recommended that research on the ecological, economic and social questions concerning the widespread application of GM crops should be increased, particularly in the public R&D sector, whose scientific advances could be more broadly and equitably available for use in developing countries.

Table 2 presents selected evidence on the costs and benefits of plant and animal health management strategies (PAHM). Plant and animal health management practices reduce farmers' input costs and their exposure to hazardous chemicals while effectively supporting productive crop yields. Plant and animal health management practices also reduce or replace the use of chemical insecticides that often kill non-targeted insects. Many insect species killed as collateral damage from such insecticides have beneficial environmental and agricultural roles as pollinators and as predators of other pests, and are part of the natural food chain.

Evidence presented in Table 2 show that all PAHM interventions are highly profitable. Intercropping is a particularly useful strategy with high benefit to cost

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Intercropping	Maize intercropped with Desmodium uncinatum, East Africa (Khan et al. 2008).	Most costs are associated with additional labour costs.	Maize grain yield increases ranged from double to five times in plots using push-pull strategies compared to monocropped plots. Levels of pests reduced significantly and were completely eliminated in some. (Reductions ranged from 75% to 99%).	Benefit to cost ratio is 2.5 to 1 using the push-pull strategy. Gross revenues with push-pull were US$ 424-880/ha compared to 82-132/ha using a mono-maize cultivation strategy.
Pest Management	The wasp predator to fight the cassava bug in Africa (Norgaard 1988). Cocoa in Cameroon (Dieu et al. 2006).	The cost of introducing the wasp across cassava growing countries in Africa (1978-2003) is estimated at US$ 14.8 million. This includes research and distribution costs. For cocoa, IPM meant that labour costs increased by 14%. But total production costs decreased by 11% due to reduced use of fungicides.	Introducing the wasp predator introduction helped avoid 60% of the losses caused by the cassava mealy bug. In cocoa plantation, IPM reduced cost of fungicides by 39%.	Benefit cost ratio of 149 to 1 for the wasp predator strategy, across all cassava growing countries in Africa, 1978-2003. Reduced costs of fungicides in the context of obtaining similar yields can lead to increase in profitability for the farmers.
Bio-pesticides	Fungal spores in fighting grasshopper in Benin, maize and cassava, cowpea and groundnuts crops (De Groote et al. 2001).	Estimated cost for effective intervention was US$ 4/ha.	Cumulative mortality of grasshoppers after 20 days of spraying was over 90%.	Bio-pesticides have small costs and major benefits of avoided damage. Yield losses due to grasshoppers can reach 90% in cowpea and 33% in maize.

Table 2: Selected evidence on benefits and costs of plant and animal health management

ratios of 2.5 to 1. Compared with mono-cropping strategies push pull strategies and intercropping both imply an increased use of labour, but demonstrated returns are more than 200 per cent.

Similarly, pest management strategies that include introducing new predator species in Africa to combat losses caused by the mealy bug have proven to be extremely effective. Most significant costs are associated with research development and extension but the resulting increase in effective produce and diminished post-harvest losses contribute to more than an order of magnitude increase in returns. Unlike push-pull, these types of strategies are usually managed at a country or inter-country level and thus benefit from scale, while providing benefits to all farmers, regardless of their size and their possibility to invest in pest control.

Scaling up adoption of green agriculture by partnering with leading agribusinesses

A small number of corporations control a large share of the global agribusiness. The four biggest seed companies control more than half of the commercial seed market (Howard 2009), the biggest ten corporations (four of them are among the top 10 seed companies) together control 82 per cent of the world pesticides business. The share of the top-ten corporations in the global market for food processing is 28 per cent, and the top 15 supermarket companies represent more than 30 per cent of global food sales (Emmanuel and Violette 2010). Investment decisions of these approximately 40 companies have the power to determine, to a large extent, how the global agriculture sector could endorse and encourage green and sustainable farming practices.

By greening the core business operations and supply chains, these corporations can play a major role in supporting a transition to greener agriculture. In addition, they can provide investments to develop and implement viable strategies for ensuring global food security based on optimal use of inorganic inputs and building capacity to recycle on-farm nutrients. Investing in building consumer awareness about benefits of sustainable agrifood products is another area that offers benefits for the environment and these businesses. One of the promising developments in the area of agribusiness and NGO partnerships to promote green agriculture is the Sustainable Food Laboratory.[16]

Strengthening the supply chains for green products and farm inputs

Demand for sustainably produced products is increasing but it is concentrated in developed countries. Investments in developing new markets in developing countries and expanding existing markets in developed countries could (i) create new and high return employment opportunities for on- and off-farm sectors (e.g. certification auditors); (ii) shorten the field-to-market supply chains, and thus offer better prices to farmers in these countries; and (iii) help maintain the price premiums, which can range from 10 per cent to more than 100 per cent over a variety of conventionally- produced foods (Clark and Alexander 2010). A major challenge in this regard is consumer demand for less expensive food and high demand elasticities associated with premium prices for organic food and other products. As incomes rise and consumers learn more about lifestyle diseases, and in the absence of good food safety regulations or lack of their implementation, the negative health effects of some cheaper, conventionally produced foods, we expect to see in upper and middle income consumers an increasing willingness to pay for more environmentally sustainable and ethically produced (e.g. fairtrade, etc.) foods at prices that would cover their higher costs.

The limited availability of substantial quantities of natural fertiliser and pesticides in many countries is a major constraint to the growth of sustainable farming practices. Large-scale composting of organic matter and recovery of livestock manures for commercial organic fertiliser products will be required in most farming regions. Investments in the production, supply and marketing of non-synthetic, natural inputs for farming will not only offer competitive returns but will also help in setting up new small-scale businesses in rural areas. The bulk and volume of organic fertilisers that are required for equivalent applications of inorganic fertilisers make them not very cost-effective for long distance transport, thus necessitating relatively localised or regional compost-production capacities.

Farm mechanisation and post-harvest storage

Appropriate mechanisation of small and medium farms can significantly increase agricultural productivity and help green the farming practices. The degree to which there is access to farm mechanisation equipment (both draft animal and modern fuel-powered technology) will substantially determine achievable levels of productivity per unit of labour and of land. Use of (i) more energy-efficient cultivating machines that incorporate plant residues into the soil to increase fertility, (ii) zero-tillage and minimal-tillage direct seeders for optimum planting uniformity and minimal topsoil disturbance, (iii) precision application systems for more efficient use of agrochemicals, (iv) drip and sparkling irrigation, and (v) harvest and post-harvest operations that include village-level processing of farm products and by-products are central to the green mechanisation of farms (Rodulfo and Geronimo 2004).

Since most farm mechanisation technologies require modern fuels or electric power to operate and fossil fuel

16. http://www.sustainablefoodlab.org.

Box 5: Simple storage: low investment, high returns

An FAO programme that supported the production and use of household and community- scaled metal silos for grain storage estimated that farmers who invested in silos were able to earn nearly three times the price for maize sold four months following harvest as opposed to the price paid at harvest (US$ 38/100 kg of maize compared with US$ 13/100 kg). The production costs for these metal silos ranged between US$ 20 for a 120 kg small-capacity unit to US$ 70-US$ 100 for an 1800 kg large-capacity silo in a variety of countries. Most farmers realised a full return on their investment within the first year of use (Household Metal Silos, FAO 2008). The FAO reports that although reducing post-harvest losses could be relatively quickly achieved, less than 5 per cent of worldwide agricultural research and extension funding currently targets this problem.

Similar improvements in reducing post-harvest losses are possible with cost-effective hermetically sealed packaging materials and handling processes that protect grains and pulses from insect and mold contamination. A notable example of such technologies is the Purdue Improved Cowpea Storage (PICS) system, which is composed of two polyethylene bags and a third outer bag of woven polypropylene. The PICS materials are made by several West African manufacturers and have proven to offer safe and inexpensive storage of cowpea and other grains for 4-6 months and longer (Baributsa et al. 2010).

price increases are seen as inevitable, it is important that non-conventional energy sources such as biodiesel fuels and biogas power generation and process heat be developed and used in mechanised farming systems in developing countries. While there are examples of rural bioenergy production technologies operating throughout the world, in most cases these technologies remain uncompetitive mainly due to subsidies and policy support for fossil fuels and related farm machinery.

Coupled with farm mechanisation, which may negatively affect on-farm employment opportunities, investment in off-farm employment opportunities is needed. Food packaging and processing in rural areas would enable new non-farm jobs and could improve market access for agricultural produce. However, the feasibility of added value processing would be substantially determined by the quality of rural road infrastructure that connect to urban centres, ports and airports and the availability of skilled labour capable of operating food-handling facilities. In those cases where rural food processing is implemented, the residues from food processing should be composted or processed into organic fertilisers in order to avoid waste and to return needed organic nutrients to the nearby farm land.

With regard to post-harvest storage, simple technologies with small investments can make a big difference. Small holder farmers with limited access to dry and sanitary storage and cold chain facilities often suffer post harvest food losses that can range from 20 per cent to more than 30 per cent of their crop yields. Furthermore, without crop storage systems, farmers are usually compelled to sell their entire crop immediately at the time of harvest when market prices are much lower than levels possible several months after harvest (Kader and Rolle 2004). Investments in post-harvest storage can bring multiple economic and development benefits (Box 5).

Improving soil and water management and diversifying crops and livestock

One of the most significant consequences of conventional agriculture is the rapid depletion of soil organic matter (SOM). Repeated cultivation degrades soils and lowers crop yields hence increases production costs. Strategies for better soil management have been experimented in Colombia, England, Mexico, Morocco and the USA. Results show yield increases ranging from 30 per cent to 140 per cent. Some of these strategies include, growing and integrating back in soil nitrogen fixing fodder and green manure crops such as pea, ferns and cloves or rice straw, no-tillage and planting new seeds in crop residues, using waste biomass or biochar (still needs research to fully understand its true potential), and organic and mineral fertilisers. Table 3 presents evidence from field trials and plots in Colombia, England, Morocco, Mexico and the USA that show yield increases ranging from 30 per cent to 140 per cent resulting from better soil management strategies. Nonetheless, each strategy does require some additional investments. Strategies such as nitrogen-fixing fodder or green manure mainly involve additional labour costs: additional labour is required to distribute fodder over land and for sowing and growing green manure plants. In addition, in some countries, the cost of fodder can be substantial since it can be used alternatively for feeding animals. Nevertheless, crop yield increases as high as 40 per cent are capable of making the investments profitable for farmers.

The use of a no-tillage system strategy mainly requires additional capital outlays, which can be significant. In countries with developed markets for agricultural equipment no-tillage systems can be cheaper than

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Use of nitrogen-fixing fodder and cultivating green manure	Cultivation of maize in Spain and rice in India, Indonesia and Philippines. (Tejada et al. 2008); (Ali 1999).	Costs varied depending on methods and country. Rice straw use (for green manure) costs ranged from US$ 18/ha in Indonesia and Philippines, to US$ 40/ha in India. Azolla (type of fern) for nitrogen fixing and green manure meant additional costs ranging from US$ 34/ha in India, to US$ 48/ha in the Philippines.	Maize crop yields increased approximately 40% in the first year, 5% in second year and 20% in year three. No significant increases in yields were observed in rice crops compared to the use of inorganic fertilisers but result in long term soil improvements. Maize crop yields increased after the first year, by 28%, 30% and 140% in the last 3 years of the study. No impact was seen on soybean crop yields.	Revenues increased even though there was no difference in the costs of using green manure over inorganic fertiliser for rice crops.
No-tillage practices	Maize in Mexico, wheat in Morocco and cereal grain crop in England. (Erenstein et al. 2008); Mrabet et al. 2001; Baker 2007). Sorghum and maize in Botswana, (Panin 1995) Maize, sorghum and cowpea in Nigeria, (Eziakor 1990). Soybean in Australia (Grabski et al. 2009).	The capital costs for a small scale No-tillage planting system are estimated to be US$ 25,000 to 50,000 (ICARDA). No tillage system was cheaper by US$ 156/ha when rented from a contractor in England, compared to renting tilling systems. In Botswana, cost per household of tractor was US$ 218.	Maize yields increased by 29 per cent; wheat yields by 44 per cent. No impact on total cultivated areas, crop yields and total crop output in traditional tillage systems vs. animal power or manual usage (Botswana and Nigeria). An average yield increase in soybean yields of 27% over 14 years in no-tillage vs. till systems.	No-tillage systems are economically profitable, even after incorporating the costs of no-till systems. (Baker 2007).
Biochar use	Cultivation of maize intercropped with soybean (Colombia) and wheat (USA). (Major et al. 2010; Galinato et al. 2010).	Biochar production costs range between US$ 87-350/tonne depending on source of inputs and mode of production.	Maize crop yields increased after the first year, by 28%, 30% and 140% in the last 3 years of the study. No impact was seen on soybean crop yields.	In the US, wheat production increased sufficiently to generate a profit of US$ 414/acre, but only while using low-price biochar. Higher-cost biochar reduces profits.

Table 3: Selected evidence on benefits and costs of soil management strategies

using tilling machinery, in developing countries the investment in farm equipment may represent a significant barrier. Farmer cooperatives and extension services can help defray these costs.

Biochar usage represents a costly investment, mainly because of the high cost of production for biochar (US$ 87-350 per tonne depending on the source of inputs and mode of production). Although it can bring significant increases in crop yields, biochar profitability is still highly dependent on the cost of production.

Similarly, the use of water for irrigation is rapidly exceeding the natural hydrological rate of recharge in many river basins (Johansson et al. 2002; WWAP 2003; Wani et al. 2009). Practices such as flooding fields, poor drainage and excessive pumping imply that there are many opportunities for using ground and rainwater in more efficient and sustainable ways (Steinfeld et al. 2006). Some sustainable water-use strategies include drip irrigation systems, pressurised water pipe and sprinkler systems and use of manual treadle pumps. According to some studies (Burneya et al. 2009; Sivanappan 1994; Belder et al. 2007), drip irrigation has resulted in yield gains of up to 100 per cent, and water savings of 40 to 80 per cent.

Using leaf and straw mulch reduces surface evaporation and helps to retain moisture near plant roots, thus increasing water-use efficiency (Sharma et al. 1998). Landscape contouring and vegetative barriers are an effective means of minimising rainfall runoff and retaining moisture in fields. Using drought-resistant varieties of crops can also help conserve water. For example, System Rice Intensive (SRI) practices substantially reduce the amount of water and other external inputs through decreased planting densities, which require less seed and fewer workers. The approach generally achieves between 40 per cent and 200 per cent greater crop yields compared with conventional flooded rice cultivation (Zhao 2009). Table 4 demonstrates that most water-saving technologies can bring about increased profits despite additional infrastructure and operating costs. Most water-saving techniques require additional equipment and increased working capital to cover the costs of increased labour use. Additional labour is required for strategies such as the use of mulching fields, raising plant beds and aligning furrows, and in other land contouring strategies. Such labour costs are nevertheless easily recovered through increased crop yields, and the reduced risk of losses during drought or dry years.

Table 4 shows that investment costs in drip irrigation systems and in manual treadle pumps are recovered more quickly; returns to investments have on average been more than 10-fold. These technologies have demonstrated their effectiveness in reducing income vulnerability and uncertainty for small-holder farmers across the continent. Drip irrigation systems also allow the more efficient use of water and are particularly useful for multiple cropping; in Nepal women farmers have been able to earn additional incomes by growing high value crops on otherwise barren land. Strategies such as the use of drought-resistant varieties of crops mainly involve investment in research and distribution of new seeds. In this context, estimated returns on investment are an order of magnitude higher, especially as witnessed in water-starved regions of Africa.

The success of these strategies also implies that agronomic research and development on improving water management practices in rain-fed agriculture and on tilling practices has been successful although much more is required. A strategy that remains relatively untapped is community-led watershed management. Watershed management has conventionally meant large hydraulic engineering efforts that are applied to local streams or river basins to establish a network of water reservoirs, catchment areas and other water impoundment and storage infrastructures. However, community-led watershed management strategies that protect and improve soil, water and plant resources in a catchment area are rapidly gaining traction and are rapidly becoming a lucrative opportunity for farmers who can benefit from Payment for Ecosystem Schemes (PES). These community led watershed management strategies offer important opportunities for increased efficiencies in irrigation (Krishna and Uphoff 2002).

As far as crop and livestock diversification is concerned, genetic resources for plant and animal breeding are the basis for food production. Genetically diverse crops can combine the best traits of local varieties of crops derived from indigenous species and other higher yielding varieties. Similarly, selecting and mating local animal breeds with high-performance breeds increases

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Cover mulch	Grain in India (Sharma et al. 1998); Groundnut in India (Ghosh et al. 2006).	In groundnut cultivation the cost of wheat straw mulch was US$ 58/ha. Cultivation required 5 tonnes of mulch per hectare. Black plastic covers cost much more (US$ 1.8 /kg, vs. straw at US$ 0.01/kg).	Average yields for grain and straw were the highest in fields that received cover mulch of 6 tonnes/ha: Yields increased by 130-149% over 3 years. Using wheat straw mulch cover increased pod yield of groundnut by 17–24%. Using both– wheat straw mulch and black plastic covers led to yield increases of 30 to 86% across test fields.	For groundnut crops, analysis of profitability showed that both systems (wheat straw and wheat straw with plastic cover) have positive income returns of US$ 92/ha and US$ 42/ha respectively. For grain crops, long-term profitability is possible with the use of mulch depending on the costs of mulch.
Furrow contouring	Corn in China (Li X. et al. 2001).	Technique used plastic covers and constructed furrows. Costs of plastic and labour are not provided.	Corn yields increased by 60-95% during drought years, 70-90% in wet years and 20-30% in very wet years.	Revenues and profits are likely to be positive and increase, except during very wet year.
Manual treadle pump	Major staples including cassava, maize, rice and yam in Ghana (Adeoti et al. 2007 and 2009) and a variety of crops, Zambia (Kay and Brabben 2000).	Depending on region the cost of a manual treadle pump in Ghana was US$ 89. Users had to pay additionally for labour. Total production costs increased by US$ 162/farm on average. In Zambia the cost of suction pumps ranged from US$ 60–77 and cost of pressure pumps was US$ 100–120.	In Ghana, treadle pump users were able to grow multiple crops. In Zambia Treadle Pump users of were able to grow three crops a year.	Incomes for Treadle Pump users increased by more than 28 per cent in Ghana. On average users earned almost US$ 343/farmer over non-users in Ghana. In Zambia, incomes rose more than six- fold. Farmers earned US$ 125 with bucket irrigation on 0.25 ha of land to US$ 850-1,700.
Drip irrigation	Vegetables in Nepal (Upadhyay 2004) Maize and vegetables in Zimbabwe (Maisiri et al. 2005).	On average farmers had to pay US$ 12/farmer in Nepal for drip irrigation system (perforated tubing and a suspended water container).	Barren land became more productive in Nepal. In Zimbabwe no significant differences in yield were observed. Water use reduced by 35%.	In Nepal, women farmers earned an additional US$ 70 annually by selling surplus vegetables.
Using low-water varieties of crops	Maize varieties in 13 countries of eastern, southern and West Africa (La Rovere et al. 2010).	US$ 76 million was invested in cultivating low-water varieties of crops over 10 years in these countries.	Average yield increases estimated to be between 3-20%.	Maize yield increases translate into US$ 0.53 billion. The ratio of returns to investment is estimated to be between 7 and 11 times.

Table 4: Selected evidence on benefits and costs of water management strategies

diversity and can bring significant biological, social and economic benefits. Replenishing soil nutrients with biological nitrogen fixation and crop-residue recycling, reducing thermal stress and water evaporation rates, and attracting beneficial insects for pollination and pest predation, and deterring pests are all important benefits of crop diversification. Combining the horticultural production of higher-value vegetables and fruits with the cultivation of cereals and cash commodity crops can raise farm income, along with grass-fed livestock, which also enables people to acquire protein and calories derived from otherwise inedible biomass resources. Recycling of livestock manures as organic nutrients for soil is an essential element of greening agriculture. In addition, there are numerous opportunities for combining a wide variety of trees and shrubs with the cultivation of crops, horticulture and specialty crops (e.g. coffee, tea, vanilla, etc.) to maximise the output of a farm.

Diversification strategies are not useful to ensure diminished vulnerability but also to increase profitability and yields of existing farming systems. Table 5 presents selected evidence for costs and benefits of agricultural diversification strategies in Asia and Africa. Diversifying across crops has demonstrated increased yields in India and Bangladesh and shows potential for recovering research and extension costs. In both Africa and Asia, diversifying into animal husbandry has meant increased profits. The main on-farm costs for all these strategies is usually the cost of increased labour, but also the cost of training and learning new practices. In addition, diversification into animal husbandries may involve important capital costs in farm equipment. In countries where employment opportunities are few, diversification represents a potent poverty alleviation strategy for both the farmer and the labourer. After the analysis of costs of current agriculture and some strategies for a managed transition away from BAU, the following section lays out the benefit expected from greening the agriculture sector.

3.3 The benefits of greening agriculture

The greening of the agriculture sector is expected to generate a range of benefits including increased profits and income for farmers, gains at the macroeconomic level, enabling the sector to adapt to climate change and benefits for ecosystem services.

Profitability and productivity of green agriculture

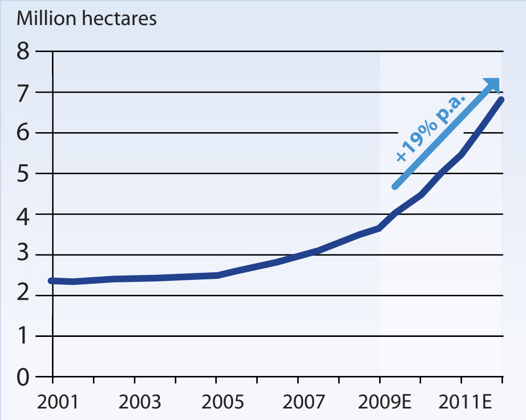
No business is sustainable unless it is also profitable. Many studies have documented the profitability and productivity of sustainable farms, both in developed and developing countries. An FAO study (Nemes 2009) that analysed 50 farms, mostly in the USA, reported: "The overwhelming majority of cases show that organic farms are more economically profitable".

There are various examples of higher productivity and profitability in developing countries. Another study by Pretty et al. (2006) showed an average yield-increase of nearly 80 per cent as a result of farmers in 57 poor countries adopting 286 recent best practice initiatives,

Box 6: Investment in sustainable agriculture – case study

Current trends of population growth, climate change and resource scarcity make sustainable agriculture a compelling investment opportunity. Sustainable Asset Management AG (SAM) taps into this potential through its sustainable theme funds, investing in companies that offer cost- effective, eco-friendly technologies that enable more efficient use of water or more sustainable food production.

SAM has pursued water investments because the need for adequate water supplies is one of today's major challenges. Advanced micro or drip irrigation systems can halve farmers' water requirements and limit the need for chemicals while boosting yields by up to 150 per cent. Countries affected by water shortages are adopting these technologies at rapid rates (see chart).



The SAM Sustainable Water Fund currently encompasses an investment universe of about 170 companies worldwide and assets under management of € 1.14 bn. The fund has consistently outperformed its benchmark, the MSCI World, with annual return on average outperforming the benchmark by 4.14 per cent (in Euros) since launch in 2001 at a risk comparable to that of the MSCI. Strong growth in micro irrigation fosters sustainable agriculture and creates interesting investment opportunities.

Source: Based on text provided by Daniel Wild, PhD, Senior Equity Analyst, SAM (2010)

Strategy	Crop and country	Costs	Benefits	Trends in revenues and profits after including additional costs of greening
Crop diversification	Rice with pigeon pea, groundnut and blackgram in India (Kar et al. 2004). Variety of crops in Bangladesh (Rahman 2009).	US$ 41.8 million allocated to promoting crop diversification for a 5-year plan in Bangladesh. Empirical study shows reduced variable cost for diversified farmers of US$ 40/ farm (Jan. 1997 exchange rate).	In India, intercropping of rice with pigeon pea, groundnut and blackgram approximately tripled the yield of crops (rice and alternative crops) vs. rice alone.	In Bangladesh, similar net profits were earned by diversified and non diversified farmers; but positive environmental benefits accrued to the diversified farms.
Diversification into animal husbandry and horticulture	Variety of crops and animals in Africa (Seo 2010). Survey of crops and countries in Africa and South East Asia (Weinberger 2007).	In Kenya the production of snowpeas and French beans, require 600 and 500 labour days per ha, respectively. In Mexico, the horticultural sector required more than 20% of the total labour days within the agricultural sector.	The impacts of climate change on farms diversified into animal husbandries range from 9% loss to 27% gain depending on climate scenarios.	Profits of farmers diversified into horticulture were consistently higher compared to non-diversified farmers (29% in Bangladesh to 497% in Kenya). Estimates show that integrated or diversified farms have the potential to become more profitable compared to non-integrated farms 50 years from now, in the context of climate change.

Table 5: Selected evidence on benefits and costs of agricultural diversification

including integrated pest and nutrient management, conservation tillage, agroforestry, aquaculture, water harvesting and livestock integration. The study covered 12.6 million farms, encompassing over 37 million hectares (3 per cent of the cultivated area in developing countries). All crops showed water use efficiency gains, with the highest improvement occurring in rain-fed crops. Carbon sequestration potential averaged 0.35tC/ha/year. Of projects with pesticide data, 77 resulted in a decline in pesticide use by 71 per cent, while yields grew by 42 per cent. In another example, bio-dynamic farms recorded a 100 per cent increase in productivity per hectare due to the use of soil-fertility techniques such as compost application and the introduction of leguminous plants into the crop sequence (Dobbs and Smolik 1996; Drinkwater et al. 1998; Edwards 2007).

For small farms in Africa, where the use of synthetic inputs is low, converting to sustainable farming methods has increased yields and raised incomes. In a project involving 1,000 farmers in South Nyanza, Kenya, who were cultivating, on average, two hectares each, crop yields rose by 2-4 tonnes per hectare after an initial conversion period. In yet another case, the incomes of some 30,000 smallholders in Thika, Kenya rose by 50 per cent within three years after they switched to organic production (Hines and Pretty 2008).

A significant part of a farm's production costs is linked to its energy inputs and organic agriculture tends to be more energy-efficient. Growing organic rice can, for example, be four times more energy-efficient than the conventional method (Mendoza 2002). The study also shows that organic farmers required 36 per cent of the energy inputs per hectare compared with conventional rice farmers. Niggli et al. (2009) found that organic agriculture reduces production systems' energy requirements by 25 to 50 per cent compared with conventional chemical-based agriculture. Energy consumption in organic farming systems is reduced by 10 to 70 per cent in European countries and by 28 to 32 per cent in the USA compared with high-input systems, with the exception of certain crops including potatoes and apples, where energy-use is equal or even higher (Pimentel et al. 1983; Hill 2009).

Market price premiums often exist for certified sustainably produced products, however this incentive may not be adequate in the long run unless there is a commensurate increase in global consumer demand for sustainable agricultural products (e.g. in countries other than primarily the EU and USA). Premium price incentives are likely to relatively decrease in response to supply and demand elasticities (Oberholtzer et al. 2005). However, if prices of conventionally grown food (crops and animals) included the costs of their externalities, sustainable products may become relatively less expensive than conventional products. Furthermore, if the positive ecosystem service benefits of sustainable practices were valued and monetised as incremental payments to green farmers, greener agriculture products would become more competitive with conventional products.

Macroeconomic benefits from greening agriculture

Significant secondary macro-economic and poverty reduction benefits are expected from greening agriculture. Investments aimed at increasing the productivity of the agriculture sector have proved to be more than twice as effective in reducing rural poverty

Box 7: Innovative sustainable and social capital investment initiatives

Institutional investments for greening agriculture are emerging. For example, Rabobank Group is supporting sustainable agriculture through the launch of the Rabo Sustainable Agriculture Guarantee Fund and supporting initiatives such as the Dutch Sustainable Trade Initiative (IDH), the Schokland Fund and Round Table of Sustainable Palm Oil (RSPO), the Round Table on Responsible Soy (RTRS), and the Better Sugar Initiative (BSI). In addition, it has launched programmes to improve the financial strength and resilience of small farmers in developing countries via the Rabobank Foundation and Rabo Development. It has also introduced new financial services such as the Sustainable Agricultural Fund to try out innovative financing models such as the Xingu River Basin Project in Brazil, under which 83 hectares have been replanted in the last two years. Rabobank has invested nearly US$ 50 million to purchase carbon emission reduction credits that are created by the Amazon reforestation by farmers.

Another example of social capital investment institutions is the Acumen Fund, which has channelled investment worth millions of US dollars to private entrepreneurs in developing countries, enabling businesses and other initiatives to flourish, from those that provide drip-irrigation products to those operating village-scale biogas power-generation services. Acumen provides both patient capital investments and business management capacity-building support to the private businesses in their portfolio.

than investment in any other sector (ADB 2010). The greatest success stories in terms of reducing hunger and poverty are from China, Ghana, India, Vietnam and several Latin American nations, all of which have relatively higher net investment rates in agriculture per agricultural worker than most developing countries (FAO n.d.). The World Bank has estimated that the cost of achieving the first Millennium Development Goal (MDG 1) amounts to between US$ 554 and US$ 880 per head (based on growth in income in general), while a study published by the Asian Development Bank Institute has concluded that the cost of moving a household out of poverty through engaging farmers in organic agriculture could be only US$ 32 to US$ 38 per head (Markandya et al. 2010).

Box 8: Organic versus conventional cotton production

An Indo-Swiss research team compared agronomic data of 60 organic and 60 conventional farms over two years and concluded that cotton-based organic farming is more profitable. Organic farming's variable production costs were 13-20 per cent lower and inputs were 40 per cent lower. But yields and profits margins were 4-6 per cent and 30-43 per cent higher respectively during the two years. Although crops grown in rotation with cotton were sold without a price premium, organic farms achieved 10-20 per cent higher incomes compared with conventional agriculture (Eyhorn et al. 2005). Similarly, an impact assessment study for organic cotton farmers in Kutch and Surendranagar in eastern India, concluded that farmers who participated in the project enjoyed a net profit gain of 14 to 20 per cent resulting from higher revenues and lower costs. The updated version of the study surveying 125 organic cotton farmers concluded that 95 per cent of respondents found their agricultural income had risen since adopting organic agriculture, on average by 17 per cent. Most farmers attributed this largely to the reduced cost of production and an increase in output price (MacDonald 2004). Raj et al. (2005) also found in Andhra Pradesh that organic cotton was much more profitable.

Source: Nemes (2009)

In addition, green agriculture directs a greater share of total farming input expenditures towards the purchase of locally-sourced inputs (e.g. labour and organic fertilisers) and a local multiplier effect is expected to kick in. Overall, green farming practices tend to require more labour inputs than conventional farming (e.g. from comparable levels to as much as 30 per cent more) (FAO 2007 and European Commission 2010), creating jobs in rural areas and a higher return on labour inputs. This is especially important for developing countries, where large numbers of poor people continuously leave rural areas in search of jobs in cities and growing proportions of young people are imposing enormous pressures for job creation (Figure 6). In addition, most developing countries run substantial trade deficits (World Bank 2010) with the lack of foreign exchange representing a key resource constraint. Greening agriculture can relax the foreign-exchange constraint by reducing the need for imported inputs and by increasing exports of sustainable agrifood products. Reducing deficits would

Scenario	South Asia	East Asia and the Pacific	Europe and Central Asia	Latin America and the Caribbean	Middle East and North Africa	Sub-Saharan Africa	Developing countries
NCAR with developing-country investments							
Agricultural research	172	151	84	426	169	314	1,316
Irrigation expansion	344	15	6	31	–26	537	907
Irrigation efficiency	999	686	99	129	59	187	2,158
Rural roads (area expansion)	8	73	0	573	37	1,980	2,671
Rural roads (yield increase)	9	9	10	3	1	35	66
Total	1,531	934	198	1,162	241	3,053	7,118
CSIRO with developing-country investments							
Agricultural research	185	172	110	392	190	326	1,373
Irrigation expansion	344	1	1	30	–22	529	882
Irrigation efficiency	1,006	648	101	128	58	186	2,128
Rural roads (area expansion)	16	147	0	763	44	1,911	2,881
Rural roads (yield increase)	13	9	11	3	1	36	74
Total	1,565	977	222	1,315	271	2,987	7,338

Table 6: Incremental annual agricultural investment figures by region needed to counteract climate-change impacts on child malnutrition[17]

Note: These results are based on crop model yield changes that do not include the CO_2 fertilisation effect.

Source: Nelson et al. (2009)

enable these countries to purchase technology and other critical inputs for their economies.

Climate adaptation and mitigation benefits, and ecosystem services

Making agriculture more resilient to drought, heavy rainfall events, and temperature changes is closely linked to building greater farm biodiversity and improved soil organic matter. Practices that enhance biodiversity allow farms to mimic natural ecological processes, enabling them to better respond to change and reduce risk. The use of intra and inter-species diversity serves as an insurance against future environmental changes by increasing the system's adaptive capabilities (Ensor 2009). Improved soil organic matter from the use of green manures, mulching, and recycling of crop residues and animal manure increases the water holding capacity of soils and their ability to absorb water during torrential rains.

The International Food Policy Research Institute (IFPRI) estimates that an additional US$ 7.1-7.3 billion per year are needed in agricultural investments to offset the negative impact of climate change on nutrition for children by 2050 (Table 6). The International Food Policy Research Institute recommended investments were needed primarily for basic infrastructure such as rural roads in Africa and expanded irrigation, and for agricultural research (Nelson et al. 2009). However, assessments of green investment options that would include agro-ecological soil fertility enhancement; water-use efficiency improvements for rain-fed farming; breeding for drought and flood tolerance; integrated pest management; and post harvest handling infrastructures, still remain to be done.

The IPCC estimates that the global technical mitigation potential from agriculture by 2030 is approximately 5,500-6,000 Mt CO_2-eq/yr (Smith et al. 2007). Soil carbon sequestration would be the mechanism responsible for most of this mitigation, contributing 89 per cent of the technical potential. Therefore, agriculture has the potential to significantly reduce its GHG emissions, and possibly to function as a net carbon sink within the next 50 years. The most important opportunity for GHG mitigation is the application of carbon-rich organic matter (humus) into the soil. This would significantly reduce the need for fossil fuel-based and energy-intensive mineral fertilisers and be a cost-effective means of sequestering atmospheric carbon. Further GHG mitigation gains could be achieved by improving yields on currently farmed lands and reducing deforestation pressures and by adopting no/low tillage practices that reduce fuel usage (Bellarby et al. 2008; ITC andFiBL 2007; Ziesemer 2007).

The environmental services provided by greening farms are substantial. The Rodale Institute, for example, has

17. Note: 1) NCAR: The National Center for Atmospheric Research (US); 2) CSIRO: The Commonwealth Scientific and Industrial Research Organisation (Australia).

estimated that conversion to organic agriculture could sequester additional 3 tonnes of carbon per hectare per year (LaSalle et al. 2008). The carbon sequestration efficiency of organic systems in temperate climates is almost double (575-700 kg carbon per ha per year) that of conventional treatment of soils, mainly owing to the use of grass clovers for feed and of cover crops in organic rotations. German organic farms annually sequester 402 kg carbon/ha, while conventional farms experience losses of 637 kg (Küstermann et al. 2008; Niggli et al. 2009). From such studies, it is possible to approximate that if only all the small farms on the planet employed sustainable practices, they might sequester a total of 2.5 billion tonnes of carbon annually. Such verifiable carbon sequestration levels could be equivalent to US$ 49 billion in carbon credits per year, assuming a carbon price of US$ 20/tonne. The FAO has documented that a widespread conversion to organic farming could mitigate 40 per cent (2.4 Gt CO_2-eq/yr) of the world's agriculture greenhouse gas emissions in a minimum implementation scenario; and up to 65 per cent (4 Gt CO_2-eq/yr) of agriculture GHG emissions in a maximum carbon sequestration scenario (Scialabba and Muller-Lindenlauf 2010).

Furthermore, emissions of nitrous oxides and methane could be reduced if farmers use nitrogen and other fertilisers more efficiently, including through precision applications and introducing improved crop varieties that more effectively access and use available nitrogen in the soil. Greening agriculture also has the potential to eventually become self-sufficient in producing nitrogen through the recycling of manures from livestock and crop residues via composting; and by increased intercropping rotations with leguminous, nitrogen-fixing crops (Ensor 2009; ITC and FiBL 2007).

Additional ecosystem benefits resulting from greening of agriculture include better soil quality[18] with more organic matter, increased water supply, better nutrient recycling, wildlife and storm protection and flood control (Pretty et al. 2001; OECD 1997). Systems that use natural predators for pest control also promote on-farm and off-farm biodiversity and pollination services.

3.4 Modelling: Future scenarios for green agriculture

In this section we assess a scenario in which an additional 0.16 per cent of the global GDP is invested in green agriculture per year (equalling US$ 198 billion) between 2011 and 2050. This is as part of a green investment scenario in which an additional 2 per cent of global GDP is allocated to a range of key sectors. More details are available in the Modelling chapter of this report. In the part of the modelling exercise, which focused on agriculture sector, these additional green investments are undertaken equally in the following four activities:

- Agricultural management practices: one-fourth of the investment is assumed to be invested in environmentally sound practices;

- Pre-harvest losses: another one-fourth of the additional budget is invested in preventing pre-harvest losses, training activities and pest control activities;

- Food processing: one-fourth of the investment is assumed to be spent on preventing post-harvest losses, better storage and improved processing in rural areas.

- Research and Development: the remaining one-fourth amount is assumed to be spent on research and development especially in the areas of photosynthesis efficiencies, soil microbial productivity, climate adaptation biological processes, and improvements of energy and water-use efficiency.

The green scenario[19] is compared with a BAU2 scenario, where the same amount of additional investment is made in conventional and traditional agriculture over the 40-year period.

The results are stark. Overall, the green investments lead to improved soil quality, increased agricultural yield and reduced land and water requirements. They also increase GDP growth and employment, improve nutrition and reduce energy consumption and CO_2 emissions (Table 7).

- *Agricultural production and value added:* In the green scenario, total agricultural production (including agricultural products, livestock, fishery and forestry) increases significantly compared to other scenarios.[20] This change is driven by increased crop production, which is able to satisfy a growing population that is projected to reach 9 billion by 2050. Similarly value added in agricultural production increases by 9 per cent compared with the BAU2 scenario. It is important to note that despite an increase in agricultural production and value added, there is no increase in area harvested. This suggests positive synergies between ecological agriculture investments and forest management. Similarly, improved water-efficiency reduces water demand by almost one-third by 2050, compared with the BAU2 scenario. On the other hand, energy consumption

18. Such soils are better quality, contain greater organic matter and microbial activity, more earthworms, have a better structure, lower bulk density, easier penetrability and a thicker topsoil (Reganold et al. 1992).

19. Here we have presented results of scenarios that are referred to as G2 and BAU2 in the Modelling chapter.

20. Detailed information about these results can be found in the Modelling chapter.

	Year	2011	2030		2050	
	Scenario	Baseline	Green	BAU2	Green	BAU2
Agricultural sector variables	Unit					
Agricultural production	Bn US$/Yr	1,921	2,421	2,268	2,852	2,559
Crop	Bn US$/Yr	629	836	795	996	913
Livestock	Bn US$/Yr	439	590	588	726	715
Fishery	Bn US$/Yr	106	76	83	91	61
Employment	M people	1,075	1393	1,371	1,703	1,656
b) Soil quality	Dmnl	0.92	0.97	0.80	1.03	0.73
c) Agriculture water use	KM3/Yr	3,389	3,526	4276	3,207	4,878
Harvested land	Bn Ha	1.20	1.25	1.27	1.26	1.31
Deforestation	M Ha/Yr	16	7	15	7	15
Calories per capita per day (available for supply)	Kcal/P/D	2,787	3,093	3,050	3,382	3,273
Calories per capita per day (available for household consumption)	Kcal/P/D	2,081	2,305	2,315	2,524	2,476

Table 7: Results from the simulation model (a more detailed table can be found in the Modelling chapter)

increases by 19 per cent in 2050 compared with BAU2, due to higher production volumes.

■ *Livestock production, nutrition and livelihoods:* Additional investment in green agriculture also leads to increased levels of livestock production, rural livelihoods and improved nutritional status. An increase in investment in green agriculture is projected to lead to growth in employment of about 60 per cent compared with current levels and an increase of about 3 per cent compared with the BAU2 scenario. The modelling also suggests that green agriculture investments could create 47 million additional jobs compared with BAU2 over the next 40 years. The additional investment in green agriculture also leads to improved nutrition with enhanced production patterns. Meat production increases by 66 per cent as a result of additional investment between 2010-2050 while fish production is 15 per cent below 2011 levels and yet 48 per cent higher than the BAU2 scenario by 2050. Most of this growth is caused by increased outlays for organic fertilisers instead of chemical fertilisers and reduced losses because of better pest management and biological control.

■ *GHG Emissions and biofuels:* Total CO_2 emissions to increase by 11 per cent relative to 2011 but will be 2 per cent below BAU2. While energy-related emissions (mostly from fossil fuels) are projected to grow, it is worth noting that emissions from (chemical) fertiliser use, deforestation and harvested land decline relative to BAU2. When accounting for carbon sequestration in the soil, under ecological practices, and for synergies with interventions in the forestry sector, net emissions decline considerably.

We also specifically analyse the generation of agricultural waste, residues and biofuels in these models. In the green economy case, we assume that investment is allocated to second-generation biofuels, which use agricultural residues, non-food crops and are primarily grown on marginal land. On average we find that the total amount of fresh residues from agricultural and forestry production for second-generation biofuel production amounts to 3.8 billion tonnes per year between 2011 and 2050 (with an average annual growth rate of 11 per cent throughout the period analysed, accounting for higher growth during early years, 48 per cent for 2011-2020 and an average 2 per cent annual expansion after 2020). Using the IEA's conversion efficiency standards (214 litres of gasoline equivalent (lge) per tonne of residue) we project that additional green investments lift the production of second-generation biofuels to 844 billion lge, contributing to 16.6 per cent of world liquid fuel production by 2050 (21.6 per cent when first-generation biofuels are considered). This would cost US$ 327 billion (at constant US$ 2010 prices) per year on average and would require 37 per cent agricultural and forestry residues. The IEA estimates that up to 25 per cent of total agricultural and forestry residues may be readily available, and economically viable (IEA Renewable Energy Division 2010), for second-generation biofuel production. Residues not used for second-generation biofuels are expected to be returned to the land as fertilisers, and in other cases may be used as livestock feed. More details on the projections on first- and second-generation biofuels production are available in the Modelling and Energy chapters.

Overall, combining these results with research from other sources we find the following results:

■ Return on investments in BAU agriculture will continue to decrease in the long run, mainly owing to the increasing costs of inputs (especially water and energy) and stagnated/decreased yields;

■ The cost of the externalities associated with brown agriculture will continue to increase gradually, initially neutralising and eventually exceeding the economic and development gains; and

■ By greening agriculture and food distribution, more calories per person per day, more jobs and business opportunities especially in rural areas, and market-access opportunities, especially for developing countries, will be available.

While any of the proposed measures contributes to the shift towards a green agriculture sector, the combination of all these interacting actions together will yield positive synergies. For instance, the investment in more sustainable farming practices leads to soil conservation, which increases agricultural yield in the medium to longer term. This allows more land for reforestation, which in turn reduces land degradation and improves soil quality. The higher yield and land availability also benefits the promotion of second-generation biofuels, which may help mitigate the effects of climate change.

4 Getting there: Enabling conditions

Despite the clear logic and economic rationale for moving more rapidly towards greener agriculture, the transition will require a supportive policy environment and enabling conditions that could help level the playing field between conventional and green agricultural practices.

Environmental and economic performance in agriculture is most likely to be improved by employing a mix of policies. There needs to be a greater use of regulations and taxes that impose penalties for pollution in order to include externality costs into market prices for these inputs, as well as economic incentives that reward green practices. There are also opportunities for applying market solutions as alternatives to direct regulation, for example, by using tradable permits and quotas to reduce pollution from greenhouse gases and water-borne nutrients. In general, governmental subsidies for farmer (producer) support should be increasingly decoupled from crop production and alternatively be retargeted to encourage farmers' efforts and investments in adopting green agriculture practices.

In the absence of good governance, collusion and excessive profit taking are constant dangers for incentive programmes. Instilling greater levels of transparency could help reduce such abuses of public-support programmes. In this section we present some of the key conditions that will facilitate a transition to a green agriculture.

4.1 Global policies

At the global level, the enabling conditions are synonymous with improvements to the international trading system and economic development cooperation for promoting sustainable agriculture. An enabling environment for greening agriculture should include a range of interventions at various points along the entire agri-food supply chain:

Elimination of export subsidies and liberalising trade in agricultural products

Current multilateral trade policies at the global level have primarily focused on the gradual reduction and removal of national tariff barriers. While such policies aim at facilitating trade, many developing nations are concerned that they are not well positioned to benefit from such trade policies as are the more developed nations.

These concerns are particularly relevant while domestic subsidies and other producer-support programmes remain in many developed countries. These measures effectively distort and diminish any competitive advantages that developing nations might have. In addition, subsidies have effectively reduced global commodity prices, making it frequently unprofitable to produce certain products in many developing countries, especially for smallholder farmers. This combination of international trade laws and national subsidies can impede development of commercial agriculture in many developing countries, negatively affecting their efforts to achieve economic growth and poverty reduction.

Such trade and subsidy policies need to be reformed to liberalise trade in environmentally- friendly products and services while allowing developing countries to protect some domestic food crops (special products) from international competition when they are particularly important to food security and rural livelihoods. The World Trade Organisation (WTO) already makes a dispensation for countries with a per capita GDP of less US$ 1,000 (Amsden 2005). Furthermore, agricultural subsidies need to be redirected to encourage more diverse crop production with long-term soil health and improved environmental impacts. A major shift of subsidy priorities is needed in which governments would help reduce the initial costs and risks of farmers' transition efforts to implement sustainable farming practices.

Market power asymmetry

Asymmetric market power in trade is an important issue for WTO competition policy. Leading firms are predominantly located in industrialised countries and maintain significant control over the food system standards and regulatory processes at all stages of the supply chain (Gereffi et al. 2005). In such market conditions, primary producers generally capture only a fraction of the international price of the commodity. Thus, the degree of poverty reduction and rural development benefits of supplying global trade have been limited. A recent study (Wise 2011) shows that even in a resource-rich country like the United States, despite rapid increase in prices for food commodities since 2006, "small-to-mid-scale family farmers had lower farm incomes in 2009 than they did earlier in the decade when prices were lower". A green agriculture system would require trade policies that redress these chronic asymmetries.

Food safety standards

The already stringent food safety standards and verifiable logistics management systems that are applied in international markets are likely to become more sophisticated over the next few decades. Currently, most domestic food supply chains in developing countries have relatively low levels of food safety and handling practices. Improving capacity to develop and implement sanitary and food safety standards that can ensure compliance with international requirements can increase prospects for small farmer communities to supply international markets (Kurien 2004). Furthermore, it is particularly important to support international efforts to harmonise the variety of sustainable and organic certification protocols and standards. Today's fragmented certification procedures impose high transaction and reporting costs on farmers and limit their access to international markets.

Another important issue is that the cost of certification and reporting is to be borne only by sustainable producers while polluters can market their products freely. The burden of proof must be shifted to the polluter through introduction of certification protocols and labeling schemes which, at a minimum, show the quantities of different agrochemical inputs used in the production and processing of a product, and whether the product contains GMOs or not.

Intellectual property

The application of Intellectual Property (IP) regimes has, in some cases, restricted the results of agricultural research and development being made available as public goods. Private-sector and often public-sector IP rights restrict the access of many in developing countries to research, technologies and genetic materials. Supporting the implementation of the World Intellectual Property Organisation's (WIPO) Development Agenda and providing improved access to and reasonable use of IP that involves traditional knowledge, ecological agriculture techniques and genetic resources in international IP regimes would help advance development and sustainability goals.

4.2 National policies

At the domestic public policy level, the key challenge is creating the conditions that would encourage more farmers to adopt environmentally sound agriculture practices instead of continuing to practice unsustainable conventional farming methods.

Support for improved land tenure rights of smallholder farmers

In order for farmers to invest capital and more labour into the transition from brown to green agriculture, major land reforms will have to be implemented, particularly in developing countries. In the absence of more secure rights to specific plots of land for many years into the future, many poor farmers are unlikely to take on additional risks and efforts to gradually build up the natural capital of their farms beyond a one or two-year horizon.

Targeting programmes for women smallholder farmers

Small-farm diversification often requires a division of labour at the household level that may result in gender-based distribution of management roles and responsibilities for both on and off-farm tasks. This has resulted in the majority of smallholder farms, especially in Africa, being run by women. Securing collective and individual legal rights to land and productive resources (e.g. water, capital), especially for women, indigenous people and minorities is important. Improving women's access to working capital through microfinance is an option that would allow much greater numbers of small-scale producers to procure green inputs and related mechanisation technologies (World Bank, IFAD and FAO 2009).

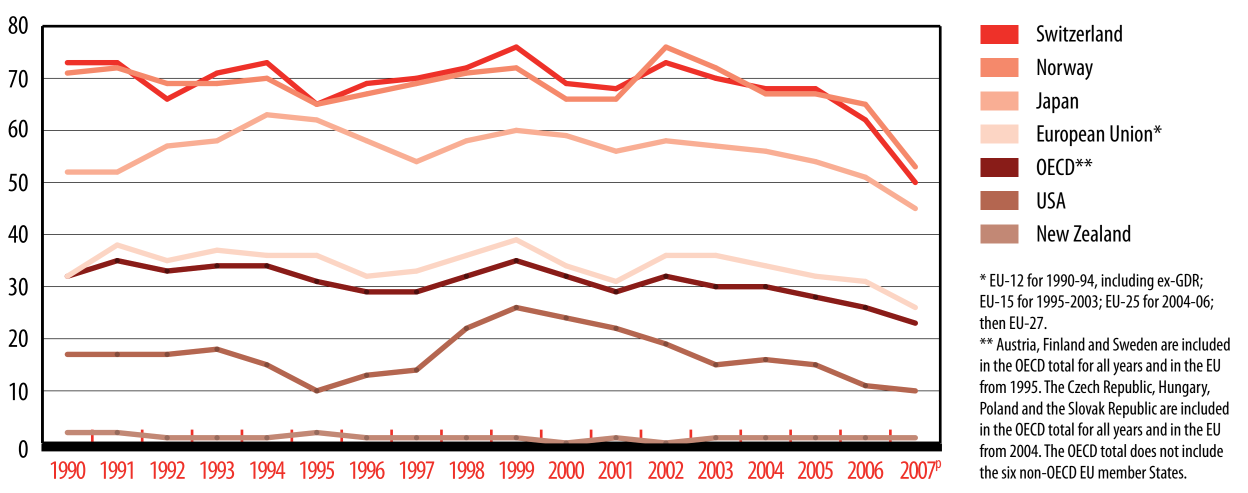


Figure 13: Estimated producer support by country (as a percentage of total farmer income)

Source: Bellmann (2010), adapted from OECD (2007). Available at: http://poldev.revues.org/143

Public procurement of sustainably produced food

Government-sponsored food programmes for schools and public institutions and public procurement policies should be encouraged to source foods that are sustainably produced. The Strategic Paper on Public Procurement, prepared by the UK Department for Environment, Food and Rural Affairs (DEFRA) in January 2008, provides a good example of how organic and sustainable products can be supported through public procurement policies.[21]

4.3 Economic instruments

Agriculture's environmentally damaging externalities could be reduced by imposing taxes on fossil fuel inputs and pesticide and herbicide use; and establishing specific penalties for air emissions and water pollution caused by harmful farming practices. Alternatively, tax exemptions for investments in bio-control integrated pest management products; and incentives that value the multi-functional uses of agricultural land have proven effective in improving the after tax revenues for farmers that practice sustainable land management. The OECD countries have developed a wide range of policy measures to address environmental issues in agriculture, which include economic instruments (payments, taxes and charges, market creation, e.g., tradable permits), community based measures, regulatory measures, and advisory and institutional measures (research and development, technical assistance and environmental labelling).

In OECD countries, the partial shift away from production-linked support has enabled the agricultural sector to be more responsive to markets, thus improving growth. Importantly, some support measures have been linked to specific environmental objectives, research and development, information, and technical assistance, food inspection services, biodiversity, flood and drought control, and sinks for greenhouse gases and carbon storage. There is a need to strengthen these recent trends in developed countries and replicate them in those developing countries that offer farm subsidies in order to target these funds to specific objectives for greater and sustainable economic and environmental performance (OECD 2010).

Payment for Ecosystem Service (PES) can further incentivise efforts to green the agriculture sector. This is an approach that verifies values and rewards the benefits of ecosystem services provided by green agricultural practices (Millennium Ecosystem Assessment 2005; Brockhaus 2009). A key objective of PES schemes is to generate stable revenue flows that help compensate farmers for their efforts and opportunity costs incurred in reducing environmental pollution and other externality costs that adversely impact the shared commons of the local, national and global environment. Such PES arrangements should be structured so that small-scale farmers and communities, not just large landowners, are able to benefit. Innovative PES measures could include reforestation payments made by cities to upstream communities in rural areas of shared watersheds for improved quantities and quality of fresh water for municipal users. Ecoservice payments by farmers to upstream forest stewards for properly managing the flow of soil nutrients, and methods to monetise the carbon sequestration and emission reduction credit benefits of green agriculture practices in order to compensate farmers for their efforts to restore and build SOM and employ other practices described in this chapter are important elements of PES programmes that have been implemented to date (Pagiola 2008; Ravnborg et al. 2007).

4.4 Capacity building and awareness-raising

The availability and qualitative capabilities of rural labour are critical resources needed for implementing green agriculture practices. Green agricultural practices emphasise crop and livestock diversification; local production of natural fertiliser and other more labour-intensive farm operations. The seasonal variability of crop-specific farming tasks affects temporal labour surpluses and shortages, which must be managed throughout the year. Whether rural labour provides an advantage or a constraint for the adoption of green agriculture practices is highly contextual with specific regional and national conditions. The relative age and gender distribution of rural populations, their health, literacy and family stability, gender equity with respect to access to training and financial services, and other factors will determine the degree to which rural farming communities respond to public and private encouragement of their adoption of green agriculture (Foresight 2011).

Supply chains, extension services and NGOs

Green farming practices in developing countries must be promoted and supported by information outreach and training programmes that are delivered to farmers and their supply-chain partners. These enhanced and expanded training programmes should build upon established agriculture extension service programmes in those countries where they are now functioning. However, in order to effectively use existing agriculture extension services, it should be recognised that some extension services over the past 50 years have failed due to a pervasive attitude that small farmers need to be "taught". The green agriculture paradigm requires participatory learning in which farmers and

21. The paper is available at http://www.sustainweb.org/pdf2/org-238.pdf.

professionals in agro-ecological sciences work together to determine how to best integrate traditional practices and new agro-ecological scientific discoveries. Efforts should also be made to partner with NGOs that support farmers, field schools, demonstration farms and other such initiatives. It is also important to support small and medium business enterprises that are involved in supplying agriculture inputs; particularly those firms that offer green agriculture products and services such as organic certification auditing and reporting.

Integrating information and communications technologies with knowledge extension

Support is needed to improve farmers' access to market information including through IT in order to enhance their knowledge of real market prices so that they can better negotiate the sale of their crops to distributors and end customers. There are also opportunities to support the construction of meteorological monitoring telemetry stations that could support national and regional weather forecasting capabilities that would help farmers determine best times for planting, fertiliser applications, harvesting and other critical weather-sensitive activities. Such networks could help support the introduction of innovative financial services such as weather-indexed crop insurance that would help reduce risks associated with adopting new technologies and shifting to green practices and marketing methods.

Better food choices

In an era where global human health is undermined by malnourishment and obesity, there is an opportunity to guide and influence people's food consumption into a greater balance with sustainably produced and more nutritious foods. Raising awareness about better food and its availability at affordable prices can reduce and reshape food demand trends. In this regard, there is a need to invest in public education and marketing that would encourage consumers to adopt more sustainable dietary habits (OECD 2008).

Large-scale industrial farming practices, in many cases, pose enormous public health risks due to the overuse of inputs such as antibiotics, pesticides and synthetic growth hormones. There are neither policies nor any labels that transparently display the level of use and residues of these inputs. Introducing labelling schemes that can help consumers to make informed choices will dramatically shift the consumer behaviour towards safe and healthy food.

5 Conclusions

A transformation of today's predominant agriculture paradigms is urgently needed because conventional (industrial) agriculture as practiced in the developed world has achieved high productivity levels primarily through high levels of inputs (some of which have limited known natural reserves), such as chemical fertilisers, herbicides and pesticides; extensive farm mechanisation; high use of transportation fuels; increased water use that often exceeds hydrologic recharge rates; and higher yielding crop varieties resulting in a high ecological footprint. Similarly, traditional (subsistence) agriculture as practiced in most developing countries, which has much lower productivity, has often resulted in the excessive extraction of soil nutrients and conversion of forests to farmland.

The need for improving the environmental performance of agriculture is underscored by the accelerating depletion of inexpensive oil and gas reserves; continued surface mining of soil nutrients; increasing scarcity of freshwater in many river basins; aggravated water pollution by poor nutrient management and heavy use of toxic pesticides and herbicides; erosion; expanding tropical deforestation, and the annual generation of nearly a third of the planet's global greenhouse gas emissions (GHG).

Agriculture that is based on a green economy vision integrates location-specific organic resource inputs and natural biological processes to restore and improve soil fertility; achieve more efficient water use; increase crop and livestock diversity; support integrated pest and weed management and promotes employment and smallholder and family farms.

Green agriculture could nutritiously feed the global population up to 2050, if worldwide transition efforts are immediately initiated and this transition is carefully managed. This transformation should particularly focus on improving farm productivity of smallholder and family farms in regions where increasing population and food insecurity conditions are most severe. Rural job creation would accompany a green agriculture transition, as organic and other environmentally sustainable farming often generate more returns on labour than conventional agriculture. Local input supply chains and post-harvest processing systems would also generate new non-farm, value added enterprises and higher skilled jobs. Higher proportions of green agricultural input expenses would be retained within local and regional communities, and the increased use of locally sourced farm inputs would substitute for many imported agri-chemical inputs, helping to correct developing countries' foreign trade imbalances.

Ecosystem services and natural capital assets would be improved by reduced soil erosion and chemical pollution, higher crop and water productivity, and decreased deforestation. A greener agriculture has the potential to substantially reduce agricultural GHG emissions by annually sequestering nearly 6 billion tonnes of atmospheric CO_2. The cumulative effect of green agriculture in the long term will provide the adaptive resilience to climate-change impacts.

Investments are needed to enhance and expand supply-side capacities, with farmer training, extension services, and demonstration projects focusing on green farming practices that are appropriate for specific local conditions and that support both men and women farmers. Investments in setting up and capacity building of rural enterprises are also required.

Additional investment opportunities include scaling up production and diffusing green agricultural inputs (e.g. organic fertilisers, biopesticides, etc.), no-tillage cultivation equipment, and improved access to higher yielding and more resilient crop varieties and livestock. Investments in post-harvest storage handling and processing equipment, and improved market access infrastructures would be effective in reducing food losses and waste.

In addition to production assets, investments are required to increase public institutional research and development in organic nutrient recovery, soil fertility dynamics, water productivity, crop and livestock diversity, biological and integrated pest management, and post-harvest loss reduction sciences.

Secure land rights, and good governance, as well as infrastructure development (e.g. roads, electrification, the internet, etc.) are critical enabling conditions for success, especially in the rural sector and particularly in developing countries. These investments would have multiple benefits across a wide range of green economy goals and enable the rapid transition to greener agriculture.

Public policies are needed to provide agriculture subsidies that would help defray the initial transition costs associated with the adoption of more environmentally friendly agriculture practices. Such incentives could be funded by corresponding reductions of agriculture related subsidies that reduce the costs of agricultural inputs, enabling their excessive use, and promote commodity crop support practices that focus on short-term gains rather than sustainable yields.

Public awareness and education initiatives are needed in all countries to address consumer demand for food. Investments in consumer-oriented programmes that focus on nutritional health and the environmental and social equity implications of dietary behaviours could encourage local and global demand for sustainably produced food.

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