THE GREENING OF AGRICULTURE
AGRICULTURAL INNOVATION AND SUSTAINABLE GROWTH

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EXECUTIVE SUMMARY

In the decades since World War II world agriculture has become considerably more efficient. Improvements in production systems and crop and livestock breeding programs have resulted in significant increases in food production. However, climate change — as well as competing challenges posed by market concerns of global competitiveness and the need to feed ever-increasing populations — is expected to exacerbate the existing challenges faced by agriculture.

It is increasingly clear that climate change as the dominant global scale environmental concern will have a profound influence on the agro-ecological conditions under which farmers and rural populations need to develop their livelihood strategies, manage their natural resources and achieve food security and other ends. Some major challenges to the sustainability of the world's agriculture are:

- **i)** Pollution
- **ii)** Biodiversity loss
- **iii)** Soil Degradation/ Nutrient loss/Erosion
- **iv)** Water Scarcity/ Salinity
- **v)** Carbon Foot-print
- **vi)** Natural Resource Depletion

Enhancing food security requires agricultural production systems to change in the direction of higher productivity and also, essentially, lower output variability in the face of climate risk and risks of an agro-ecological and socio-economic nature. More productive and resilient agriculture requires transformations in the management of natural resources (e.g., land, water, soil nutrients, and genetic resources) and higher efficiency in the use of these resources and inputs for production. Agriculture also presents untapped opportunities for mitigation.

This report — prepared to inform OECD's green growth strategy 2011 — reviews the role of agricultural innovation — R&D, technology and the use of these and other sources of knowledge in agricultural production systems — toward greener growth in agriculture. The overall aim of the paper is to illustrate agricultural innovation and the circumstances of the use of innovation in sustainable agricultural production, and in sustainable economic regimes more widely, and draw out conclusions about how policy and market approaches could better enable the contribution of innovation to greener growth.

The challenges posed by climate change to agriculture and food security require a holistic and strategic approach to linking knowledge with action. Key elements of this are greater interactions between decision-makers and researchers in all sectors, greater collaboration among climate, agriculture and food security communities, and consideration of interdependencies across whole food systems and landscapes. Food systems faced with climate change need urgent action in spite of uncertainties.

This report discusses the green challenges of agriculture through the lens of four modes through which innovation can best contribute:

1. **New Science and Generic Technologies with Green Potential:** Specific technologies and generic platform technologies that may have significant transformation potential. Biotechnology, Information and computing technology and bioproduction are discussed as exemplars in this mode.

2. **Farming Systems Innovations:** The second mode is a discussion of farming systems innovations with green potential; these are different ways of organizing agricultural production. This may involve the use of one or more specific technological innovations as defining characteristics, or it may be purely to do with how production and marketing is organized — or a combination of the two. Organic farming, Integrated Pest Management and the Systems of Rice Intensification are exemplars of this.

3. **Integrated National Green Regimes:** The third mode is a discussion of integrated green national regimes. Here specific technologies or agricultural production systems operate as part of national (or regional) green agenda. Exemplars include bio-fuels in Brazil, organic states in India, agritourism, and the potential for renewable energies in agriculture.

4. **Cross-cutting mode:** The fourth mode is a cross-cutting mode and examines whether market or policy-driven mechanisms are most suited to driving innovation in pursuit of a green agenda, and under what circumstances.

The goal here wasn't to come up with a one-size-fits-all solution for green growth in agriculture — that clearly isn't possible. Rather, this report aims to raise several discussion points that OECD needs to address in order to come up with a strategy for green growth. The following points emerged:

1. **Expectations of the role of agriculture in an era of environmental challenges are expanding:** The greening of agriculture presents an enormous innovation challenge of producing more food and fibres without relying on most of the technological mainstays of productivity gains of the past. New demands are also being placed as agriculture is being asked to replace environmentally-damaging products and industrial production systems, protect biodiversity and mitigate climate change as well as address livelihoods and lifestyles.

2. **The role of R&D and technology is a critical factor in shaping the green credentials of agriculture:** Technical change associated with the drive for agricultural intensification in the post-World War II period has raised environmental challenges, but it will also be a major element of strategies to address these sustainability issues. This underlines the need for increased research.

3. **Technology is usually necessary, but rarely acts alone as a way of making agriculture sustainable:** While it is useful to discuss the potential contribution to sustainability of new technological options, technology is often part of a wider set of linked changes that together bring about green innovation. Deploying technology requires

a high degree of policy coherence and strong communication across different stakeholder groups.

4. **New technology is not inherently more sustainable and requires planning processes inclusive of a wider set of stakeholders:** The potential of new technology to contribute to sustainable agriculture will depend on policy finding a way of managing technological change in a way that provides a balanced outcome for society and the environment. This suggests that networking and communicating between different groups of stakeholders is going to assume much great importance and that participatory processes are going to be key in the discussion about the deployment of new technology for sustainable agriculture.

5. **The contribution of technology and innovation to sustainable agriculture is determined by broad strategies adopted and these in turn are shaped largely by national and regional historical and socio-political contexts:** Technical change and innovation are organized differently and play different roles in different strategies — identified in this report as: technological fixes, consumer/market-driven fixes, intensive agricultural systems with strong ecological principles, sporadic practices of alternative modes of sustainable agriculture, and integrated national sustainable regimes. These strategies are not necessarily transferable between countries as these often emerge from and require a particular set of starting conditions. The critical observation here for the OECD countries in their pursuit of sustainable agriculture is that while there are clearly higher-performing strategies that can be adopted it is essential that strategies are tailored to national contexts. Similarly full consideration will need to be given to the trade-offs involved and this will have a national flavour as it will involve consideration of the level of public and private investments required and the positioning of different stakeholder interests in the national debates about sustainable agriculture.

6. **The civil society and the market have been major forces in promoting green agriculture:** Civil society-led movements and market-led forces are increasingly powerful forces of change toward greener agriculture. The role for policy in this case may be to assist agriculture to make the transition to modes of ecological production desired by consumers. Also green innovation will best be promoted by market, policy and technical innovation and as a result public-private sector partnerships are going to be critical in pursuing a green agricultural agenda

7. **Sustainable agriculture win-wins are more likely when an integrated system-level approach to technical change and innovation is adopted:** Generally sustainable agriculture is characterized by reduced inputs and there are a number of innovations that simultaneously increase production and or profitability. This observation underlines the importance of devising innovation strategies to promote sustainability that make the most of market incentives and which are inclusive of market stakeholders.

8. **Opportunities to learn from non-OECD countries:** A range of green agricultural practices and farming systems have originated in non-OECD, emerging economy countries. Many of these green innovations possibly could not transfer directly to OECD countries. However, international research and development collaboration around the

topic of green agricultural innovation could be a very fruitful area of co-development and should not be framed in the conventional development assistance sense, but as essential for the development of green economies in the OECD countries.

9. **Green agriculture in OECD must mean green agriculture outside OECD:** The internationalization of agricultural value chains means that the greening of any OECD countries — those in Europe, for example — concerns the nature of agricultural practices in countries where food products are sourced from. Apart from regulatory standards, there is a much wider policy issue here concerning the question of how to upgrade the environmental standards in the agricultural production systems of trading partners, many of whom are emerging economies with limited technical expertise in sustainable practices. This needs to be a particular concern for small OECD countries with limited agricultural sectors of their own and whose environmental foot-prints are outside their own national borders.

LIST OF ACRONYMS

BSE	-	Bovine Spongiform Encephelopathy
CATIE	-	Tropical Agricultural Center for Research and Education (Centro Agronómico Tropical de Investigación y Enseñanza in Spanish)
CDH	-	Horticultural Development Centre, Senegal
CGIAR	-	Consultative Group on International Agricultural Research
CO2	-	Carbon Dioxide
DDT	-	Dichlorodiphenyl-trichloroethane
DEFRA	-	Department for Environment, Food and Rural Affairs, UK
DFID	-	Department for International Development, UK
ENTWINED	-	Environment and Trade in a World of Interdependence
EU	-	European Union
FAO	-	Food and Agriculture Organization of the United Nations
FSC	-	Forest Stewardship Council
GE	-	Genetically Engineered
GEF	-	Global Environment Facility
GHG	-	Green House Gas
GIS	-	Geographical Information Systems
GM	-	Genetically Modified
GMO	-	Genetically Modified Organisms
GPS	-	Global Positioning System
HACCP	-	Hazard Analysis and Critical Control Point

ICRISAT	-	International Crops Research Institute for the Semi-Arid Tropics
ICT	-	Information and Communication Technology
IDS	-	Institute of Development Studies, University of Sussex
IEICI	-	Israel Export and International Cooperation Institute
IFES	-	Integrated Food Energy Systems
IFOAM	-	International Federation of Organic Agriculture Movements
IFPRI	-	International Food Policy Research Institute
IIED	-	International Institute for Environment and Development
IISD	-	International Institute of Sustainable Development
ILO	-	International Labour Organization
INRM	-	Integrated Natural Resource Management
IPM	-	Integrated Pest Management
ISDA	-	Innovation and Sustainable Development in Agriculture and Food
ISO	-	International Organization for Standardization
ISRA	-	Senegalese Institute of Agricultural research
LINK	-	Learning, Innovation and Knowledge
LISA	-	Low Input Sustainable Agriculture Program of USDA
NCAP	-	National Centre for Agricultural Economics and Policy Research, India
NGO	-	Non-Governmental Organization
NPM	-	Non-Pesticidal Management
NRM	-	Natural Resource Management
OECD	-	Organization for Economic Cooperation and Development

PEFC	-	Programme for the Endorsement of Forest Certification
R&D	-	Research and Design
REDD	-	Reducing Emissions from Deforestation and forest Degradation
SARE	-	Sustainable Agricultural Research and Education (formerly LISA)
SAT	-	Soil Aquifer Treatment
SECURE	-	Socio-Economic and Cultural Upliftment in Rural Communities (an NGO in India)
SRI	-	Systems of Rice Intensification
TIBRE	-	Targeted Inputs for a Better Rural Environment
UK	-	United Kingdom
UN	-	United Nations
UNCTAD	-	United Nations Conference on Trade and Development
US	-	United States
USA	-	United States of America
USDA	-	United States Department of Agriculture
VACVINA	-	Vietnamese Gardeners’ Association (Vuon Ao Chuong)
WWF	-	World Wildlife Fund

1. INTRODUCTION

Technological change has been the major driving force behind increased agricultural productivity around the world — particularly so for the 33 countries that form the Organization for Economic Cooperation and Development (OECD). In the past agricultural technologies were designed and adopted with the primary aims of increasing production, productivity and farm incomes. Today, however, the challenges before agriculture are much more complex and much more immediate. Global issues such as climate change and food security need to be addressed simultaneously, which means that agricultural innovation must necessarily emerge out of a complex decision-making process that weighs immediate concerns of feeding the world against future concerns of sustainability.

This delicate balancing act is one that OECD is well aware of, as demonstrated by its 2009 declaration on green growth (OECD, 2009a) in which it was reported that economic recovery and environmentally and socially sustainable economic growth were the key challenges that all countries faced today. That declaration is a precursor to a larger Green Growth Strategy that OECD is developing (to be released in 2011), where 'green growth' is described as "a way to pursue economic growth and development, while preventing environmental degradation, biodiversity loss and unsustainable natural resource use. It aims at maximising the chances of exploiting cleaner sources of growth, thereby leading to a more environmentally sustainable growth model" (OECD, 2010a).

This paper reviews the role of agricultural innovation — R&D, technology and the use of these and other sources of knowledge in agricultural production systems — toward greener growth in agriculture. The overall aim of the paper is to illustrate agricultural innovation and the circumstances of the use of innovation in sustainable agricultural production, and in sustainable economic regimes more widely, and draw out conclusions about how policy and market approaches could better enable the contribution of innovation to greener growth. The paper does not limit itself to an examination of the OECD countries, but draws in examples from non-OECD countries as well.

The paper presents this review in the following way: Section 2 briefly examines the historical role of agricultural innovation in the post-World War II era to help us understand how we have arrived at such a critical juncture. The next section presents an overview of the major sustainability concerns associated with technological change and the related intensification of agricultural production — all of which a green agenda is going to need to address. Section 4 presents three existing modes through which innovation can contribute to greening and examines the possibility for a fourth cross-cutting mode. Finally, the paper raises several points for discussion.

2. HISTORICAL ROLE OF AGRICULTURAL INNOVATION IN THE POST-WORLD WAR II PERIOD

Agriculture, as a sector, was viewed in the post-World War II era as a sector from which resources could be extracted to fund development in the industrial sector — success of the latter being seen as key to the economic well-being of OECD countries (Rostow, 1956). While growth in agricultural production was viewed almost as an essential precondition for growth in the rest of the economy, the process(es) by which agricultural productivity was increased did not come under much scrutiny from policy-makers, agricultural researchers and scientists, development practitioners or even environmentalists at the time (Ruttan, 2002).

What then followed was an unprecedented period of agricultural intensification in most OECD countries, with an increasing reliance on a wide range of agricultural innovations: mechanisation; chemical fertilisers; improved crop varieties and livestock breeds; improved irrigation and water management technologies; increased use of pesticides/ herbicides; the greater use of animal healthcare products; technological improvements in the extractive sub-sector (fisheries and forestry); introduction of a variety of intensive farming system innovations, including mono-cropping, intensive livestock rearing, among others. Early innovations focused on ways to make agricultural production more capital-intensive rather than labour-intensive. Advances in hybrid seed and agrichemical technology resulted in major increases in yields *per acre* (Olmstead and Rhode, 1993).

Negative Environmental Consequences

The term ‘agricultural treadmill’ has frequently been used to explain how the development of agriculture in developed countries resulted in a range of negative environmental consequences (Ward, 1993). In this context, it refers to farmers becoming increasingly dependent on pesticide use, resulting in the disruption of ecosystems and the consequent need to use more chemicals to maintain effective pest control — thus, ‘trapped on a treadmill’. More generally, agricultural intensification of the kind that took place in the post-war years is associated with: land and soil degradation, salinisation of water resources, pesticide pollution of soil, water and food chains, depletion of ground water, genetic homogeneity of agricultural products and associated vulnerability (Altieri & Rosset, 1996). All of this raises serious concerns about the sustainability of modern agriculture.

- *Water scarcity and salinity*: Water is becoming scarcer and more expensive. Irrigation systems can be a double-edged answer to water scarcity, since they may have substantial environmental externalities that affect agricultural production directly. Common problems of surface water irrigation systems include water logging and salinity resulting from excessive water use and poorly designed drainage systems (Murgai, Ali and Byerlee, 2001). Also of concern are issues of falling groundwater levels and rising pumping costs.

- *Soil*: Soil degradation (loss of nutrients), retrogression (erosion) and land-cover change have been regarded as major threats to sustainable growth in agricultural production around the world — a crisis that has also largely been brought to a head by conventional modes of agriculture. Increased pesticide use over the years has contributed to the loss of essential nutrients, as have mono-cropping, intensive mechanised tilling or ploughing practices, overgrazing, land-use conversion and deforestation.

- *Pests*: Pest control has become an increasingly serious constraint on agricultural production despite dramatic advances in pest control technology. In the US, for instance, pesticides have been the most rapidly growing input in agricultural production over the last half-century for 'pests' such as pathogens, insects and weeds. For much of the post–World War II era, pest control has meant application of chemicals. The pesticidal activity of Dichlorodiphenyl-trichloroethane (DDT) was discovered in the late 1930s. Early tests found DDT to be effective against almost all insect species and relatively harmless to humans, animals and plants. It was relatively inexpensive and effective at low application levels, and its use in agriculture was followed by chemical companies introducing a series of other synthetic organic pesticides in the 1950s. The initial effectiveness of DDT and other synthetic organic chemicals for crop and animal pest control after World War II led to the neglect of other pest control strategies. By the early 1960s, an increasing body of evidence suggested that the benefits of the synthetic organic chemical pesticides introduced in the 1940s and 1950s were obtained at substantial cost, including direct and indirect effects on wildlife populations, not to mention on human health. A second set of costs involved the destruction of beneficial insects and the emergence of pesticide resistance in target populations. A fundamental problem in efforts to develop methods of control for pests and pathogens is that the control results in evolutionary selection pressure for the emergence of organisms that are resistant to the control technology.

- *Climate change and other concerns*: In the late 1950s and early 1960s scientists began to record increasing levels of carbon dioxide (CO2) in the atmosphere. Beginning in the late 1960s, computer model simulations indicated possible changes in temperature and precipitation that could occur due to human-induced emission of CO2 and other "greenhouse gases" into the atmosphere. By the early 1980s, a fairly broad consensus had emerged in the climate change research community that energy production and consumption from fossil fuels could, in the foreseeable future, result in a doubling of the atmospheric concentration of CO2, a rise in global average temperatures and a complex pattern of worldwide climate change (Ruttan, 2001). Subsequent research has attempted to assess how an increase in the atmospheric concentration of greenhouse gases could affect agricultural production through three channels: higher CO2 concentrations in the atmosphere, which may have a positive "fertilizer effect" on some crop plants (and weeds); higher temperatures, which could result in a rise in sea levels, resulting in inundation of coastal areas and intrusion of saltwater into groundwater aquifers; and changes in temperature, rainfall and sunlight that may also alter agricultural production with both negative and positive effects, although the effects will vary greatly across regions.

The table below (Table 1) sums up features that describe agricultural innovation upto and beyond the post World War II era.

Table 1: Paradigms of Agriculture

	Traditional Agriculture Prior to 1950	**Modern Agriculture 1950-1985**	**New Agriculture Post-1985**
Technology	- Relatively Constant Technology	- Mechanization - Agrochemical - Better Seeds and Breeds	- Information Technology - Biotechnology - Integrated Technologies
Organization	- Relatively Stable	- Labour Saving - Yield Enhancing - Intensification - Specialization - Concentration	- Quality Orientation - Protecting the Environment - Direct Marketing - Ethical Marketing - New Products
Social Impact	- Static Rural Society	Dynamic Structural Change	- Continuing Structural Change - Rural Development - Direct Payments - Pluriactivity
Driving Forces	- Driven by Tradition	- Driven by Economies of Scale (produce more, faster, easier)	- Driven by Markets Consumer Preferences and Information
Innovators	- Individuals - “Local Geniuses” - Outsiders	- Technical Experts - Sector-Specific Innovation	- Social Experts - Social and for-profit hybrid enterprises - Strategic Innovation
Technology Forecast		- Visions of Technical Experts - What is the Technical Solution to a Technical Problem	- Social Experts looking for mega-trends - Technology Assessment - What is a good technology that meets with consumer and social preferences? - Technology that ‘responsible’ and aimed at addressing sustainability concerns

Adapted from OECD (2002a)

3. MAJOR SUSTAINABILITY CONCERNS: WHAT A GREEN AGENDA IS GOING TO NEED TO ADDRESS

It is increasingly clear that climate change as the dominant global scale environmental concern will have a profound influence on the agro-ecological conditions under which farmers and rural populations need to develop their livelihood strategies, manage their natural resources and achieve food security and other ends (Leeuwis and Hall, 2010). In most contexts, climate change can be regarded as part of a 'complex' problem situation in several senses: (a) there is often considerable uncertainty about specific climatic and ecological dynamics at play; (b) climatic and ecological change have (initially unknown) consequences for several interrelated societal realms (e.g. agriculture, forestry, fisheries, health, energy, economy, migration, etc.), and (c) it is likely that there are different and competing human interests and values at stake (e.g. between rich and poor, farmers and pastoralists, 'food' and 'fuel', economy and ecology, etc.). It is amidst this complexity that appropriate human responses will have to be developed.

However, while certain agricultural practices in the past have had negative environmental and sustainability consequences, it is also in agriculture that we find solutions to the question of sustainability.

Some major issues for concern currently are:

a) Nitrate and pesticide residue pollution arising from agriculture
b) Loss of biodiversity due to pollution, agronomic practices such as mono-cropping, destruction of natural habitats, over-exploitation of natural stocks of fish and forests
c) Soil nutrients, organic matter and natural resource degradation, including salinification associated with irrigation
d) Agriculture's carbon foot-print — fossil fuel use in production of chemical inputs, in farming practice, in food processing and related agro-industries. Transport of agricultural produce to distant markets
e) Agriculture's water use foot-print — excessive water use in intensive agricultural production and competition with others uses, particularly drinking water as well as effects on water quality through pollution
f) Agriculture's contribution to climate change, both in terms of it contribution of greenhouse gases CO2 but also methane; and its role in climate change mitigation strategies (biofuel production, but also a range of bio-production systems with benign or beneficial environmental consequences, carbon sequestration)

The Green Agenda in Agriculture

While post-World War II agriculture can be viewed as driven primarily by goals of increasing production, productivity, incomes and reducing labour costs and inputs, concerns over the negative environmental impacts of conventional farming systems began to find a voice in the 1960s and 1970s (Welch and Graham, 1999). With growing evidence of the negative effects of the Asian Green Revolution (a package of intensive agricultural practices that used high-yielding varieties to boost food production in Asia) in the 1980s — due to heightened worries about pesticide poisoning and fertiliser pollution (Conway and Pretty, 1991) and the increasing popularity of studies of agro-ecosystems analysis (Conway, 1985) and agro-ecological approaches (Altieri, 1996) — ideas around sustainable agriculture began to gain ground, ultimately finding voice in policy in the Nineties. Soon, the production-at-all-and any-costs approach began to give way to concerns about environmental costs and risks and a greater consideration of the benefits of alternative approaches to agricultural production and development. The case of the Dutch agricultural system is illustrative of the way concerns about sustainability and the environment led to system-wide changes in the way farming systems were organized (see Box 1 below).

Box 1

Sustainability as a Goal: The Case of Dutch Agriculture

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

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

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

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

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

Adapted from OECD (2002a)

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

In the last 20 years much has been written about sustainable agriculture within a complex backdrop that has expanded from individual farm practices to one that includes national agricultural policies, international environmental regulations and agricultural agreements, global food markets and the agro-food chain, as well as growing awareness and concern for the environment among consumers. While environmental, food safety and quality, and animal welfare regulations are increasingly impacting on the agricultural sector, it is faced with new challenges to meet growing demands for food, to be internationally competitive and to produce agricultural products of high quality. At the same time, it must meet sustainability goals in the context of on-going agricultural policy reform, further trade liberalization and the implementation of multilateral environmental agreements as agreed to by OECD Ministers. What is increasingly clear is that no one system can be identified as sustainable, and there is no single path to sustainability. All farming systems — from intensive conventional farming to organic farming to something that falls between the two extremes — have the potential to be environmentally-sustainable (OECD, 2002a).

In the rest of this report we explore ways several approaches to greener growth in agriculture.

4. APPROACHES TO GREENNESS: MODES THROUGH WHICH INNOVATION CAN CONTRIBUTE TO SUSTAINABILITY

This section discusses the green challenges of agriculture through the lens of four modes through which innovation can best contribute: (i) New science and generic technologies with green potential (ii) farming system innovations (iii) national integrated green regimes. It also offers up a fourth potential cross-cutting mode to examine whether market or policy-driven mechanisms are best suited to driving innovation in pursuit of a green agenda, and under what circumstances. It must be noted that some of the examples discussed below could fall under more than one theme — for example, precision agriculture is discussed in the context of new science technologies with green potential because it relies on information and communication technology, but could very well have been discussed as a farming system innovation. Examples are provided to illustrate the way these modes map onto the challenges to sustainability discussed in the previous section, with examples from different countries and of different 'innovations' provided. (More detailed case studies of some of these 'exemplars' are provided in boxes included in the text that follows).

It is also important to note that some of the innovations discussed offer win-win potential: production benefits and environmental benefits (See Box 19 in the next section). For example "Green technologies", such as Integrated Pest Management, conservation tillage and precision farming can increase productivity and farm profitability, all the while reducing environmental degradation and conserving natural resources. Precision agriculture similarly can reduce adverse environmental impacts by using advanced technologies, such as the global positioning system (GPS), to collect data at exact locations, and geographical information systems, to map more precisely fertiliser and pesticide requirements across a field. There are also cases of triple dividends (OECD, 2002a) where social, economic and environmental advantages occur. Agri-tourism is one example of this.

Table 2 below summarises these approaches to 'greenness' by mapping them against the challenges they have been shown to address.

Table 2: Approaches to Greenness vs. Environmental Challenges

		Environmental Challenges					
	Approach to 'Greenness'	Pollution	Biodiversity Loss	Water Scarcity/ Salinity	Carbon Foot-Print	Soil Degradation/ Nutrient Loss/ Erosion	Natural Resource Depletion
New science and generic technologies with green potential							
1.	Biotech GM/GE Crops	✓	✓	✓		✓	✓
2.	ICT applications		✓	✓			✓
3.	Sustainable Bio Production		✓		✓		✓
Farming system innovations							
4.	Integrated Pest Management (IPM)	✓	✓				

5.	Systems of Rice Intensification (SRI)	✓		✓		✓	
6.	Organic Agriculture	✓	✓		✓	✓	
7.	Conservation Agriculture/ Zero Tillage			✓		✓	
8.	Water Management Systems			✓		✓	
9.	Natural Resource Management		✓	✓	✓		✓
10.	Urban and Peri-Urban Agriculture				✓	✓	
Integrated national green regimes							
10.	Use of Renewable Energies in Agriculture		✓		✓		✓
11.	Biofuels	✓					✓
12	Agri-tourism				✓	✓	

(A) NEW SCIENCE AND GENERIC TECHNOLOGIES WITH GREEN POTENTIAL

The first mode is a discussion of specific technologies and generic platform technologies that may have significant transformation potential. Biotechnology, information and computing technology and bioproduction are given as exemplars. Technological innovation can improve the environmental performance of farming systems through innovations in engineering, information technology and biotechnology. Newer technologies can reduce the load of known toxins in agricultural production, substitute safer alternatives, protect ground or surface waters, conserve natural habitats, reduce nutrient loads in soils, lower gaseous nitrogen loss and reduce the amount of non-renewable energy used in the cropping cycle. These innovations imply changing current farm practices and using different technologies to enhance resource productivity and eco-efficiency.

(i) Biotechnology

Biotechnology is a field of applied biology that involves the use of living organisms and bioprocesses in engineering, technology, medicine and other fields requiring bioproducts. It has a high potential for green agriculture but its use has proved highly controversial. It has been argued that the application of biotechnology to primary production, health and industry could result in an emerging “bioeconomy”, where biotechnology contributes to a significant share of economic output (Arundel and Sawaya, 2009; OECD, 2009c), and provides solutions to ecological problems. Biotechnology can support sustainable development by improving the environmental efficiency of primary production and industrial processing and by helping repair degraded soil and water. Examples include (i) the use of bioremediation — using micro-organisms to reduce, eliminate, contain or transform to benign products contaminants present in soil, sediments, water or air (ii) improved crop varieties that require less tillage (reducing soil erosion) or fewer pesticides and fertilisers (reducing water pollution); (iii) genetic fingerprinting to manage wild fish stocks and prevent their collapse; (iv) and industrial biotechnology applications to reduce greenhouse gas emissions from chemical production (OECD, 2009c).

Biotechnology is currently being used to develop new varieties of food, feed and fibre crops that have commercially valuable genetic traits, such as: herbicide tolerance, pest resistance, agronomic traits that improve yields and provide resistance to stresses, product quality traits that improve flavour and colour and technical traits such as chemical markers essential for breeding. Although genetically modified (GM) varieties of over a dozen plants species have received regulatory approval in different parts of the world, the large majority of GM plantings are for cotton, maize, rapeseed and soybean.

Genetic modification is also currently being used in forestry to develop tree varieties that can reduce paper production costs and for the propagation of trees. However, apart from GM poplar tree plantations in China these are mostly still at an experimental or pilot stage (OECD, 2009c). Biotechnology also has applications for livestock, poultry and aquaculture — for breeding, propagation and health. Diagnostics can also be used to identify serious inherited diseases.

There are distinct national and regional differences to acceptability of GM crops (see Box 2). Europe has been anti-GM while the US has been an active promoter of the technology both at home and abroad. GM cotton has been approved in India and adopted quite enthusiastically, although not without opposition. A number of African countries have also adopted GM crops, although some are more permissive than others.

It also needs to be understood that biotechnology applications do not necessarily involve genetic transformation. Marker assisted selection techniques, for example, use molecular biology tools (in combination with information technology) to speed up the identification of promising crop traits with the normal plant breeding cycle reduced from 10 years to 2. Of course whether these traits selected are in support of a sustainable agenda depends very much on the institutional setting of crop improvement efforts. The international agricultural research centres of the Consultative Group on International Agricultural Research (CGIAR) have been using these breeding approaches routinely for some time to develop drought-tolerant, pest resistant varieties. The same techniques, however, could be used to address environmentally-damaging traits; for example, responsiveness to chemical fertilisers. These techniques are, therefore, not intrinsically sustainable.

Clearly, for biotechnology to be perceived as a win-win solution for sustainable agriculture, policy will have to play a significant role — in investing in research, in establishing regulatory frameworks necessary to ensure that biotech applications meet acceptable bio-safety and environmental standards, in ensuring that the technologies are not monopolised by commercial interests to the detriment of the poor, and in increasing awareness among the public of potential benefits (as well as risks) (OECD, 2009c). The growing gap between public and private sector investments in research (see Table 3 on the following page) suggests that this is an area that policy will need to act much more forcefully in pursuit of both consumer and environmental concerns (see Box 2)

Table 3: Total Public and Private Spending on Agriculture R&D in select OECD countries, 1981 and 2000 (in millions international dollars, 2000)

Country	1981		2000	
	Public	Private	Public	Private
USA	2,568.7	2,495.0	3882.2	4,118.8
Japan	1,821.3	1,048.5	1,646.2	2,331.8
Germany	547.4	701.1	758.2	877.6
Australia	522.0	32.6	588.6	193.9
UK	533.4	676.5	495.5	1,244.6
Canada	520.7	109.2	474.3	244.5
France	478.5	377.7	341.9	1,009.2
Total OECD	8339.8	6,478.4	10,267.6	12,184.5

Alston et al., 2008

Box 2
The Biotech Debate

While there is a good case to be made for the increased use of biotechnology in agriculture by arguing the potential benefits — economic and environmental — there is not much that can be done without public support for it. Few people are opposed to the use of biotechnology in the development of therapeutics or vaccines, but its application in animal cloning or even GM crops is highly contested in the public and even policy domain.

The debate extends beyond questions of contributions to food security and of commercial interests, as it encompasses issues of ethical, legal and scientific concerns.

Vocal advocates of GM and GE food argue that biotechnology-related food research is going to be essential in feeding growing populations while keeping environmental concerns at the forefront. As Gordon Conway, then president of the Rockefeller Foundation, put it: "*By 2020 there will be an extra 2 billion mouths to feed. Biotechnology is going to be an essential partner if yield ceilings are to be raised, if crops are to be grown without excessive reliance on pesticides, and if farmers on less favoured lands are to be provided with crops that are resistant to drought and salinity, and that can make more efficient use of nitrogen and other nutrients*" (Conway, 1999). Officials from developing countries such as India and China, where population growth is expected to be greatest, put forth similar arguments.

There are many, however, who dispute claims of a technology-based food revolution, on grounds of distribution and access, as well as a vociferous group that argues on the basis of ethics. Several NGOs, researchers and activists point out that the claims of biotechnology's potential to feed the world come from commercial interests that have the biggest stakes in its use. According to Altieri and Rossett (1999), "Biotechnology companies often claim that genetically modified organisms (GMOs) — specifically genetically altered seeds — are essential scientific breakthroughs needed to feed the world, protect the environment, and reduce poverty in developing countries. This view rests on two critical assumptions, both of which we question. The first is that hunger is due to a gap between food production and human population density or growth rate. The second is that genetic engineering is the only or best way to increase agricultural production and thus meet future food needs… There is no relationship between the prevalence of hunger in a given country and its population… The world today produces more food per inhabitant than before… The real causes of hunger are poverty, inequality and lack of access."

Public attitudes to the issue of GM and GE crops vary, even across the OECD countries, and change very quickly based on perceived risks and benefits. For instance, public perceptions are comparatively favourable in Australia (45% favourable in 2005 compared with 73% in 2007) while being less so in several European countries. Public perception, of course, ultimately does play out in policy; while the EU imports large quantities of GM maize and GM soy products for animal feed from countries such as Argentina, Brazil and the US, it restricts the use of GM plant varieties in domestic agriculture.

Adapted from OECD (2009c) and Scoones (2002)

(ii) ICT Applications/ Global Positioning Systems/ Precision Agriculture

Information and Communication Technology (ICT) has three distinctly different roles in green agriculture. The first is through precision farming. *Precision farming*, or precision agriculture, is a technique that uses technology to collect and analyse data for the assessment of variations in soil or climate conditions, in order to guide the application of the right agricultural practices, in the right place, in the right way, at the right time. It relies greatly on new technologies, including the Global Positioning System, sensors, satellite or aerial images, and information management tools, to collect information on such variables as optimum sowing density, fertilisers and other input needs. This information is then used to apply flexible practices to a crop. This has the potential to increase agriculture productivity and raise farm incomes (through more efficient/ low input use), while at the same time decreasing costs for producing and accessing goods and services. Such tools also offer a cost-effective way to improve access and coverage of public services.

The second role of ICT in green agriculture is the use of ICT platforms and processes to promote communication, information exchange and networking among very large numbers of individuals, organizations and businesses. Such tools can also be used to monitor citizens' engagement in regional governance and sustainable development as well as allowing for their contribution and participation in practical and feasible solutions. It is predicted that this mechanism will be invaluable in the rapid distribution of information and knowledge to address the very substantial and unpredictable challenges presented by climate change.

The third role of the use of ICT in green agriculture is the monitoring of land use patterns Effective environmental databases can be used to track the status of various environmental indicators and impacts for sustainable environmental management and protection. China has created a range of national databases for land evaluation and management, population, environment and sustainable development. Other applications have included land cover assessment (by county), soil erosion, land use and cultivated land by slope and steepness and wetland inventories. GIS and satellite remote sensing have played an important role in collecting information, pinpointing sensitive and vulnerable forest, watershed and fragile marine ecosystems which are of critical relevance to the livelihoods of the most excluded sections of the population. They provide essential information on both the quantity and quality of forest land, wildlife and marine resources. GIS has also been instrumental in monitoring changes in forest land. In Thailand, the ‘Forest Loves the Water and the Land’ project used satellite images to identify denuded forest areas in five northern provinces. See Box 3 for more examples.

Linking these three roles unleashes the potential that ICT offers to address environmental concerns with a high degree of precision and timeliness than was previously possible. Public investments in ICT applications will be particularly important in coping with the unpredictability of climate change. Similarly it will be an important accompaniment to regulatory policy, helping ensure that sustainable land uses practices are followed.

Box 3
ICTs and Agriculture: Snapshots from around the world

ICTs in rural development appear to be most widely and relevantly used for information dissemination and gathering. Both India and China have several programmes and projects that apply ICTs for purposes that use data for comparisons or towards policy decisions.

In India, the Jal-Chitra software is being used to create an interactive water map of villages to enable communities to keep records of the water available from each water source, record water quality testing, list maintenance work done and required, estimate water demand, generate future monthly water budgets (based on past records) and show the community needs met through rainwater harvesting systems. The software is currently being tested out in a few villages in Rajasthan in North India. China is carrying out similar water-mapping exercises in several villages.

In the Philippines, the Manila Observatory has partnered with a mobile phone service provider, SMART, to provide telemetric rain gauges and phones to farmers in disaster-prone areas. Local farmers read the rain gauges and phone in information to the observatory. The observatory can also use the phones to issue early storm warnings to fisherfolk and farmers.

The International Centre for Research in the Semi Arid Tropics (ICRISAT's) integrated climate risk assessment and management system uses remote sensing and GIS techniques to study rainfall patterns and prepare advisories for farmers in the drylands of Asia and sub-Saharan Africa (http://www.icrisat.org/impi-climatechange-justification.htm).

(iii) Bio-production/ Biofortification

Bioproduction refers to the propagation and protection of all useful bioresources that support sustainable agriculture necessary for human existence and man's living biosphere. The subject topics of bioproduction apply not only to every kind of cultivated plant, but also to useful animals such as natural enemies to crop pests and useful microorganisms used in the food industry or as pest control agents. Bioproduction science covers the broad fields of agriculture, biochemistry, biotechnology, food science and bioengineering.

Bio-based strategies hold great promises for sustainable solutions as they offer the potential to substitute industrial, fossil fuel-based production with natural/ agricultural-based production. Based on the significant progress of knowledge and technologies in the area of biosciences in the past two decades, they have the potential to provide novel sources for energy and materials. It is generally expected that the development and implementation of a bio-based economy will play a crucial role for the competitiveness of economies in the future. One concern is the competition between the role of agriculture in increasing food for an increasing population at increasing quality standards and the contribution of agriculture as a future source of renewable energy and innovative materials and chemicals. Box 4 illustrates some early experience with bio-production.

Box 4
Biofortification: Creating Golden Rice and Orange Sweet Potato

Biofortification — the creation of plants that make or accumulate micronutrients — aims to increase the nutritional quality of staple crops through breeding and is used for the production of functional foods. The breeding can either be through conventional or traditional ways or through genetic engineering methods. Crops produced through biofortification tend to be rice in nutrients like iron, zinc, and Vitamin A. Biofortification differs from ordinary fortification because it focuses on making plant foods more nutritious as the plants are growing, rather than having nutrients added to the foods when they are being processed. This is an improvement on ordinary fortification when it comes to providing nutrients for the rural poor, who rarely have access to commercially fortified foods. *Golden Rice* is a good example of a biofortified crop. In this specific case biofortification was obtained by genetic modification of the rice plant to produce and accumulate provitamin A in the grain, a trait not found in nature. Initially produced in Switzerland and Germany in the late 1990s, golden rice has now spread to other places — although its detractors point out that dealing with Vitamin A deficiencies may not best be achieved "through the engineering of a yellow rice which consumers may not accept" (Scoones, 2002). There are more biofortified crops in the pipeline waiting to be launched into markets in developing countries, such as millet rich in iron (to be launched in India in 2011), wheat abundant in zinc and cassava fortified with extra beta-carotene (to be released in Nigeria and Zambia in 2012). Despite fears that farmers and consumers don't take to biofortified crops easily, given issues such as colour, supporters say policy can play an effective role in changing habits. For instance, trials of orange-fleshed sweet potato in Uganda were deemed a success when the benefits of vitamin A were explained to mothers.

(B) FARMING SYSTEMS INNOVATIONS

The second mode is a discussion of farming systems innovations with green potential; these are different ways of organising agricultural production. This may involve the use of one or more specific technological innovations as defining characteristics, or it may be purely to do with how production and marketing is organised — or a combination of the two. Organic farming, Integrated Pest Management and the Systems of Rice Intensification are exemplars of this.

(i) Integrated Pest Management (IPM)

Integrated Pest Management (IPM) is an ecologically-based approach that focuses on long-term solutions to pest control through a combination of techniques such as biological control, habitat manipulation, modification of agronomic practices, and use of resistant varieties. IPM uses a whole suite of practices to reduce the need for chemical pesticides, including crop rotation; scouting and monitoring the presence and growth stage of pests; and the use of antagonistic and parasitic organisms, as well as biological pesticides. IPM is therefore more complex for farmers to implement, as it requires skills in pest monitoring and understanding of the pest dynamics, besides the cooperation among all farmers in a given area for effective implementation (otherwise pests simply move from one field to the next).

The IPM approach has been deployed in two types of farming systems. The first is in developing countries where labor is relatively abundant and where pesticides are expensive as well as environmentally-damaging. In this context farming systems innovation has been driven by resource scarcity (See Box 5).

The other type of farming system in which this technique has been deployed is in high value export horticulture. Here it has been compliance with pesticide residue norms in the European market that has driven this type of innovation. The use of bio-control agents in the Kenyan horticultural sector is now quite commonly being used for the control of, among other things, red spider mite (see Box 6).

Box 5
IPM and Sustainable Agriculture in India

The Indian government provides financial assistance to state agricultural universities and other research organizations for research on developing and producing biopesticides and biocontrol agents as part of its IPM strategy. A number of biopesticide production units and plant protection clinical centers have been established and strengthened in recent years. As a result, the use of biopesticides and biocontrol agents in India is rising, although it has yet to reach desired levels. Biopesticides are cheaper than chemical pesticides, besides being eco-friendly and less risky in terms of resistance development.

An alternative to IPM is Non-Pesticidal Management. While IPM can still use pesticides as a last resort, NPM gets rid of pesticides altogether. Non-pesticidal management relies on the farmers' knowledge, skills and labor, and their work together as a community. It looks at the pest complex as a whole, rather than at individual insects. Farmers have to understand the many factors that influence pest numbers in their fields: the life cycles of the insects, the incidence of pests and diseases, predator-prey relationships among different creatures, the relationship between growing mono-crops and the pest population, and the management of soil fertility. Non-Pesticide Management uses many different practices, including: deep ploughing in the summer to expose insect pupas, using light-traps and bonfires, setting pheromone traps, using biological pesticides including need extracts and chilli-garlic extracts, etc.

The Centre for Sustainable Agriculture in Hyderabad, India has had great success in helping cotton farmers in Andhra Pradesh switch to the more sustainable non-pesticide management system with the help of an NGO SECURE (Socio-Economic and Cultural Upliftment in Rural Communities). With the help of NGO activists scientists were able to convince reluctant farmers to switch off pesticide use through on-farm demonstrations. As yields of farmers who switched to the new system grew, the project began to take off with more farmers joining in. An approach that started as a demonstration project in one small village is now part of an official state policy package, with the Andhra Pradesh government deciding to scale out the project in 11 districts in 2005.

Adapted from Singh and Sharma (2004)

Box 6

Kenya's Real IPM: Responding to European Norms

The Real IPM Company is a Kenya-based company that aims to commercialise biological control pest agents for the horticultural industry. Its origins can be traced back to 2000, when Kenya's largest horticultural and floriculture exporter, the Flamingo Holdings Group (better known as Homegrown Company), established Dudutech as a subsidiary to develop biological controls systems to reduce pesticide use in the horticulture/ floricultural sector. Dudutech was established as a response to regulatory issues in its major market of Europe; there was a both a need to reduce pesticide residues, but also human rights issues associated with exposing workers to these during application.

Two of Dudutech's key personnel established Real IPM in 2004 with a vision of practical, sustainable and affordable reductions in pesticide use for both large-scale commercial growers and small-scale subsistence farmers throughout Africa and elsewhere. Real IPM's website explain its niche as one of providing a comprehensive suite of training and consultancy packages aimed at bringing clients up to speed on all aspects of best practice in sustainable pest and disease management programmes, with particular focus on compliance with the regulatory regimes governing imports of fresh produce into the EU (food safety, pesticide residues etc). The company also produces and sells seven biological control agents to deal with a range of crop pests.

(Adapted from Hall et al., 2010 and http://www.realipm.com/)

(ii) Systems of Rice Intensification (SRI)

Systems of Rice Intensification (SRI) is a methodology for growing rice — originally developed in Madagascar — that involves principles that are at times radically different from traditional ways of growing rice and as a result reduces water and fertilizer use drastically. It involves the careful transplantation of single young seedlings instead of the conventional method of using multiple and mature seedlings from the nursery. SRI spaces rice plants more widely and does not depend on continuous flooding of rice fields, uses lesser seed and chemical inputs, and promotes soil biotic activities in, on and around plant roots, enhanced through liberal applications of compost and weeding with a rotating hoe that aerates the soil. In several countries, SRI has been shown to increase rice yield considerably, apart from producing a crop that takes a shorter time to mature and is drought-resistant.

Interestingly, SRI, like IPM, seems to have emerged from and flourished in farming systems in developing countries characterised by resource scarcity. Despite it win-win characteristics it has not spread more widely into intensive agricultural systems, especially in OECD countries, where its sustainability would be of great value.

Box 7
SRI: How a Success Story was woven in India

SRI's uptake and spread in India is an unconventional one, coming about largely as the result of civil society-led initiatives, rather than from more traditional research initiatives or from policy directives. This is a story of policy having much to learn from practice. It involves farmers in the innovation process with SRI more like a contextual, evolving methodology than a fixed technology

In India the SRI methodology evolved quite independently of governmental policies and private sector involvement, and has shown considerable promise in providing innovative pathways to the solution of the connected problems of stagnating rice yields, declining soil fertility and inadequate incomes for rice farmers. Inspired by stories of SRI's success elsewhere in the world, certain civil society organisations encouraged poor farmers to experiment with the methodology on a pilot basis in different Indian states between 1999 and 2003. Despite indifference from formal research organisations and with virtually no help from agricultural departments the scattered SRI experiment grew into a wider movement as more civil society actors, farmers and even government officials from departments such as irrigation, rural development and women and child welfare took it upon themselves to spread the word. Today, several Indian states — particularly smaller states and those left out of the Green Revolution — are SRI success stories.

Small and marginal farmers are now taking to SRI enthusiastically in many parts of India and have seen in SRI an opportunity to overcome local-level food security problems, and even to cope with drought. In an important extension to the innovation, SRI principles have been extended to other crops such as wheat, finger millet, maize and kidney beans.

SRI has increased rice yields on farmers' fields in over 25 countries and yet does not figure as part of the strategy of several international agricultural research organisations and aid agencies, many of which continue to be sceptical of SRI despite increasing evidence that SRI methods raise the productivity of land, labour, water and capital concurrently.

(*Adapted from Shambu Prasad, 2006*)

SRI in the USA: A Texas-based company RiceTech has experimented with SRI methods within a more mechanised system, but is yet to witness the scale of success witnessed in other parts of the world, probably due to soil biological conditions associated with its production techniques. However, despite certain universities — primarily Cornell University — expressing an interest in SRI techniques, that interest has yet to materialise in more than a few random pilot studies across the country, and little to no uptake.

SRI in Japan: The uptake of SRI in Japan is still at a field experiment stage in Chiba during the 2008 growing season. However, early results indicate significantly higher water productivity, minimised disease and pest incidence, a shortened crop cycle and an increased yield. Scientists of the University of Tokyo, which is implementing these trials with the cooperation of smallholder farmers in Chiba, is hoping to continue their experiments with SRI on a pilot basis before developing a suitable irrigation and planting schedule that could most optimally fit conditions and local practices in Japan.

(iii) Organic Agriculture

Organic agriculture was developed as a holistic, ecosystem-based approach, conceived as an alternative to what proponents see as the ecologically unsound practices of conventional agriculture. It is necessary to distinguish between certified organic agriculture and agriculture that is practised in an organic way but without certification.

The share of agricultural area under organic farming has increased significantly in recent years, but with wide variation across OECD countries. Many countries now encourage conversion to and maintenance of organic farming by providing financial compensation to farmers for any losses incurred during conversion.

Box 8
Organic Farming: Consumers' Choice in Europe and Organic States in India

In most OECD countries, organic farming information, standards, certification and labelling are in place or being developed by the organic sector and governments, intended to aid consumer choice. In most countries, market forces largely drive the development of the organic sector but a number of governments, mostly in Europe, offer financial incentives to farmers to convert to, and continue in, organic production on the basis that some environmental benefits are not captured in the market (see Table 6). Some, such as Austria, use a mixture of the carrot and stick approach, where farmers have to sign a strict five-year contract and agree to comply with certain measures of the Austrian organic programme in return for cash benefits. Generally such incentives are higher than would otherwise be the case where existing support to agriculture raises the cost of entry into organic production. There has also been some shift in publicly-financed agricultural research towards organic systems, while in a few countries procurement policies feature the purchase of organic food by public institutions.

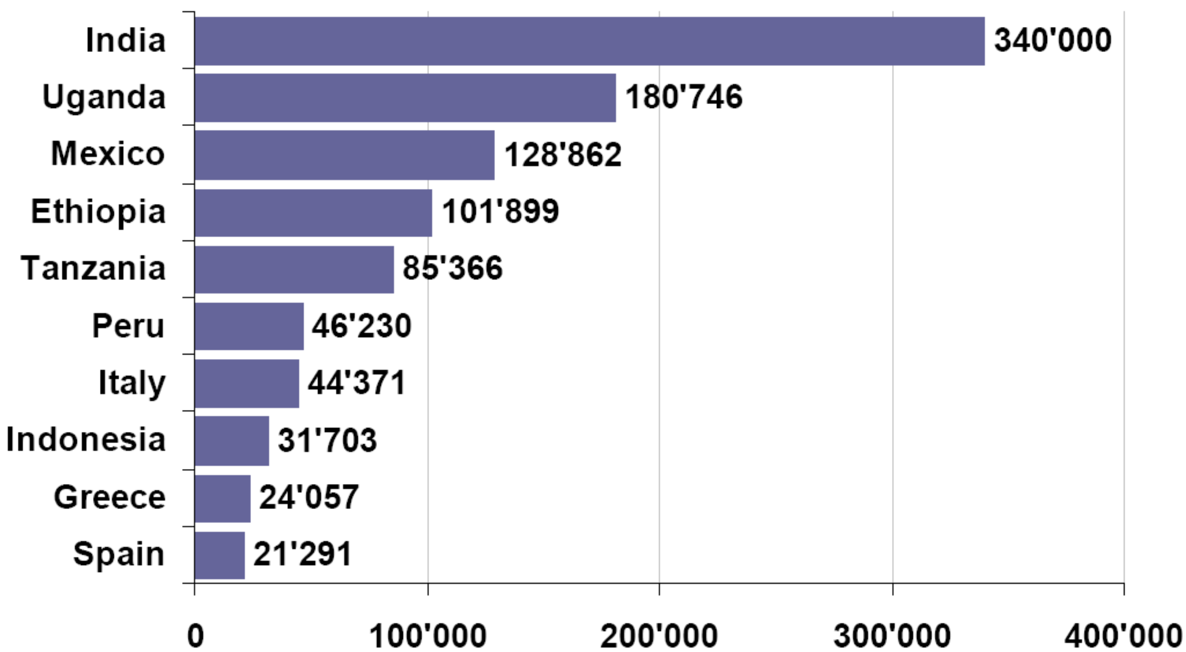
Growth, however, has largely been led by demand from consumers in high income European countries, and the European organic consumer market is the largest in the world. Consumers may favour organic produce for a variety of reasons, including perceived benefits to health and the environment, perceived improvements in food quality and taste, accessibility of fresh produce, and helping small-scale local producers, communities and markets. Recent food safety scares in some countries — BSE and foot and mouth disease in particular — and concerns among some consumers about genetic modification in agriculture, have also had an effect in boosting demand for organic produce.

Consumers of organic products in Europe can roughly be divided in two groups. The first group, the so-called "regular buyers", is a rather small group that has been buying organic products for decades. This group includes environmentalists, lovers of nature, and socially conscious people. Although this group is small, they are responsible for almost half of European organic sales. Regular buyers tend to buy at organic specialty shops or farmers' markets. For them price is not an important purchasing decision factor. The second and much bigger group is quite different. Double-Income-No-kids households, older consumers (aged 50-75) and New-Trends seekers will fall in this group. They buy organic products for various reasons, including healthy lifestyle, food safety concerns, animal welfare, sustainability, quality and taste of food, price, innovative packaging.

Organic production in developing countries has also been increasing as rapidly, as has exports to meet rising consumer demand in Europe and the West. There are several reasons for this rapid increase. There are several studies that show organic farmers earn higher incomes than their traditional counterparts, and organic products easily meet the stringent quality and safety standards of export markets in the West. More significantly, organic production is well-suited for small-holder farming, and it builds on traditional knowledge and farming systems already practiced, to an extent, in developing countries.

In India, for instance, a committee set up by the federal Planning Commission in 2000 recommended organic farming as the most viable option for the states in the Northeast. Following the report, the states of Sikkim, Mizoram and Uttaranchal have declared themselves to be "organic states", committed to switch to an official agricultural policy that supports and encourages organic smallholder farming. What this effectively means is supporting farmers in adapting to or adopting organic farming practices, facilitating the certification of organic products, helping build connections to export markets, inviting donor funds from agencies such as FAO to fill knowledge gaps, etc.

Countries With The Largest Number Of Organic Producers



(Sourced from IFOAM, 2010 and OECD, 2002b)

(iv) Conservation Agriculture/ Zero Tillage/ Crop Rotation

No-tillage techniques and conservation agriculture, based on minimal soil disturbance, the maintenance of plant cover and a diversification of rotations and intercropping, are developing rapidly in both the North and the South. Conservation Agriculture — which took off in Brazil in the 1970s — is based on the application of three major principles of agrosystem management: (1) minimal soil disturbance, (2) protection of the soil through the permanent maintenance of plant cover at the surface, (3) the diversification of rotations and intercropping (FAO, 2010). The diversity of production conditions and of farmers' needs has led to a considerable diversification of practices in the application of these three principles. Conservation Agriculture, thus, corresponds to a family of cropping systems rather than to a single technology or system. In some cases, seeds are sown directly through the crop residues (direct drilling through stubble), while in others, the soil is still lightly prepared to facilitate crops installation. In all cases anywhere, changes related to the introduction of Conservation Agriculture goes beyond a mere change in soil tillage techniques, and must be considered in a broader context including other innovations, such as the use of cover crops and intercropping for example.

Box 9
From Brazil to France: Conservation Agriculture moves from the South to the North

Although no-tillage techniques had been developed and practiced in France since the 1990s, it was only very recently that the more sustainable approach of conservation agriculture started being practiced in the country (De Tourdonnet et al., 2010). Inspired by the experiences of Brazilian agriculture in decreasing production costs and labor requirements, a group of French farmers applied conservation agriculture techniques to field crops. The practice started to spread through informal networks formed by these farmers, which helped share information on factors of production and cropping practices. The learning process, initially firmly focused on equipment and soil, gradually shifted to the use of cover crops. There has been a general drift away from no tillage practices towards conservation agriculture through the construction of socio-technical networks combining a number of objectives and stakeholders, associated with technical, agronomic and environmental questions, through multiple clusters (De Tourdonnet et al., 2008).

Conservation Agriculture is also being tested in organic farms in the Rhône-Alpes region of France. However, it is more difficult to reduce soil tillage in organic farming, as any attempt to do so is confronted by two major technical obstacles: weed control and nitrogen nutrition. The use of leguminous cover crops to fix nitrogen is of particular interest in organic farming. Given the difficulty of controlling weeds mechanically, farmers and researchers are going through a process of determining whether the environmental conditions in organic farming lead to a spontaneous change in the flora or whether the presence of a mulch or cover crop can modify weed emergence.

(*Adapted from De Tourdonnet et al., 2008*)

Box 10
Zero Tillage in Argentina

Zero Tillage technology is all about allowing farmers to sow seed into the ground with minimum disturbance of the soil structure. Agriculture in Argentina underwent a boom in the 1950s with large commercial cultivation of crops such as soybeans and the accompanying technological inputs that allowed for agricultural production to rise rapidly up until the 1990s. However, the new practices, such as double-cropping, took a toll on soil fertility (through erosion, loss of organic matter, etc.) and production began to dip even in resource-rich areas of the country.

As awareness of the effects of inadequate soil management practices grew, so did interest in new and improved crop management techniques in the late 90s. The state encouraged research on the issue and commissioned studies to learn from the experience of other countries, besides organizing numerous study tours for researchers and farmers. This active building of an informal network of policy-makers, researchers, farmers and extension workers working around similar issues and towards the same goal resulted in a successful switch to zero-tillage farming practices in the country. Factors that inhibited wide adoption of zero tillage technology — absence of suitable weed control alternatives, farmers' lack of funds or access to loans, etc. — were dealt with by all actors of the network along the way. Apart from significantly improved yields of soybeans since the adoption of zero tillage technology, the country is already reporting results of lower rates of depletion of organic matter, higher moisture-holding capacities of soil and a consequent reduction (even reversal) of decades-long degradation processes. Argentina sees the widespread adoption of zero-tillage technology as a result of a win-win policy — with positive economic and environmental outcomes, and as a result of active buy-in to the process by several agricultural sector actors.

(*Adapted from Trigo et al., 2009*)

(v) Water Management Systems

Agriculture is the major user of water in most countries (OECD, 2010b). As the population continues to grow, agriculture faces the enormous challenge of producing almost 50% more food by 2030 and doubling production by 2050. This will likely need to be achieved with less water, mainly because of growing pressures from urbanization, industrialization and climate change. In this context, it will be important in future for farmers to receive the right signals to increase water use efficiency and improve agricultural water management, while preserving aquatic ecosystems, especially as agriculture is the major user of water, accounting for about 70% of the world's freshwater withdrawals and over 40% of OECD countries' total water withdrawals.

The scope of sustainable management of water resources in agriculture concerns the responsibility of water managers and users to ensure that water resources are allocated efficiently and equitably and used to achieve socially, environmentally and economically beneficial outcomes. It includes: irrigation to smooth water supply across the production seasons; water management in rain-fed agriculture; management of floods, droughts, and drainage; and conservation of ecosystems and associated cultural and recreational values

The case of Israel, in particular, offers a unique insight into what an integrated water management system may look like in practice, and provides lessons on how to efficiently manage a scare resource (see Box 11).

Box 11
Managing Water Resources Efficiently: The Case of Israel's Agriculture

Israel's agricultural sector is characterized by an intensive production system, which stems from the need to overcome the scarcity of natural resources, particularly water, and climate conditions that are largely arid and semi-arid. A narrow coastal strip and several inland valleys represent most of the fertile areas, where water supplied from aquifers and the Sea of Galilee make irrigation possible. Saline seawater is used extensively and advanced technologies are employed to make maximum use of every cubic meter of water. Although most of the water resources are in the north and center, agriculture is being developed in the arid south and east. This reality has necessitated construction of an integrated water supply system, which delivers water from the north to the south.

Israel has made intensive efforts and invested millions in irrigation research since the 1950s. Early research indicated that water use is much more efficient in pressurized irrigation than in surface irrigation. An irrigation equipment industry was established to develop innovative technologies and accessories, such as drip irrigation (surface and subsurface), automatic valves and controllers, media and automatic filtration, low-discharge sprayers and mini-sprinklers, compensated drippers, and sprinklers. Fertigation is routine in most of the irrigated areas. Fertilizer producers have developed highly soluble and liquid fertilizers which are compatible with this technology. Most of the irrigation is controlled by automatic valves and computerized controllers. Due to the division into plots and harsh topographical conditions, only limited areas can be irrigated by mechanized systems, such as pivot irrigation.

The water constraints and varied climate have stimulated the development of unique agro-technologies and the use of marginal water, such as brackish and reclaimed water. Brackish water is used for irrigation of salinity-tolerant crops like cotton. In several crops, such as tomatoes and melons, brackish water improves produce quality although lower yields are achieved. The use of reclaimed water for irrigation of edible crops requires a high level of purification. For that purpose, farmers in Israel use a unique technology, the Soil Aquifer Treatment (SAT), in the densely populated Dan region. After tertiary purification, the water percolates through sand layers, which serve as a biological filter, into the aquifer. From there it is pumped at nearly potable quality and can be used for unrestricted irrigation.

Technological innovations in water management
Israel has a countrywide network of agro-meteorological stations to deliver real-time weather data to farmers. Data is used to adjust the irrigation regime. Diverse soil-moisture monitoring

devices, including tensiometers, pressure chamber systems, and electrical resistance sensors, are utilized for more precise specific local adjustment. Vegetal indicators, such as leaf water potential and fruit growth rate, are used to achieve further precision in water application.

Water management and aquaculture
One of the main methods currently used in intensive farming is the closed water system. The unique feature of this system is the constant flow of water from the reservoir, through the covered breeding ponds, and back to the reservoir. In this case the reservoir also serves as a bio-filter, reducing the concentration of nitrogen in the water, which is directly absorbed by the algae and bacteriologically broken down. Due to the high density of fish in the breeding ponds, farmers enrich the water with oxygen and feed the fish protein-rich food. The result is a 40-fold increase in production. Other closed water systems based on biofiltration units are also being developed. The result is that more fish will be produced with less water.

Another method is the utilization of water in reservoirs intended for irrigation. The use of reservoir water for two branches of agriculture also contributes to water savings. Fish farming in the desert provides a long-term solution to the problem of increasing fish production in a small country with limited water resources. This is feasible due to the desert aquifers or underground water sources. Due to the lack of fresh water, fish farmers have also begun to exploit the sea. One method involves offshore cages along the coasts of the Mediterranean and the Red Sea. Another method is breeding ponds located near the sea, which utilize seawater in a closed water system, whereby water is circulated from the ponds to the sea and back again.

In the Future
The expanding urban population, as well as potential political developments, will likely further reduce the fresh water supply for agriculture. The solution for Israel lies in the desalination of brackish water and high-level water reclamation. A more significant part of annual crops will be grown under cover, where recycling will become routine.

The water management policies adopted to address Israel's chronic scarcity have not been without environmental consequences. Yet, through a trial-and-error process, a combined strategy of water transport, rainwater harvesting, and wastewater reuse and desalination, along with a variety of water conservation measures, has put the country on a more sustainable path for the future.

Adapted from IEICI (2004)

(vi) Natural Resource Management

Natural Resource Management refers to the management of natural resources such as land, water, soil, plants and animals, with a particular focus on how management affects the quality of life for both present and future generations. Natural resource management specifically focuses on a scientific and technical understanding of resources and ecology and the life-supporting capacity of those resources.

Integrated natural resource management is a process of managing natural resources in a systematic way, which includes multiple aspects of natural resource use (biophysical, socio-political, and economic) meet production goals of producers and other direct users (e.g., food security, profitability, risk aversion) as well as goals of the wider community (e.g., poverty alleviation, welfare of future generations, environmental conservation). It focuses on sustainability and at the same time it tries to incorporate all possible stakeholders from the planning level itself, reducing possible conflicts in future. The conceptual basis of INRM has evolved in recent years through the convergence of research in diverse areas such as sustainable land use, participatory planning, integrated watershed management, and adaptive management.

One example of INRM in practice is REDD: Reducing Emissions from Deforestation and forest Degradation (REDD). This is a proposed mechanism to slow the loss of forests, which involves paying forest countries to stop deforestation from 2013 onwards. REDD was expanded to REDD-plus in 2008 to account for measures to conserve and sustainably manage forests, forest restoration and reforestation. REDD would involve a massive transfer of funds from rich countries to poorer countries, but funding mechanisms are still being debated over; a mixture of government and private sector funding (especially with regards to carbon trading) is expected to cover costs. To measure a REDD project, it will be necessary to calculate the amount of carbon stored in the forest in question and then predict how much carbon could be saved by halting or slowing deforestation.

Box 12

NRM: The Silvopastoral Approach

Silvopasture is the practice of combining forestry and grazing of domesticated animals in a mutually beneficial way. Advantages of a properly managed silvopasture operation are: enhanced soil protection and increased long-term income due to the simultaneous production of trees and grazing animals.

The Regional Integrated Silvopastoral Approaches to Ecosystem Management Project was an initiative funded by GEF and involving CATIE, FAO and other partners. The project’s objective was to assess silvopastoral (forest grazing) systems to rehabilitate degraded pastures to protect soils, store carbon, and foster biodiversity. It also aimed at developing incentives and mechanisms for payment for ecosystem services, which would result in benefits for farmers and communities and distil lessons for policy-making on land use, environmental services and socio-economic development.

From 2003 to 2006, cattle farmers, from Colombia, Costa Rica and Nicaragua, participating in the project received between US$2000 and US$2400 per farm, representing 10 to 15 percent of net income to implement the program. This resulted in a 60 percent reduction in degraded pastures in the three countries, and the area of silvopastoral land use (e.g., improved pastures with high density trees, fodder banks and live fences) increased significantly. The environmental benefits associated with the project include a 71 percent increase in carbon sequestration, increases in bird, bat and butterfly species and a moderate increase in forested area. Milk production and farm income also increased by more than 10 and 115 percent respectively. Herbicide use dropped by 60 percent, and the practice of using fire to manage pasture is now less frequent. Other demonstrated environmental benefits of Silvopastoral systems included the improvement of water infiltration; soil retention; soil productivity; land rehabilitation, and the reduction of fossil fuel dependence (e.g., substitution of inorganic fertilizer with nitrogen fixing plants). The project has successfully demonstrated the effectiveness of introducing payment incentives to farmers and in increasing the awareness of the potential of integrated ecosystem management for providing critical environmental services including the restoration of degraded pasture.

Adapted from FAO (2010)

(vii) Urban and Peri-Urban Agriculture

Although agriculture in rural areas will continue to meet food security needs of the world's populations in cities for years to come, an alternative that is growing rapidly and starting to provide significant quantities of food, particularly perishables, is that of urban and peri-urban agriculture. According to FAO estimates (FAO, 2010) up to 15 percent of the world's food is produced by urban agriculture and 70 percent of urban households in developing countries participate in agricultural activities, including producing vegetables, fruits, mushrooms, herbs, meat, eggs, milk and even fish in community gardens, private backyards, schools, hospitals, roof tops, window boxes and vacant public lands (including at the side of roads and rail tracks). In addition, urban agriculture also generates micro-enterprises such as the production of compost, food processing and sale.

Urban agriculture also contributes to the greening of cities by improving air quality and lowering temperatures. However if the full potential of urban agriculture is to be achieved there are a number of key constraints and issues that need to be addressed; for example, the lack of access to water and other productive resources. There are also issues concerning competition for land. Some experts also point out that urban agriculture raises food safety concerns of using waste water and organic material and the risk of the spread of diseases and contamination of toxic pollutants (DFID, 2006). However, the counter-argument is that the positives far outweigh the (possible) negative implications of urban agriculture. For instance, many urban and peri-urban producers (especially those in OECD countries) use bio-intensive methods (companion planting, double-digging, solid and waste recycling, open pollinated seeds, composting, etc.) of production. Vertical farms and stacked greenhouses are examples of systems that produce potable water from waste water and recycle organic waste back to energy and nutrients. In several OECD countries urban and peri-urban production is also linked to the expanding farmers' market movement. Urban agriculture also reduces the carbon footprint of agriculture as transportation to markets uses much less energy (see Box 14). Urban agriculture also eliminates the need for preservatives.

Box 13
Urban Agriculture: Micro-Gardens in Dakar, Roof Gardens in Mumbai

Senegal: Launched by FAO and the Government of Senegal in 1999, the Micro-Gardens project in Dakar has a dual purpose of generating incomes for poor farmers in the city without access to farmland and providing fresh vegetables to poor families, thereby improving their food supply and nutrition — all the while contributing to a cleaner, greener city.

The project, which has trained 4,000 families in micro-garden technology, involves training and organizing beneficiaries, helping them access equipment and inputs, as well marketing their produce. The project benefits from R&D by the Horticultural Development Centre (CDH) of the Senegalese Institute of Agricultural Research (ISRA), whose facilities include an office, laboratory and national reference micro-garden. Despite planners not having created spaces for the urban farms, some city halls, schools and hospitals have made their backyards available to micro-gardeners. The micro-gardens project has also established outlets in all the regional capitals to provide access to alternatives to high-cost chemical fertilisers, including tea manure, manure, and Biogen. Annual yields have increased and costs of inputs reduced through the use of alternative materials and drip irrigation kits promoted by the FAO. The project is also collaborating with Italian NGOs in Dakar to establish a specific supply chain mechanism for micro-gardeners' produce. Television programmes and advertisements promote the micro-garden produce. The project is now also working on branding the produce.

India: India is the setting of a wide array of urban and peri-urban agricultural initiatives, some civil society-led, some private, and some even public sector and donor-funded (DFID, 2006). In Mumbai, rooftop gardens use recycled waste, compost and garden soil to produce fruits and vegetables and even pulses and cereals. Urban aquaculture is even practiced in Kolkata's Salt Lake marshlands, with fishing cooperatives leasing patches of the wetlands from landlords, who in turn own long-term leases from the municipality.

USA: Rooftop gardens that grow food are an increasingly growing phenomenon in New York City. Certain non-profits even offer free seedlings for those interested in such initiatives, while another non-profit, Just Food, runs a project that offers courses on growing and selling food.

Adapted from FAO (2010), DFID (2006)

Box 14
Food Miles: An Effective Way to Measure Sustainability?

A recent trend — particularly in Europe — has been the increasing demand for locally-produced food as a result of growing concerns that transportation of agricultural produce over long distances greatly increases its carbon foot-print. Food miles is a term that originated in the UK and refers to the distance food is transported from the time of its production until it reaches the consumer. Some scholars believe that the increase in distance from point of production to the point of consumption is due to the globalization of trade; the focus of food supply bases into fewer, larger districts; drastic changes in delivery patterns; the increase in processed and packaged foods; and making fewer trips to the supermarket.

Food miles are one factor used when assessing the environmental impact of food, including the impact on global warming. Wal-Mart was an early adopter of food miles as a profit-maximizing strategy while reiterating its environmental benefits as well.

The concept has come under some criticism for its use by industry and retail to suggest some measure of environmental sustainability. Recent findings indicate that it is not only how far the food has traveled but the method of travel that is important to consider. The positive environmental effects of organic farming may be compromised by increased transportation, unless it is produced by local farms. Also, there are many other aspects of the agricultural processing and the food supply chain that also contribute to greenhouse gas emissions which are not taken into account by simple food miles measurements (Chi, 2009).

Researchers say a more complete environmental assessment of food that consumers buy needs to take into account how the food has been produced and what energy is used in its production. A recent DEFRA case study indicated that tomatoes grown in Spain and transported to the UK may have a lower carbon footprint in terms of energy efficiency than tomatoes grown in heated greenhouses in the UK.

(C) INTEGRATED NATIONAL GREEN REGIMES

The third mode is a discussion of integrated green national regimes. Here specific technologies or agricultural production systems operate as part of national (or regional agenda) green agenda. Exemplars include bio-fuels in Brazil, Organic states in India (discussed in the previous sub-section under organic farming), agritourism and the potential for renewable energies in agriculture, etc.

(i) Biofuels

Biofuels are a wide range of fuels that are in some way derived from biomass — including solid biomass, liquid fuels and various biogases. There is increased public, policy, industry and research attention on the role of biofuels in achieving sustainability; an interest that is driven by factors such as oil price spikes, the need for increased energy security, and concern over greenhouse gas emissions from fossil fuels.

However, uncertainty on the overall assessment of biofuels has also been growing with differing reports on their possible benefits and risks for sustainable agricultural production. As a result, the topic of biofuels has triggered sharply polarised views among policy-makers and the public, characterised by some as a panacea representing a central technology in the fight against climate change. Others criticise them as a diversion from the tough climate mitigation actions needed or a threat to food security — a criticism that has gained ground against the backdrop of the global food crisis — and thus a key challenge to the achievement of the poverty-related Millennium Development Goals.

Sound legal and regulatory frameworks for bioenergy are gaining increased importance as means to ensure that socio-economic and environmental sustainability considerations are taken into account in the production, promotion and use of bioenergy, with a view to minimizing risks of negative impacts and maximizing benefits in the immediate and long term. With regards to potential benefits, the primary policy drivers for bioenergy promotion have been recognised as energy security and self-sufficiency, although the contribution of liquid biofuels to meet transport and energy needs is limited. Many countries are also looking to bioenergy as a mechanism for climate change mitigation, both as a way to reduce the consumption of fossil fuels and also to emit reduced greenhouse gases from the use of liquid biofuels (OECD, 2006). Other countries, developing ones in particular, may benefit from the increased demand in bioenergy-related agricultural commodities to revive agricultural trade and stimulate agricultural and rural development. Other potential benefits include: the restoration of degraded lands; reduced land abandonment; increased income-base for farmers and forest owners; and improved employment opportunities in rural areas.

These opportunities should be addressed alongside the risks associated with bioenergy. The increased competition over agricultural crops for bioenergy purposes instead of food production has been highlighted as a concern for food security. Competition over the use of land and water resources for bioenergy production and for agricultural purposes augments pressures on these resources at a time where global water reserves are dwindling and potentially greater effects are feared on indigenous and local communities and small-holder farmers.

Indeed, in 2008 OECD published an economic assessment of biofuel support policies (OECD, 2008a). It concluded that government support of biofuel production in OECD countries is costly, has a limited impact on reducing greenhouse gases and improving energy security, and has a significant impact on world crop prices. The report also found finds that other forms of bioenergy, such as bioheat, biopower and biogas could represent economically more viable and environmentally more efficient ways to reduce GHG.

Box 15 presents how one country, Brazil, managed to implement an integrated biofuel policy.

Box 15
Brazil and Biofuels

Today, Brazil is the world's largest biofuel market and Brazilian ethanol from sugarcane is arguably the first renewable fuel to be cost-competitive with a petroleum fuel for transport. Ethanol production is more economical in Brazil than in the United States. This is due to several factors, including the superiority of sugarcane to corn as an ethanol feedstock, Brazil's large unskilled labour force (sugarcane production is very labour intensive), and a climate ideally suited to growing sugarcane. While the U.S. and Brazil make about the same volume of ethanol, the U.S. uses almost twice as much land to cultivate corn for ethanol as Brazil does to cultivate sugarcane for the same purpose. Given these advantages, the productivity and efficiency of Brazilian sugarcane ethanol production are virtually unmatched by any other country.

Brazil is considered to have the world's first sustainable biofuels economy and the biofuel industry leader, a policy model for other countries. The National Alcohol Program — *Pró-Álcool* — was launched in 1975 as a nation-wide program financed by the government to phase out automobile fuels derived from fossil fuels, such as gasoline, in favor of ethanol produced from sugar cane. Brazil's 30-year-old ethanol fuel program is based on the most efficient agricultural technology for sugarcane cultivation in the world, using modern equipment and cheap sugar cane as feedstock, the residual cane-waste (bagasse) is used to process heat and power, which results in a very competitive price and also in a high energy balance (output energy/input energy), which varies from 8.3 for average conditions to 10.2 for best practice production.

There are no longer any light vehicles in Brazil running on pure gasoline. Since 1976 the government made it mandatory to blend anhydrous ethanol with gasoline, fluctuating between 0% to 22%.

In Brazil, sugar and ethanol are produced on an integrated basis. The option to produce more or less of each product is influenced by the relative prices. When sugar prices increase, for example, producers can divert sugarcane production from ethanol to sugar.

However, some experts consider that the successful Brazilian ethanol model is sustainable only in Brazil due to its advanced agri-industrial technology and its enormous amount of arable land available. According to them the Brazilian ethanol program also shows that biofuels should not be considered a panacea for the world's energy challenges. Brazil's ethanol infrastructure model required huge taxpayer subsidies over decades before it could become viable.

Adapted from Xavier (2007) and OECD (2006)

(ii) Agritourism
Also known as farm tourism or rural tourism, agritourism broadly refers to any agricultural-based operation or activity that involves bringing visitors to a farm. The activity may range from

buying farm produce directly from the farm, to less strenuous farming activities that the visitor may take part in. This is becoming increasingly popular in several countries around the world, especially with organic farms.

Agritourism's recent growth is both demand and supply-driven. On the supply side, cost/price pressures have forced farmers and ranchers to augment their income through diversification, both within agriculture itself, and through non-agricultural pursuits. On the demand side, increases in discretionary income and demand for more specialised forms of vacation experiences have stimulated growth for tourism and recreational activities in rural areas. Increased awareness and concern over quality of food among urban consumers has stimulated a growth in agritourism around the world. However, there is great variation of demand for it even within OECD countries; for example, the concept is popular in European countries such as France, but is yet to take off in a big way in the US.

From the perspective of the agricultural industry, agritourism is perceived to be a means of: expanding farm operations, improving farm revenue streams, increasing the long-term sustainability of farm businesses, increasing awareness of local agricultural products, and creating new on-farm revenue streams to family members who might otherwise have to work off the farm. From a rural community and region perspective, agritourism is viewed as an opportunity for: generating additional direct revenue for local businesses, stimulating the upgrade of local facilities and services, and helping diversify and stabilise the local economy.

(iii) Renewable Energies in Agriculture
Agriculture has great potential to contribute to generating energy in the form of biofuels, but modern agricultural production systems also use a significant amount of energy. Renewable sources of energy of energy for agriculture are a green option for cutting back on energy consumption in developed countries or even providing energy in developing countries, where electricity supply in rural areas is intermittent at best. In rural communities in developing countries this often results in encroachments into natural ecosystems — for example the cutting down of forests for fuel — leading to major sources of emissions. Integrated Food Energy Systems (IFES) aim at addressing these issues by simultaneously producing food and energy. This generally translates into two main methods. The first combines food and energy crops on the same plot of land, such as in agroforesty systems (for example, growing trees for fuelwood and charcoal). The second type of IFES is achieved through the use of by-products/residues of one type of product to produce another. Examples include biogas from livestock residues, animal feed from by-products of corn ethanol, or bagasse for energy as a by-product of sugarcane production for food purposes. While simple IFES systems such as agroforestry or biogas systems are widespread, more complex IFES are less frequently implemented due to the technical and institutional capacity required to establish and maintain them and the lack of policy support to provide for them. Solar, thermal, photovoltaic, geothermal, wind and water power are other options and can be included in IEFS, despite the high start-up costs and specialized support required for their installation and servicing.

Box 16
Renewable energy: Biogas in Vietnam

Vietnam embarked on an integrated land management scheme, following land rights being given to individual farmers. This is supported by the Vietnamese Gardeners' Association (VACVINA), which works at all levels, and has national responsibility to promote this concept, called the VAC integrated system. It involves gardening, fish rearing and animal husbandry to make optimal use of the land. Realizing that traditional fuels such as wood and coal for cooking are becoming increasingly scarce and expensive and can contribute to deforestation and that increasing livestock production in rural communities with high population density leads to health and environmental issues from the quantity of animal dung being produced, the project came up with a novel problem to address energy issues and environmental concerns simultaneously. Biogas digesters are part of the solution offered by this initiative, using the waste to generate energy, while the resultant slurry can be used as a fertilizer to improve soil quality. The program adopted a market-based approach to disseminate the plants and the digesters.

A customer must have at least four to six pigs or two to three cattle that provide the animal dung. They pay the total installation cost for the digesters to local service providers, and operate the biodigester using instructions provided by them. It produces enough daily fuel for cooking and lighting.

Adapted from FAO (2010)

(D) CROSS-CUTTING MODE TOWARD GREENNESS

The fourth mode is a cross-cutting mode and examines whether market or policy-driven mechanisms are most suited to driving innovation in pursuit of a green agenda, and under what circumstances.

(i) Policy-Driven Mechanisms

Box 17

Scotland's TIBRE Project:

Some years ago, Scottish Natural Heritage took up the challenge of environmental sustainability and set up a project, TIBRE (Targeted Inputs for a Better Rural Environment), to investigate the range of technological options that could encourage intensive farming systems to become more environmentally sustainable without undermining their economic competitiveness. The TIBRE project was therefore set up to directly enable farmers to contribute to the environmental sustainability of Scottish agriculture, while at the same time continuing to contribute to its agricultural sustainability. Policy-makers felt this could be achieved through the uptake of technological innovations in the areas of chemical technology, biotechnology, engineering and information technology.

The rationale for the project was:

- Withdrawal of financial support to farmers under the EU's Common Agricultural Policy could lead to greater reliance on cheaper and more environmentally-damaging technology
- It will become progressively harder for expensive, new and more environmentally-sustainable technology to get a toe-hold in a market dominated by these cheaper technologies
- Industry is less likely to spend money on new green technologies under these market conditions
- Policies designed to reduce surplus production, such as set-asides, are likely to be reversed once EU prices approach those of the world market
- The use of productive land for alternative, non-food crops will increase pressure to intensify food production on remaining land
- A return to a situation of maximum food production is likely to be damaging for the environment with the current generation of technological inputs

As part of its first phase the TIBRE project undertook a review of current technology inputs with regards to their costs balanced against their environmental impacts. Next the project consulted a list of farmers — most of whom held influential positions in the farming community and who were motivated to a high degree by business concerns. Some of these farmers were known also to have an interest in the environment, but this was not a factor in their choice. These farmers were asked to discuss the long list of products identified by the option appraisal and the technological assessment as being of possible environmental benefit and to rank them according to their perceived attractiveness for use on their farms. The resulting shorter list of technological options formed the basis for the set of activities in the next phase of TIBRE — forming a set of demonstration and advisory packages to be taken forward by the farming community with the help of policy-makers, industry and retail sector actors and the research community.

(Adapted from OECD, 2002a)

(ii) Voluntary Sustainability Initiatives: Where Markets Take the Lead

There is now widespread recognition that current market activity is leading to the destruction of the global environment due to the inability of the market to communicate the full social and environmental costs of individual and firm-level economic activity. It is generally left to public policy to put forth rules, property rights and other market signals that correct for market imperfections. However, what we are now noticing in the realm of environmental sustainability

— perhaps in the absence of adequate policy measures in place for the same — is the emergence of market-led, voluntary sustainability standards and initiatives, which act as multi-actor, rules-based systems with public-good sustainable development objectives. These initiatives play a role similar to public sustainable development policy. By setting rules for communication across a broad number of market players, they have the capacity to improve the communication function of the market, particularly with respect to matters of importance to sustainable development outcomes. Voluntary sustainability initiatives are now being seen in prominent global agricultural commodity value chains.

Following the Rio Earth Summit of 1992, a growing number of supply chain decision-makers and economic actors have demonstrated a realization of common responsibility concerning issues of sustainability, as well as growing capacity to act "together" through individual choice. This realization is evident in the increasing numbers of voluntary labels, standards and other market-based sustainability initiatives such as Fairtrade, Organics, Forest Stewardship Council, the Global Compact and the Global Reporting Initiative, to name but a few.

Box 18

Features of Voluntary Sustainability Initiatives

A core feature of such market-based approaches is their ability to generate new markets and investment for sustainable practice by allowing decision-makers to explicitly support sustainable supply chains through improved information. In a recent review (IISD, 2010) of several of these standards and sustainability initiatives, UNCTAD and the Institute of Sustainable Development (IISD) found that:

- 70 per cent of the initiatives surveyed were member-based organizations, and organizations that sign up go through periodic voluntary or third-party audits to ensure that standards set by the initiative are adhered to
- Non-governmental organizations (NGOs) remaining a dominant force at the board level, with industry actors the next major player at the board level in almost all of the initiatives surveyed
- There was significant developing country representation at the board level across a large majority of the initiatives
- 70 per cent of the initiatives reporting compliance with ISO 65 or application of an independent accreditation system
- Almost all of the initiatives surveyed applying an annual audit process to ensure compliance with specified criteria, although there is considerable diversity in the degree of flexibility with which such processes are implemented
- 70 per cent of the initiatives surveyed managing a separate Chain of Custody standard and a majority of initiatives applying some form of segregation of compliant products to allow for traceability
- Environmental criteria remain the most prevalent and robust across initiatives. Criteria related to energy conservation, GMO prohibitions and greenhouse gas management, however, tend to have less presence or emphasis across initiatives. Strong convergence exists on synthetic inputs criteria, with almost all initiatives either requiring integrated

pest management or compliance with a prohibited chemicals list. Among the environmental issues, around which sustainability criteria are created, are: soil indices (related to soil conservation and soil quality maintenance), biodiversity indices (related to habitat set-asides, flora densities, and prohibition of high conservation value land), GMO prohibition, waste indices (related to waste disposal, waste management and pollution), water indices (related to water practices, water use management, water reduction criteria and wastewater disposal), energy indices (related to energy use, management and reduction), greenhouse gas indices (related to GHG accounting, GHG reductions and soil carbon sequestration) and synthetic input indices (related to integrated pest management, enforcement of prohibited lists and complete prohibition of synthetics)

- Social criteria revolve largely around International Labour Organization (ILO) conventions, with virtually all initiatives requiring compliance with core ILO conventions as well as most initiatives having strong criteria coverage of health and safety and employment conditions. The majority of the initiatives reviewed place less emphasis on gender, employment benefits, community involvement, and humane treatment of animals in their criteria
- Economic criteria are the least developed across the initiatives surveyed, with the majority of initiatives reviewed having few or no economic criteria. Where economic criteria exist, the most common revolve around product quality requirements and minimum wage requirements. Requirements related to living wages, price premiums and written contract requirements are particularly rare.

Adapted from IISD (2010)

These voluntary sustainability initiatives are particularly prevalent in agricultural sectors such as forestry (FSC and PEFC), coffee (Fairtrade, Rainforest Alliance and IFOAM), tea (Ethical Tea Partnership, Rainforest Alliance, GLOBALGAP and UTZ Certified), cocoa (Harkin Engel protocol, World Cocoa Foundation and RSCE) and banana (Fairtrade and Rainforest Alliance); and while this may say something about the efforts of private sector actors dominating these sectors, there is also much to say about the role consumers here have in demanding environment sustainability and fair practice standards.

The coffee sector is also notable for a number of whole private sector-led sustainability initiatives, such as Starbucks' CAFÉ practices — that are setting standards for other private sector actors to follow. Although traditional coffee farming systems have relatively low-level negative environmental impacts, efforts over the past several decades to increase productivity have intensified the negative impacts of coffee production on the natural environment considerably. Four countries — Colombia, Brazil, Peru and Vietnam — account for 77 per cent of total sustainable coffee production.

In the last four years major corporations such as Walmart, Mars, Cadbury, Nestle, Kraft and Unilever have made explicit commitments to only sourcing major products from producers who comply with or are linked to one or more multi-stakeholder voluntary sustainability initiatives.

Table 4 below sums up the potential of the different approaches to greenness discussed in this section to both producing positive effects on the environment and mitigating the negatives. It also summarises potential shortcomings of the approaches.

Table 4: Pros and Cons of Approaches to Greenness

APPROACHES TO GREENNESS	**PROS**		**CONS**
	Enhancing positive effects	**Reducing Negative effects**	
Mode 1: New Science and Generic Technologies with Green Potential			
Biotechnology/GM/GE Crops	- improves the environmental efficiency of primary production and industrial processing - Helps repair degraded soil and water	- Reduces soil erosion - Reduces Water use and pollution - Reduces greenhouse gas emissions	- Contentious issue, often caught up in politics of opposing sides
ICT applications/ Precision Farming	- Can raise agricultural productivity and farm incomes -	- Mapping techniques can reduce overuse of water	- Can prove prohibitively expensive for many countries. Does it fall upon the public sector or the international community to bear costs?
Sustainable Bio Production/ Biofortification	- Improves efficiency of resource use - Improves plant resistance to drought/ temperature change - Increases nutritional value of crops		- Can be contentious depending on the type of breeding (GE invites a lot of controversy)
Mode 2: Farming System Innovations			
Integrated Pest Management	- Increases Agricultural Productivity - Conserves natural resources	- Reduces environmental degradation	- Complex system of measures - Requires farmers' skills to be built up and the cooperation of all farmers in an area to be completely effective

Systems of rice intensification	- Promotes soil biotic activities - Increases output, usually by 50% or more - Increases farm incomes	- Reduces water use - Reduces seed and chemical inputs - Reduces costs of production - Reduces pest and disease damage	- Pilot projects in OECD countries have yet to match the success of SRI that has been witnessed in several non-OECD countries
Organic Production Systems	- Improves/maintains soil quality - Improves water quality by reducing runoff from pesticide use - Improves quality of food - Increases biodiversity	- Reduces the use of pesticides and thus the their harmful effects on the environment - Decreases fossil fuel emissions - Reduces nitrate leaching	- Costs are still higher than traditional farming methods
Conservation Agriculture/ Crop Rotation	- Increases soil protection through the permanent maintenance of plant cover - Increases soil fertility - Increases farm profitability by decreasing working time - Increases biodiversity	- Reduces erosion, soil disturbance - Reduces pollutants	- More difficult to practice on organic farms - Risk of failure because of the difficulty of learning new techniques - Cost of learning can be high - In some cases can increase dependence on pesticides (particularly herbicides)
Water Management Systems	- Improves soil and water quality	- Reduces use of an increasingly scarce resource, water	- Costs for complex water management systems are high - For water management systems to work efficiently, it requires the cooperation of other actors in agriculture (fertilizer producers, seed producers, etc.)
Natural Resource Management	- Improves biodiversity - Increases carbon sequestration - Improves water infiltration - Improves soil productivity and rehabilitates the land	- Decreases the loss of forests - Reduces herbicide use - Reduces use of fire to manage pasture - Reduces fossil fuel dependence	- Costs for paying for a system like REDD are still being debated

Urban/Peri-Urban Agriculture	- Increases employment opportunities in urban areas - Improves air quality in cities, making them more 'green'	- Reduces carbon footprint of agriculture - Reduces temperatures - Reduces intensification and the risks associated with it (soil degradation, erosion, loss of nutrients, etc.) in rural areas	- Increased competition for land and water resources in urban areas - Risks of diseases and contaminants if pesticides are used
Mode 3: Integrated National Green Regimes			
Biofuels	- Increases energy security	- Reduces consumption of fossil fuels - Reduces greenhouse gas emissions - Helps restore degraded lands	- Fuel vs Food debate: Most currently-used crops for biofuels are also food crops - Use for transportation and energy needs still limited - Varying GHG savings - Eutrophication and acidification
Agritourism	- Raises consumer awareness about issues of sustainability - Allows farmers to diversify income-generating activities -Raises farm revenues - Raises appeal of 'locally-grown' produce	- Reduces intensification? - Reduces agriculture's carbon footprint by encouraging demand for locally-grown produce	- Question of exploitation? - Limited impact on farm incomes - Success depends on management skills - Risky
Use of renewable energies in Agriculture	- Increases productivity in developing countries where lack of electricity is a problem - Improves/preserves natural resources	- Reduces fossil fuel consumption - Reduces encroachment into forests and other natural ecosystems - Reduces pollution	-Start-up costs for more complex renewable energy systems (wind, solar, photovoltaic, etc.) are still prohibitively high

5. MAJOR DISCUSSION POINTS AND IMPLICATIONS

The preceding sections provide an overview of the sustainability challenges facing agriculture and the role of technology, farming systems, policy and market innovations in addressing these challenges. The following important points emerge.

- **The expanding expectations of agriculture's role in an era of environmental challenges:** The greening of agriculture presents an enormous innovation challenge of producing more food and fibres without relying on most of the technological mainstays of productivity gains of the past (artificial nutrients, pest and disease control products and intensification practices, generally). New demands are also being placed on agriculture as it is now also being asked to replace environmentally-damaging products and industrial production systems through the production of biofuels and other forms of bio-production. This has renewed the interest of the corporate sector. More generally the integration of agriculture from nearly all countries into global value chains means that the market is critical and a powerful stakeholder in the sector. In addition agriculture is being asked to protect biodiversity and mitigate climate change. There are also increasing social demands on the sector with regard to livelihoods, lifestyles and recreational uses of rural areas, often supported by well-organised civil society movements. These demands underline the importance of the sector in sustainable development strategies. These also, however, highlight the trade-offs and competing agendas that policy is going to need to deal with. This existence of multiple and often competing agendas and stakeholders, therefore, needs to be recognized as the overarching context in which the greening of agriculture needs to be considered. Similarly, technology and innovation options and strategies for sustainable agriculture need to be considered through this same lens of complex agendas and stakeholders.

- **The role of R&D and technology is a critical factor in shaping the green credentials of agriculture:** Technical change associated with the drive for agricultural intensification in the post-World War II period has raised six environmental challenges: Pollution, Biodiversity loss, Water Scarcity/Salinity, Carbon Footprint, Soil Degradation/Nutrient loss/ Erosion and Natural Resource Depletion. Technical change will also be a major element of strategies to address these sustainability issues — both by introducing more sustainable alternatives to agricultural production techniques and by allowing the agricultural sector to substitute for environmentally-damaging industrial production. The need to cope with and mitigate climate change will further highlight the importance of technical change. This underlines the need for increased research. Private sector agricultural research has been growing in recent years (See Table 3 in the preceding section). It is important, however, that public investments in research are continued and increased as many of the technological breakthroughs required for sustainable agriculture are unlikely to arise from purely market-driven research.

- **Technology is usually necessary, but rarely acts alone as a way of making agriculture sustainable:** While it is useful to discuss the potential contribution to sustainability of new technological options, technology is often part of a wider set of linked changes that together bring about green innovation. This may simply be policy incentives to encourage sustainable practices; for example, the shift away from pesticide use or incentives for sustainable land uses such as agro-forestry. Other times new technology will form part of a farming system innovation. For example, organic agriculture has coupled together new marketing systems with new production practices involving the introduction of new techniques such as bio-control of pests and this has required appropriate policy support and regulation. Technology also finds its place in higher order system innovation such as integrated green national systems where, for example, agriculture plays an important role in the energy economy. Again technical change is critical, but only has value when it is part of a larger set of institutional and policy arrangements. Deploying technology in this integrated way requires a high degree of policy coherence and strong communication across different stakeholder groups. However, understanding and planning technical change for sustainable agriculture as part of the wider process of green innovation would seem to be a high performing policy perspective; see, for example, the experience of The Netherlands and Israel in summary Table 5 on the following page).

- **New technology is not inherently more sustainable and requires planning processes inclusive of a wider set of stakeholders:** Technology is not an independent factor in determining the environmental footprint of agriculture. In particular technical choices and the decisions to use technologies for different purposes with different environmental consequences have been the result of the political economy of various stakeholders groups — notably prominent market actors, but also policy-makers, scientists and consumers and the historical practice in particular countries and contexts. Biotechnology is the most obvious example of this. The potential of new technology to contribute to sustainable agriculture will depend on policy finding a way of managing technological change in a way that provides a balanced outcome for society and the environment. The task of balancing outcomes takes on ever greater importance in an era of complex and multiple expectations of the role of the agriculture sector — food, energy, economic growth, ecological custodianship, bio-production recreation, and climate change mitigation. This suggests that networking and communicating between different groups of stakeholders is going to assume much great importance and that participatory processes are going to be key in the discussion about and the deployment of new technology for sustainable agriculture.

Table 5: Typology of Approaches to Sustainable Agriculture followed by Different Countries

TYPE	COUNTRIES	CONTEXT	EXAMPLES OF SUSTAINABLE PRACTICE	STRATEGIES	TRADE-OFFS
Technological fixes	● Most OECD countries ● China ● USA	● Strong policy frameworks ● Resource abundance	● Regulation of pesticide use ● Incentives for organic agriculture	● Policy incentives for technical change, mainly on input use ● Investments in R&D Training on sustainable practices	● Research alone is rarely a driver of technical change ● The combination of technological innovation and policy incentives can be a powerful driver of change Tends to be end of the pipe pollution control. ● Sustainable Agriculture is not necessarily integrated into wider sustainability policies ● Limited participation of markets and consumers in achieving sustainability goals
Consumer/ market-driven fixes	● Europe ● USA to some extent ● Increasingly India	● Well-developed markets ● Informed consumers with high spending power	● Organic produce value chains ● Sustainable/ ethical product labeling	● Voluntary sustainability regulation by key commodity industries and food retailers ● Farmers switch organic production to access high value markets	● Market incentives in place for self-regulation and technical change ● Often enable win wins ● Still requires public R&D support ● Efforts may be isolated for other sectoral and national sustainability efforts and so potential synergies are lost ● Environmental benefits may be over-sold by companies and other externalities overlooked
Intensive agricultural systems with strong ecological principles	● the Netherlands ● Israel	● High national levels of appreciation of consequences of environmental damage/ climate change in resource-scarce countries	● Integrated water management systems ● Shift from end-of-pipe pollution control to clean production systems	● (re)Organisation of research and supporting institutional structures around sustainable agriculture. ● Policy and market incentives for technical change ● Civil society organizations promoting good practice	● Highly effective win-win strategy ● Relies on coherent action by both markets and policy including a high degree of self regulation ● Only possible in certain socio-policies context ● A high degree of organization and institutional development required among market, consumers and producers as a starting condition. ● Managing competing demands on agriculture (food energy, recreation) needs to be given special attention
Sporadic practice of alternative modes of sustainable agriculture	● India ● Africa ● Parts of USA and Europe	● Well developed civil society movements ● Support from international development agencies	● SRI ● IPM ● Farmers markets ● Natural Resource Management	● Local organizations experiment and champion innovations in sustainable agricultural production	● Powerful source of sustainable innovation ● Isolated, small-scale and disconnected from potentially supported policies and practices ● Poorly linked to the market, but organizations in developing countries starting to see business opportunities in sustainable agriculture for the poor
Integrated national sustainable regimes	● Brazil ● Israel	● Resource scarcity combined with desire for economic independence	● Bio-fuels ● Water management and use of waste water	● Integrated agriculture, energy and environment policies and research and innovation infrastructure	● Highly effective win-win strategy ● Managing competing demands on agriculture (food energy, recreation) needs to be given special attention ● Public investments needed to strengthen networks and communication between different stakeholders in society

Table 6: Agri-Environmental Payments Applied in OECD Countries in 2008

Programme/Country	AUT	AUS[1]	BEL[2]	CAN	CZE	DNK	FIN[3]	FRA	GER	GRC[3]	HUN	IRL	ITA	JAP	KOR	MEX	NLD[3]	NZL[1]	NOR	POL	PRT	SPA	SVK	SWE	SWI	TUR	USA	UK[4]
Payments for farming practices																												
Land improvement (liming, soil erosion prevention)	X	X	X	X			X	X	X				X		X	X		X	X	X	X	X	X	X		X	X	X
Payments for nitrate reduction	X	X	X			X	X	X	X	X			X		X				X	X	X	X	X	X	X	X		X
Nutrient management plan		X		X		X					X	X	X									X		X			X	X
Extensive crop production	X							X	X		X		X	X						X	X	X		X	X			X
Organic farming	X		X		X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X
Integrated production wine, fruits&vegetables	X		X		X			X			X		X			X						X	X					X
Integrated farming			X		X	X		X			X		X								X	X		X				X
Traditional methods of cultivation	X							X			X					X			X	X	X	X		X				
Reduced tillage/Mechanic weed control	X	X	X	X			X		X		X	X	X						X		X	X			X	X	X	X
Crop rotation				X				X	X		X		X			X				X		X					X	
Biological plant protection measures									X																			
Green manure crops		X																										
Green set asside/fallows	X	X		X		X		X			X		X		X		X					X			X		X	X
Catch crops, green/winter cover	X		X	X	X	X	X	X	X			X			X				X	X		X		X			X	
Extensive management of all land							X	X			X				X					X		X		X				
Extensive grassland management (pastures/meadows)			X	X	X	X		X	X		X	X	X		X		X		X	X	X	X	X	X	X	X	X	X
Conversion of arable land into grassland (pastures/meadows)				X	X	X		X	X		X		X									X	X		X		X	X
Grassland/biodiversity/habitat schemes	X	X	X	X	X		X	X	X		X	X	X		X	X	X	X	X	X	X	X	X	X	X		X	X
Biodiversity - local breeds	X		X				X	X	X		X	X	X		X	X			X	X	X	X	X	X	X			X
Biodiversity - local species and varieties of crops	X		X			X	X	X	X				X		X	X				X		X		X	X			X
Maintenance of wetlands and ponds[5]		X	X		X	X		X			X		X		X	X	X		X			X		X	X	X		X
Protected environmentaly sensitive areas/vulnerable zones		X	X		X	X		X			X	X	X		X	X			X			X			X	X	X	X
Shelter belts/buffer strips	X	X	X	X	X	X	X	X	X		X	X	X		X			X	X	X	X	X		X	X		X	X
Landscape elements/Amenities	X		X				X	X			X		X		X		X		X	X	X	X		X	X			X
Maintaining and improving groundcover		X																									X	
Water conservation																											X	
On-farm Energy Conservation																												
Payments for land retirement																												
Long term set-aside	X	X				X			X	X		X	X									X				X	X	
Afforestation		X	X		X	X		X		X	X	X	X	X	X	X	X	X		X	X	X	X			X	X	X
Conversion of farm land land int wetland and ponds						X	X						X				X							X			X	X
Converting pasture to perennial vegetation		X																										

1. In Australia, Canada and New Zealand there is a very limited use of payments to farmers (and, where payments are made, this is in the form of one-off or transitional payments) and support to agri-environmental programmes is provided mostly through general services.

2. In Belgium only programmes used in Flanders region are reported.

3. In Finland, Greece and Netherlands, the information for 2008 is not available and the programmes in the table correspond to programmes applied in 2000-06.

4. In United Kingdom only programmes used in England are reported.

5. In Spain the payments for water quality in wetlands is included in this line.

Vojtech (2010)

- **The contribution of technology and innovation to sustainable agriculture is determined by broad strategies adopted and these in turn are shaped largely by national and regional historical and socio-political contexts:** Summary Table 5 presents five stylised approaches to sustainable agriculture observed in different countries. Technical change and innovation are organised differently and play different roles in these different strategies. For example, the first strategy — technological fixes — relies almost entirely on research and the introduction of new technology to improve sustainability. Other strategies rely on a more integrated approach where technology, policy, market and other institutional innovations are used in combination at the level of the whole agricultural system to improve sustainability. Each of the different strategies is making valuable contributions to agricultural sustainability. It is important to note, however, that these strategies are not necessarily transferable between countries as these often emerge from and require a particular set of starting conditions. For example, the consumer market-driven fixes require well-developed markets and well-informed consumers; the technological fix approach requires strong and often top-down policies; the more integrated approaches require high levels of institutional and organisational development among producers, consumers and different areas of policy support. The degree of resource scarcity has also been a critical shaping factor; more sustainable agricultural systems often emerging in resource-scare countries. The approaches also have trade-offs. For example, the more integrated approaches are effective but require high levels of public investment. The alternative modes of sustainable practice can generate highly effective innovations, but these often only impact at local scales. The critical observation here for the OECD countries in their pursuit of sustainable agriculture is that while there are clearly higher-performing strategies that can be adopted it is essential that strategies are tailored to national contexts. Some OECD countries (Australia, New Zealand) rely mostly on regulatory requirements to address environmental issues in agriculture. Others (some EU countries, Norway, Switzerland and the US, for example) have developed a wide range of agri-environmental payments within voluntary programs providing incentives to farmers to adopt certain farming practices with positive environmental effects (Vojtech, 2010). This may lead to conflicts between regional and national policies; for example, the European Union's Common Agricultural policy and how it finds itself at odds with national policies in Europe. Ways of reconciling these challenges will need to be found. Similarly full consideration will need to be given to the trade-offs involved and this will have a national flavour as it will involve consideration of the level of public and private investments required and the positioning of different stakeholder interest in the national debates about sustainable agriculture. Further observations from this analysis of different strategies are amplified below.

- **The civil society and the market have been major forces in promoting green agriculture:** Civil society-led movements demanding sustainably-produced food and other agricultural products have stimulated wider consumer demand for ecologically or organically-produced food (mainly), but also fibres and clothing. (See also below the role of civil society organisations' role in sustainable innovation). Voluntary sustainability standards have emerged in a number of prominent commodity value chains (tea, coffee, cocoa, etc.) as the industry responds to the needs of consumers to ensure the ecological standards of its products and thus serve consumer demands. This is not to say that there is no longer any role for policy in promoting sustainable agriculture. Rather it suggests an important role may be to assist agriculture to make the transition to modes of ecological production desired by consumers; for example, many countries provide incentives to farmers switching to organic production (Table 6). As already alluded to above green innovation will best be promoted by market, policy and technical innovation and as a result public-private sector partnerships are going to be critical in pursuing a green agricultural agenda.

- **Sustainable agriculture win-wins are more likely when an integrated system-level approach to technical change and innovation is adopted:** Generally sustainable agriculture is characterized by reduced inputs and there are a number of innovations that simultaneously increase production and or profitability. The use of ICT and water management technology in precision agriculture can reduce input costs and boost yields. Organic agriculture offers price premiums. The analysis present in Summary Table 5 suggests that win-wins are most common when a market-led route to sustainability and integrated system-level strategies are adopted. This is perhaps not surprising as these are situations where sustainability concerns are integral elements of successful business models of key stakeholders. This observation underlines the importance of devising innovation strategies to promote sustainability that make the most of market incentives and which are inclusive of market stakeholders.

Box 19

Sustainable Agriculture and Win-Win Policy Options

Many of the innovations in agriculture reviewed in the previous section offer great potential for win-win policy options — contributing to environmental sustainability and agricultural productivity and/ or profitability. There is even win-win-win potential for some of these, given that they can also deliver social benefits such as the recreational use of rural areas, sustaining lifestyles etc. Win-wins are often discussed in terms of increased sustainability and increased income levels, particularly in regions where food access is a policy objective. However, the issue of food security, in an era of rapidly-rising world food commodity prices, is becoming critical at a global level. It also provides a useful metaphor for exploring how win-wins can be achieved given the increasingly complex and multiple demands being made on the agricultural sector, the food vs. biofuel tension being a much cited example of this.

For policy-makers, this implies deft tightrope walking, as they need to consider potential benefits against trade-offs and go with the best possible option, especially given win-win options may be highly contextual; what constitutes a win-win policy option in one country may not necessarily mean the same for another. For example, Brazil's biofuels policies may not work as well in other (smaller) countries, where such a policy may find food security goals at odds with environmental sustainability goals. Some examples of win-win options, which worked for certain countries, are discussed below:

- Conservation agriculture and zero tillage technology was easily a win-win option for countries such as Brazil and Argentina (with abundant land resources). While such farming systems innovations helped reduce the threat of erosion by heavy rainfall, improved soil quality so that the soils sequester carbon and help increase output, they also significantly raised incomes of farmers by giving them more adaptation options. In the case of Argentina, farmers were included in consultations and decision-making all along the way, giving them a greater voice and hence stake in policy outcomes.

- The integrated green approach adopted by the Dutch is an example of a win-win policy which worked because of the socio-political context. Policy-makers were intent at the outset on policies to promote ecologically-sound agricultural development, without compromising on market competitiveness and increased productivity. Such a regime was made possible by a combination of a number of policies: through increased funding for research to develop a more preventive approach to crop protection and sustainable production, incentives to industry to develop more environmentally-friendly pesticides, policies to improve energy consumption levels in agriculture. Dutch efforts at educating consumers about environmentally-sound agriculture also helped in creating a pull factor for industry to respond to consumer demand for green products.

- Israel's water management system is another win-win strategy policy for that country although, again, it would difficult to adopt elsewhere. While significantly improving livelihoods and providing Israel with food security and production self-sufficiency as well as a strong export industry, the policy has also had profound ecological effects on greening the country, conserving scarce water resources and rehabilitating soils.

- Systems of Rice Intensification is a win-win option adopted in several developing countries that increases yields, reduces water and fertilizer use, uses less seed and chemical inputs — all the while raising farm incomes. It is a farming system innovation that has emerged out of civil society-led initiatives rather than from formal research or specific policy initiatives. Indeed the key driver of this win-win innovation has been the need to cope with resource scarcity in some of the poorest and challenging agro-ecological conditions.

- Investment in ecological infrastructure offers major win-win opportunities. For example, certain agro-forestry options will halt desertification, sequester carbon, and create jobs too. International cooperation, technical assistance and public-private partnerships will be critical in achieving such win-wins.

The characteristics of these win-win strategies are very case-specific: for example, Israel has a unique institutional architecture of cooperatives and farmer associations that work closely with research and policy-making bodies and this allows innovation (sustainable and otherwise) to take place effectively. A number of general principles, however, emerge: the importance of consultations between market and policy-makers; and policy initiatives that take an integrated approach to deal with a number of elements of the agricultural system simultaneously (regulation, incentives, public awareness, etc).

Figure 1. Win-Win Options for Policy

ENVIRONMENTAL SUSTAINABILITY

FOOD SECURITY

High Food Security Potential **Low Environmental Sustainability Potential** - Expanding crops onto marginal lands - High energy-consuming, intensive agriculture - Increased use of pesticides and other inputs - Mono-cropping **Examples:** Intensive, high-input agriculture	**High Food Security Potential** **High Environmental Sustainability Potential** - Restore degraded land - Low energy irrigation - Soil and water conservation technologies - Agro-forestry options that increase food and incomes **Examples:** Integrated National Green Regimes, IPM, SRI, Organic Farming, Precision Agriculture, Conservation Agriculture, Water management systems, Agritourism
Low Food Security Potential **Low Environmental Sustainability Potential** - Continuous cropping without use of nutrients - Overgrazing **Examples:** Traditional smallholder farming	**Low Food Security Potential** **High Environmental Sustainability Potential** - Reforestation - Restore original soils - Agro-forestry options with limited food or income benefits **Examples:** Reforestation, Biofuels, Bioproduction

- **Opportunities to learn from non-OECD countries:** A range of green agricultural practices and farming systems have originated in non-OECD, emerging economy countries. Unlike more developed economies, where the market and policy is driving green innovation, in these countries natural resource scarcity and resource depletion is the driving force. This has led (usually) civil society organisations to search for alternative sustainable agricultural production systems. Examples include: Systems of Rice Intensification, Integrated Pest Management, etc. (There are also examples of civil society organisations pioneering and supporting sustainable practices in OECD countries). Many of these green innovations possibly could not transfer directly to OECD countries. However, this does suggest that international research and development collaboration around the topic of green agricultural innovation could be a very fruitful area of co-development and should not be framed in the conventional development assistance sense, but as essential for the development of green economies in the OECD countries.

- **Green agriculture in OECD must mean green agriculture outside OECD:** The internationalisation of agricultural value chains means that the greening of any OECD countries — those in Europe, for example — concerns the nature of agricultural practices in countries where food products are sourced from (cut flowers from Kenya, horticultural products from Costa Rica, rice from Pakistan or Thailand, etc.). There are already regulatory standards that that govern, among other things, the use of pesticides in these exporting countries (for example GLOBALGAP), or forest sustainability certification. There is, however, a much wider policy issue here concerning the question of how to upgrade the environmental standards in the agricultural production systems of trading partners, many of whom are emerging economies with limited technical expertise in sustainable practices. This needs to be a particular concern for small OECD countries with limited agricultural sectors of their own and whose environmental foot-print is outside its own national borders.

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