CHAPTER 13

A Policy Framework to Promote Eco-Efficient Agriculture

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Contents

Abstract

Agricultural production systems have to meet the food needs of a growing world population without reducing the environmental carrying capacity of the planet. As standards of living improve in developing countries, people demand more and better food, often increasing consumption of foods of animal origin. Aging populations, especially in developed countries, will create new, specialized food demands. Meeting these growing and changing demands will require changes in the way we produce food if we are to support socio-economic growth for present generations without compromising the welfare of future generations. This is the essence of sustainability. These changes require shifts in the agricultural policy framework and institutional arrangements to focus on long-term food security and eco-efficiency. Life-cycle analysis, development of eco-efficient technologies and green production chains, measurement of water use and carbon footprints, and plans to adapt to and mitigate climate change must take precedence in the setting of future strategies. This chapter summarizes examples of good eco-efficiency practices and identifies policy and institutional frameworks needed to move agriculture towards global eco-efficiency.

Sustainability and Eco-efficiency on the International Political Agenda

After the Great Depression of the 1930s and the Second World War, there was a general shift in developed countries towards state intervention in the economy, including the agricultural sector. Common instruments included government-financed programs in research, extension, and irrigation; subsidized loans to farmers; and government-managed price stabilization schemes. For example the US encouraged land reforms in countries under its influence, while agriculture was collectivized in many socialist countries. Newly independent countries in Latin America, Asia, and Africa also adopted state-led agricultural development processes. Thus, from the 1930s through the early 1970s there was a common belief that state intervention was necessary to ensure equitable agricultural and rural development. Necessary elements for agriculture

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(such as land, water, transport, seeds, fertilizers, pesticides, and animal feeds, among others), as well as financial instruments (such as affordable credit, crop insurance, stability of prices), could only be provided by the state. Also, the state should provide or subsidize services like buffer stocks, trade protection, insurance, and support for processing and marketing (Chang, 2009).

However, this model led to many examples of waste, inefficiencies, and corruption, and by the 1970s there was a growing movement that promoted market-based economic development. This culminated in the implementation of structural adjustment programs by the International Monetary Fund (IMF) and the World Bank (Kay, 2006). This new approach later became known as the "Washington Consensus," a phrase coined in 1989 by economist John Williamson, then of the Institute for International Economics.

The 1960s and 1970s also saw the emergence of environmental issues in public arenas, culminating in the United Nations Educational, Scientific and Cultural Organization (UNESCO) conference on "Man and his Environment: A View towards Survival" in 1969 and the first United Nations Conference on the Human Environment in Stockholm, Sweden, in 1972 (Dunlap, 1991; Jones and Dunlap, 1992; Kraft and Vig, 2006).

Early environmental policy frameworks focused on the conservation and rational use of natural resources. This approach aimed to rationally exploit resources as a means to ensure continuous production in an optimal way. Renewable natural resources were considered as unconnected fragments: forests as a source of wood; soil as a support to monoculture production or a deposit for wastes; and freshwater resources as input for various human, industrial, and agricultural uses, or as a place to dispose of contaminated water (Rodríguez and Martínez, 2009).

By the mid-1970s, there was a growing recognition of the complex interrelations among organisms, and between organisms and non-living components in their environment. The right to a healthy environment for current and future generations (sustainable development), and the concept of environmental sustainability of productive activities and balance, including agriculture, gained more attention (Miller and Rothman, 1997). As Daly (1974) said, "It is simply a strategy for good stewardship, for maintaining our spaceship and permitting it to die of old age rather than from the cancer of growthmania."

The report of the World Commission on Environment and Development (commonly known as the "Bruntland Commission") *Our Common Future* (WCED, 1987) was a major milestone in promoting the broader concept of sustainable development at the global level, defining sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The Commission laid the groundwork for the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in June 1992; the Rio Declaration on Environment and Development; and Agenda 21, a comprehensive action plan for the UN system, governments, and others in every area in which human activities impact on the environment (www.un.org/esa/dsd/agenda21/). UNCED not only exposed 110 heads of state to the vision of sustainability, but an influential group of actors in the private sector also began to appreciate that sustainability issues extended beyond the obligation of public policy to become a fundamental part of business strategy.

After UNCED, several countries revised their institutional arrangements and policies to promote sustainability. In the agricultural sector, the emphasis has been mainly on increasing production of food while assuring the capacity of the environment to recover and provide ecosystem services. Biodiversity loss, water supply deterioration, and soil and water pollution have been increasingly recognized as severe symptoms of a crisis represented by the loss of the capacity of natural resources to sustain agricultural systems.

Eco-efficiency: A concept that arises from the private sector

For many sectors, especially private entrepreneurs, the necessary symbiosis between economic, social, and environmental sustainability meant approaching the issue from a more positive perspective. Thus, in the 1990s new concepts such as cleaner production and eco-efficiency were introduced with a focus on combining both economic and environmental efficiency.

In 1992, a group of businessmen led by Stephan Schmidheiny created the World Business Council for Sustainable Development (WBCSD) and promoted the concept of eco-efficiency in a book entitled *Changing Course* (Schmidheiny, 1992). According to the WBCSD, eco-efficiency is achieved through the delivery of "competitively priced goods and services that satisfy human needs and bring quality of life while progressively reducing environmental impacts of goods and resource intensity throughout the entire life cycle to a level at least in line with the Earth's estimated carrying capacity" (WBCSD, 2000). In the agricultural sector, eco-efficiency was promoted as the aspiration to maintain or improve the economic sustainability of crops (yields), while contributing to the environmental sustainability (less use of natural resources). Chapters 1 and 2 of this volume devote considerable space to the history and definitions of the eco-efficiency concept in agriculture.

Eco-efficiency: A paradigm shift

The ability to increase agricultural productivity will be facilitated by advances in life sciences, including a better understanding of the dynamics of ecosystems and their environmental services. One of the conclusions of the special rapporteur of the United Nations (UN) (De Schutter, 2010) is that it is not enough to designate large amounts of money for agriculture. There need to be measures that facilitate the transition to a type of agriculture that is low in carbon emissions and that conserves natural resources in a way that benefits the poor.

According to De Schutter (2010), agricultural production will have to increase by 70% by 2050 to meet anticipated demand. Achieving this will require technologies that are both more efficient and environmentally friendly, reducing the negative impacts of agriculture on the environment and society. Such production technologies will offset the harmful effects of economic development on environmental quality.

Institutions and Policies for an Eco-efficient Future

Agricultural institutions in developing countries have immense food security and eco-efficiency challenges. While most agriculture ministries tend to be based on centralized governmental models, reforms in many countries have moved toward privatization of state-owned enterprises and elimination of marketing boards and other regulatory agencies. However, the historical value of such institutions and the public goods they provided has not always been fully appreciated. Public sector investments in the development of input and output markets, in agricultural extension, and in applied agricultural research have been vital to agricultural development in every economy in the world. Institutional reform without investment in these public goods does not produce economic growth in the agricultural sector. Conducive institutional and policy environments remain cornerstones of agricultural development (Anonymous, 2007).

The changing relationship between the public sector, civil society, and the private sector will require a unified, comprehensive, and adaptive vision toward the increasing scarcity of natural resources and external factors such as climate change to achieve greater environmental and economic efficiency in the medium and long term in developing countries. There is no unique policy prescription that fits the diversity of the agricultural sector in the developing countries. While enhancing productivity is a common essential requirement, the nature of the increase in productivity envisaged, including eco-efficiency parameters, will determine the appropriate policy mix.

Change is not easy; encouraging new, sustainable, and eco-efficient agricultural practices is a slow process. It entails transaction

costs: the new practices require that farmers understand and are trained in new techniques, development of innovative financial alternatives, creation of market value and markets for new products that help alleviate poverty, and development of policies that promote long-term food security.

There are several policy dimensions that governments should address to push forward the eco-efficiency agenda into modern laws, policies, and renewed agricultural institutions. The following sections explore how states can reorient their agricultural systems towards modes that are more productive and efficient and that assure long-term sustainability and equity for present and future generations.

Investing in eco-efficiency practices

Strengthening eco-efficiency in agriculture requires changes to approaches for maintaining soil fertility and increasing yields, and increasing the efficiency of use of external inputs by farmers. Common practices such as subsidies on fertilizer and pesticides, for example, while conducive to short-term increases in production, are likely to result in farmers adopting practices that are neither eco-efficient nor sustainable. A case in point is Malawi (see box). Policies that encouraged use of hybrid seed and fertilizer resulted in record maize harvests in 2005/06 and 2006/07 (although this was in part due to good rains in those years) (Dorward et al., 2008). However, they also encouraged reliance on purchased inputs rather than more-sustainable production practices such as crop rotations. To address this, the government has subsequently implemented programs to encourage farmers to adopt sustainable land management practices and build soil fertility, prevent soil erosion, and conserve rain water through practices such as manuring, composting, contour ridging, minimum tillage, and agroforestry, as well as diversifying production of food crops (Daudi, n.d.).

Rather than relying completely on chemical fertilizers, farmers can sometimes increase soil fertility by using improved agronomic practices, such as planting trees, legumes, and forages that fix atmospheric nitrogen. Agroforestry is widely practiced in Asia, Africa, and Latin America. In Tanzania, for example, more than 350,000 ha have been rehabilitated with agroforestry practices. Diversification of agricultural systems is also an important element of eco-efficiency, contributing to maintenance of soil fertility, prevention of soil erosion, enhancing overall system productivity and provision of ecosystem services, and increasing resilience to shocks such as climate change or sudden changes in markets. It also contributes to providing a more balanced diet and creates employment opportunities.

Governments should also promote local seed systems that are able to provide farmers with high-quality seed of appropriate crops and varieties, rather than relying on imported seed. Selection of varieties for local adaptation and consumer needs can typically bring productivity and sustainability advantages over those selected in non-targeted environments. Unless modern varieties are selected for local needs, local landraces may perform just as well, and be preferred by farmers (Van Mele et al., 2011). Strengthening of local capacity for seed production will help farmers cope with changing or harsh conditions. Support might include financial instruments for seed production, empowerment of seed producers, and provision of appropriate irrigation infrastructure (Dalohoun, 2011).

Investment in human capital, research, and training

According to IFPRI's Agricultural Science and Technology Indicators (ASTI), average age of agricultural researchers, teachers, and technicians in developing countries is quite high. In some cases, this problem is a threat to the continuity of agricultural research and development (R&D) and training in developing countries. Country reports can be downloaded from ASTI's web page at www.asti.cgiar.org/publications, and examples are noted in Figure 1.

Investment in agricultural R&D and extension has stagnated in recent years except in a few countries such as Brazil, China, and India (Beintema and Stads, 2010; Stads and Beintema, 2012), despite evidence that such investment

Malawi: Policy Reforms for Enhancing Agricultural Productivity

Agriculture is a key sector of the Malawian economy. It employs over 80% of the workforce, provides an estimated 64% of total income of the rural people, contributes over 80% of foreign exchange, earnings, and accounts for 39% of GDP.

In early post-independence days, the government was heavily involved in the smallholder agricultural sector in areas of production, extension, technology development, and marketing of agricultural commodities. However, despite these efforts, poverty remained widespread and severe. In 1979, the government oriented its policies towards poverty reduction and introduced a structural adjustment program with support of the World Bank and the International Monetary Fund. There was a price decontrol to allow market forces and competition. Other reforms included the Special Crops Act, the Seed Act, and the Chemical and Pesticide Act. However, lack of concerted efforts by players in the sector compromised the success of the policy reforms.

Since the beginning of the new millennium, policies have changed to address increased productivity. Free-input programs and input subsidy programs were developed to provide farmers with coupons to buy hybrid seeds and fertilizers at subsidized prices. At the same time, the Government developed a minimum floor price for the purchase of several crops such as maize, cotton, and tobacco.

The country realized maize surplus production since the start of the program. Malawi was able to attain food security and produce sufficient surplus maize to export to other countries.

Attaining food security implied having the resources to address sustainability and eco-efficiency issues. Several programs are currently in place to sustain land and water management in view of weather variability and climate change. There are programs to encourage farmers to adopt sustainable land management practices and build soil fertility, prevent soil erosion, and conserve rain water. Current practices include manuring, composting, contour ridging, minimum tillage, and agroforestry.

Ongoing efforts to strengthen research in agricultural production and utilization of available technologies in collaboration with farmer-led extension services are being introduced with an emphasis on market- and industry-oriented research.

The experience of Malawi shows that agricultural productivity in developing countries needs concerted government efforts to raise productivity, consolidate markets, promote technologies that match the farmer resources base and have the capacity then to ensure eco-efficiency practices to sustain natural resources.

But, while the Malawi experience of concerted policy action by a national government is an encouraging sign of policy leadership, important questions remain around the sustainability of the higher-input production practices, the eco-efficiency of inputs used, and the efficiency of the whole value chain for the Malawian food systems.

SOURCE: www.un.org/esa/dsd/dsd_aofw_wat/wat_pdfs/meetings/ws0109/1_Malawi_Daudi.pdf

reduces rural poverty as well as increases agricultural productivity (Fan, 2010).

Developing and promulgating eco-efficient agricultural systems will require increased investment in training scientists and educators who can deliver new practices through renewed agricultural extension services. These services require training at all levels. Agro-ecology will need to be incorporated in high-school curricula. Agricultural technicians also should receive a strong grounding in agro-ecology. University agriculture curricula should encompass innovative research, science, and technology. Integrating traditional production systems with more modern and scientific methods will promote adaptation of technologies and knowledge assimilation and application at the local level. This will require new information platforms and technology transfer.

For agricultural R&D to accomplish their objectives, it is imperative that the target

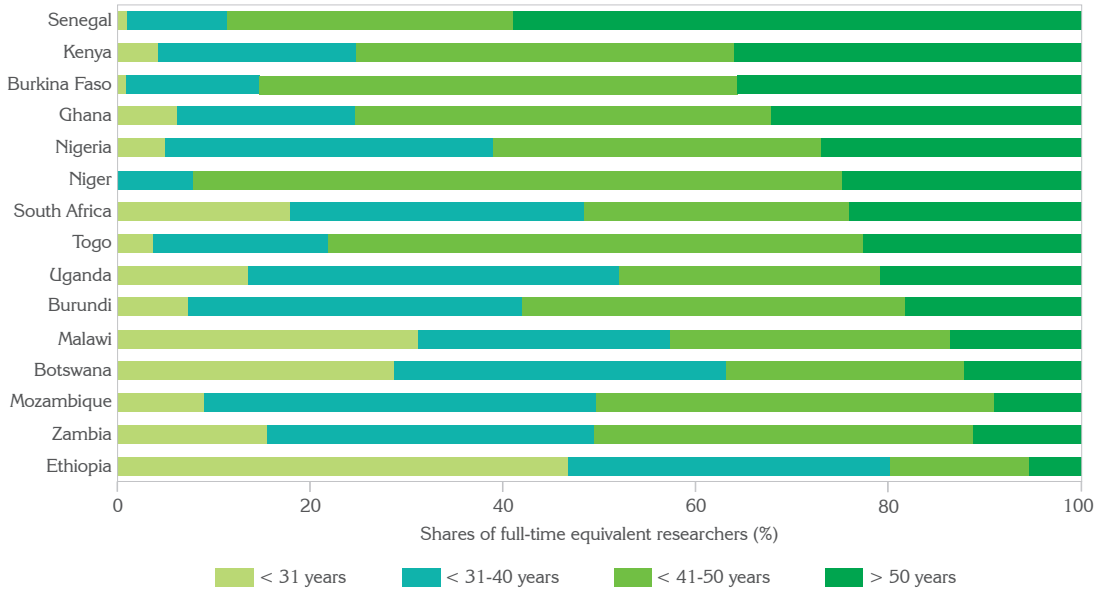

Figure 1. Age profiles of agricultural researchers, teachers, and technicians in selected countries of Africa.
SOURCE: www.asti.cgiar.org/publications

beneficiaries understand and adopt the approaches developed. Most research projects that have delivered impact have included the active participation of the target beneficiaries from the start of the project. Therefore, governmental policies should encourage extension services to actively involve farmers and other stakeholders along the value chain in developing and testing novel approaches.

Achieving greater agricultural eco-efficiency will require a push by both governments and the private sector. Both will have to seek to combine the best of traditional agricultural practices with modern technologies and inputs to deliver sustainable, eco-efficient agricultural systems (Uphoff, 2001).

Investing in public goods to promote equitable development

More people in developing countries are opting to move to the cities in order to improve their economic and social conditions, and to have better access to basic services, such as health and education, and other public goods provided by the government (Stern, 2007). The rural areas require urgent investments to maintain the rural communities in place. Agricultural growth and poverty reduction depend critically on investments in rural infrastructure (irrigation, roads, transport, power, and telecommunications), markets, rural finance, research, education, and extension. Such investments have rates of return of more than 35% in sub-Saharan Africa and around 50% in Asia (The World Bank, 2008).

The World Bank (2008) concludes that investing in public goods could have a greater impact on per capita income than investing in private goods such as pesticides or fertilizers, while assuring more-sustainable practices. In Latin America, the share of rural subsidies provided by governments is greater where income inequality is highest. Better policies are needed to ensure that the poorer, especially smallholder producers, have access to basic services and infrastructure. Reassigning spending toward public goods without increasing the overall level of spending on agriculture might be sufficient to transition into eco-efficient agriculture (The World Bank, 2008). According to Allcott et al. (2006), "even without changing overall expenditures, governments can improve the economic performance of their agricultural sectors by devoting a greater share of those expenditures to social services and public goods instead of non-social subsidies."

Political and economic pressures that determine budget allocations must be addressed to ensure

transparency, equity, and accountability of resource allocation.

Promoting green supply chains

Major businesses are increasingly aware of the benefits of eco-efficiency – at the producer level – of their production chains. For example, Unilever's target for 2020 is to source 100% of their agricultural raw materials from sustainable production systems. Other businesses are thinking not only about eco-efficiency, but also about the nutritional quality of each product. Some large companies are involving communities and small-scale growers as co-owners and participants in their production chain – sharing benefits.

To generate efficient green supply chains, producers must be linked to modern supply chains that are increasingly dominated by supermarket chains and multinational companies. For example, by the early 2000s, supermarkets accounted for more than half of all retail food sales in many countries in Latin America (Reardon and Berdegué, 2002; The World Bank, 2008). Supermarket buying agents prefer to buy from medium- and large-scale farms, as it is easier for them to deliver standardized product, and dealing with a small number of large suppliers reduces transaction costs for the buyer. However, consumers are increasingly demanding environmentally safe and socially responsible products. Retailers such as Whole Foods in the USA who meet this demand are growing rapidly (Marquis et al., 2009).

In this context, the role of public policies can be to help smallholders expand and upgrade to meet the necessary requirements of modern supply. Such policies should support market-oriented extension services, establish grades and standards, assist farmers in contract design and management (including understanding their rights and obligations), create an enabling environment for insurance and credit markets, and be based on an understanding of social and environmental requirements to be able to supply green supply chains.

Governments could also create public procurement programs, with incentives for organic food or fair-trade chains. For example, the strategy of the United Kingdom (UK) for sustainable farming and food (DEFRA, 2002) and the country's organic action plan (DEFRA, 2003) both highlight the public sector as a key area in which to market UK-produced organic food (OAPSG, 2008). The message that procuring eco-efficient goods can have a positive impact on the economy is important. There is also a potential to broaden policy goals, e.g., to improve health and education, increase opportunities for small- and medium-sized enterprises working in the food sector, and create jobs, as well as to support environmental objectives and local producers.

Generating and promoting sustainable markets

Urbanization can help reduce poverty in developing countries by increasing proximity between resources and markets and through economies of scale that enable cost-effective, efficient delivery of basic infrastructure and services (Stern, 2006). For example, Mogues (2011) found that public investment in transportation networks gave the highest return-on-investment ratios of any state interventions in Ethiopia, but variability of returns between regions within the country suggested that regional planning was necessary. However, not everyone in urban areas benefits equally, and special attention will need to be paid to the urban poor, who are particularly vulnerable to food insecurity (Mason et al., 2011). In 2002, the urban poor accounted for 59% of the total population in Latin America, 30% in sub-Saharan Africa, and 25% in India (Chen and Ravalliona, 2007).

However, changes in consumer preferences due to increased income or access to more sophisticated markets boost demand for food that requires more resources to produce, e.g., meat and animal products. Consequently, livestock numbers are expected to double by 2020 (IPCC, 2001), increasing significantly the amount of methane released into the atmosphere and contributing to climate change. Also, intensity of fertilizer use and energy is expected to increase in all developing regions.

Globalization has meant that food supply chains are increasingly long and complex, but there is also a trend toward consolidation of these chains in the

hands of large, multinational companies. These companies influence what is grown, where, how, and at what price. Increasingly, however, large companies are beginning to understand that their long-term competitiveness depends on protecting the environment and the services it provides (Bishop et al., 2010). New environmental and social concerns are influencing the way food is produced and the rules under which it is traded. Consumers are beginning to demand that producers engage in fair trade, management of the ecosystem and environmental services, minimization of climate emissions, food safety measures, and improving working conditions. This calls for transparency of production standards and traceability, which can be promoted through green certification schemes and eco-labelling. While many certification and labeling schemes have rigorous standards and third-party auditing, many more do not. Making these schemes effective will require government support for certification and verification.

In addition, elements of eco-efficiency are beginning to play a prominent role. Sustainability standards are becoming more important every day. Prices of the food products we consume must now cover not only the direct cost of production but also the costs of making the production chain sustainable and reducing the environmental and social footprint in the countries of origin.

Ministries of trade, environment, and agriculture, in concert with investment and export agencies, should consider creating efficient platforms to address green production chains and develop specific policies on fair trade and sustainability standards in general.

Organic agriculture in China and India

China and India, the two most populous nations on the planet, have chosen to support organic agriculture, especially for poor farmers, as a means of alleviating poverty in rural areas.

In both countries, organic products take up only a small fraction of the food market. According to the Foundation Ecology and Agriculture (SÖL), there were just over 300,000 ha of certified organic crops in China (Giovannucci, 2005), out of the 130 million ha of arable land. The domestic market in China was valued at nearly US$250 million. In India, according to SÖL, in 2004 the organic production was done in 76,000 ha out of the 180 million ha of arable land. Even though these values are relatively small, the organic production has been rocketing in recent years and constitutes a good example of effective strategies that promote eco-efficient practices.

In the case of China, officially supported organic farming started in the 1980s, and by the year 1990, the Nanjing Institute of Environmental Sciences (NIES) began implementing protocols of international organic certification. The objective of this strategy in China is to: (1) help decongest the farmland near big cities, which has been intensively cultivated over the centuries, and (2) assist smallholder farmers in remote areas to produce with less reliance on expensive external inputs (IFAD, 2005). While organic farms originally belonged to local governments, the central government has adopted a policy of developing market mechanisms. Thus, local governments have been gradually handing over property rights to private companies and individuals, giving financial and technical support for a more efficient resource management and market access of products to farmers.

Given the variety and importance of its agricultural products, India has had a tradition of organic farming that goes back centuries. Organic production has traditionally been practiced by civil society and particularly NGOs and farmer groups. They have also developed various practical schemes in different regions to suit weather conditions and rainfall, as well as existing varieties. Because 60% of all crops in India are rainfed, the government has placed emphasis on organic agriculture as a strategy to ensure food security and poverty reduction. To implement a plan of norms and standards, the Ministry of Agriculture has set up a special Working Committee for organics and the Ministry of Commerce set up a National Steering Committee (IFAD, 2005).

Both cases show how government could implement organic policies that could influence productivity chains at the global scale, given the large populations of both countries.

Changing consumption patterns

Every day consumers play a more fundamental role in promoting eco-efficiency options through their selections of food and other products. Food-borne diseases and poor nutrition continue to be widespread, and more consumers are interested in knowing the quality of their food. In this regard, green certification and eco-labeling are tools that play a more critical role so that consumers have references of what they buy. Under these terms, transparency and traceability are two key issues that need attention. Producers must be transparent about the eco-efficiency and sustainability parameters of their production chain. They must try to make their products, origins, and production systems traceable, as well as create a transparent system of social and environmental accountability that can be understood by the consumer and the producers. There are many eco-labels in the market, related to fair-trade schemes, eco-efficient agricultural practices, footprint reduction, tracing sources or ensuring food quality and safety. While many eco-labels have rigorous standards and third-party auditing, the labels themselves are only emblems of the certification scheme, providing consumers little information and requiring that everyone conduct their own research. With so many labels in the marketplace, even the environmentally conscious shopper can become easily confused.

Eco-labels, however, are feasible if governments support the certification and verification schemes to help market dynamics to align with equitable and sustainable development and eco-efficient principles. Governments should facilitate sustainable production systems including incentive schemes to achieve initial momentum. In addition, they should also monitor the results and foster public–private schemes that promote food sustainability.

Public subsidies and incentives

Public procurement systems, tax and credit incentives, and land policies should be designed to facilitate transition toward eco-efficient agriculture. Such policies include, for example, temporary tax "holidays" for farms adopting eco-efficient practices and preferential interest rates for investments in eco-efficient systems.

Regularization of land tenure and the creation of a solid property rights framework also encourage farmers and landowners to invest in the long-term fertility of land. These should include forms of land tenure that are more accessible to women and formal recognition of traditional forms of land ownership and tenure (The World Bank, 2008). In addition, cross subsidies and incentive schemes can also promote eco-efficient agriculture. For example, in 2009 the Government of Brazil issued a law requiring at least 30% of school meals to consist of food from local family farms.

At the same time, governments could organize or steward markets to protect smallholder farmers from price volatility, and create or eliminate production subsidies to help small-scale producers, without affecting competitiveness at the regional level. Governments often implement open-trade policies that lead to the import of products that are cheaper than those produced locally. One way of enhancing local competitiveness would be to generate models of association where scale-small producers can join value chains that add value to local activities. Another related strategy would be to discourage the use of imported pesticides and fertilizers, encouraging use of local alternatives and production practices to reduce costs and enhance sustainability.

Governments will have to increase their investment in the agriculture sector to promote eco-efficiency (Horlings and Marsden, 2011). Similarly, the financial sector can contribute with new financial instruments, e.g., equity funds that invest in green production chains. Agricultural banks need to produce collateral-free financial schemes, create consistent lines of credit and guarantees, and facilitate access to credit for small-scale farmers.

There is an ongoing debate about the wisdom of state intervention, which can distort markets and create inefficiencies (Chang, 2009). It is clear, nevertheless, that some interventions are necessary to correct situations that would create larger distortions if not addressed. Such is the case of subsidies and incentives to create or provide public goods, such as agricultural

Change of perspective in Thailand

From the 1960s, Thailand immersed itself in agricultural development based on increased productivity and use of agricultural surplus to boost other sectors, with strong orientation towards exports (Buch-Hansen, 2001). This scheme was successful during the decades of the 1970s and 1980s, making the Southeast Asian "tiger" a world-class agricultural producer. The 1997 Asian economic crisis, with the overheating of the economy and the financial meltdown, led the government to change their perspective about agricultural development in Thailand. The Eighth National Development Plan (1997–2001) and the Ninth (2002–2006) and Tenth (2007–2011) changed the emphasis of development strategy to give greater weight to citizen participation and criteria of self-sufficiency, poverty alleviation, and environmental protection. One of the biggest changes occurred in agricultural policy, which promotes sustainable agriculture, to reverse the damage to the environment (Amekawa, 2010). At present, the Thai government is putting considerable effort on research and technology developments of agricultural production that are friendly to the environment and at the same time increase productivity.

research, that otherwise would not be sustainable. Incentives or subsidies are also welcome when vulnerable groups are losing ground (The World Bank, 2008).

Finally, governmental policies in agriculture, environment, energy, transportation, and other sectors should be more coherent and interlinked. Agricultural governance[3] and resources that regulate, guide, and direct the process of agricultural and rural development must have a renewed vision. This vision is one that recognizes the benefits of eco-efficient farming methods that are more productive, sustainable, and less harmful to the environment.

Community empowerment

The empowerment and mobilization of rural communities is a very powerful tool to ensure sustainable development and eco-efficient practices. Numerous studies have shown that involvement of stakeholders, communities, and other potential beneficiaries in planning and management increases the probability of success of development efforts (Rondinelli, 1982; Uphoff, 1996; Bakker, 2011). Such community-driven development mobilizes community groups and involves them directly in decisions on public spending, harnessing their creativity, capabilities, and social capital (The World Bank, 2008). Community-driven projects have shown the potential to scale up, be more cost-effective, make fiscal transfers more efficient, and increase income from agriculture. Achieving this requires a policy environment that supports capacity strengthening in rural communities, learning and assimilation of new technologies, participatory research and R&D-extension networks, knowledge management, and sharing of best practices (Horlings and Marsden, 2011). Governance has to be reinforced by making all decision processes more transparent and participatory.

Social accountability mechanisms that guarantee transparency on government investments will increase community participation in the new production structure (Reuben, 2005). Information policies and tools will enable rural populations to assimilate and claim ownership of the new eco-efficient concepts (Keating et al., 2010).

Institutional arrangements for eco-efficiency

The structural reforms of the 1980s often dismantled the public agencies that provided services to farmers, such as access to credit, insurance, inputs, and information in the developing world (The World Bank, 2008), with the expectation that the private sector would take over these functions in a more effective way. The private sector, however, has developed only slowly, leaving farmers, especially small-scale farmers, with little or no access to these services in many countries. Restoring these services requires an analysis of what worked and what did not, and clarification of roles between the private and public sectors.

[3] Understood as the sum of organizations, policy instruments, financing mechanisms, rules, procedures, and norms.

Policy- and law-makers need to be informed about important concepts such as sustainability, agro-ecological farming, and environmental services, and should understand the implications of sustainable agricultural production, to effectively create the necessary new legislation and supervise its enforcement.

The private sector needs to be more involved in agricultural production, particularly through public–private partnerships (Swanson and Samy, 2002). Engaging the private sector will require the correct incentives, an appropriate business environment, and solid property rights (Fan, 2010).

Poor infrastructure and limited access to markets hinder production and diminish profits for smallholder farmers in remote or poorly serviced regions. Transport and communications infrastructure has to be built or improved to allow products to reach markets as fast and inexpensively as possible. This might entail the construction and improvement of roads, railways, storage and distribution centers, and market places. Improving education and health infrastructure in rural areas will help reduce rural–urban migration and promote economic growth in rural areas.

The challenges facing the agricultural sector are complex, not the least of which are population growth, environmental degradation, and climate change. Efforts to address these challenges will require concerted action of various sectors – environment, education, health, trade, among others – and planning tools that are capable of integrating these areas. Agriculture ministries will need to devise new visions and means of cooperation with the ministries responsible for these other sectors.

International Policies

Policy and climate change

The Commission on Sustainable Agriculture and Climate Change, established by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), has identified seven key actions to achieve food security in the face of climate change (Beddington et al., 2011). These are:

1. Integrate food security and sustainable agriculture into global and national policies.
2. Significantly raise the level of global investment in sustainable agriculture and food systems in the next decade.
3. Sustainably intensify agricultural production while reducing greenhouse gas (GHG) emissions and other negative environmental impacts of agriculture.
4. Develop specific programs and policies to assist populations and sectors that are most vulnerable to climate changes and food insecurity.
5. Reshape food access and consumption patterns to ensure basic nutritional needs are met and to foster healthy and sustainable eating patterns worldwide.
6. Reduce loss and waste in food systems, targeting infrastructure, farming practices, processing, distribution, and household habits.
7. Create comprehensive, shared, integrated information systems that encompass human and ecological dimensions.

Action on climate-smart agriculture will require large investments. The share of agriculture in official development assistance, which declined from 19% in 1980 to 3% in 2006, is now around 6% (The World Bank, 2008). The World Bank recently estimated the annual adaptation costs in the agriculture sector in developing countries to be US$2.5–2.6 billion per year between 2010 and 2050 (The World Bank, 2010). Mechanisms for increasing investment in climate-smart agriculture include, for example, public–private partnerships, carbon-offset markets, and long-term international official development assistance combined with carbon finance.

In the forest sector, approaches such as REDD+ (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) are emerging that involve market instruments based on real emission quantification results. Mechanisms to protect forests while increasing agricultural production will require incentives to employ eco-efficient agriculture practices in conjunction with measures to prevent deforestation from agricultural expansion. This will depend on raising awareness of the role of forests in providing

ecosystem services and their contribution to livelihoods. Ra et al. (2011), for example, indicate that households living near forests in Cambodia generate 21–34% of their income from the forests.

However, for REDD+ to be effective, new institutions capable of implementing payment mechanisms based on reporting, monitoring, and verification are required (Angelsen et al., 2009). In this context, it will be essential to implement policies that ensure that indigenous communities, peasants, and women are involved in the national-level decision-making processes of REDD+ schemes.

Many governments around the world are now promoting low-carbon economies. Member countries of the Organisation for Economic Co-operation and Development (OECD) have committed themselves to promoting green investments and sustainable management of natural resources, with incentives to build low-carbon infrastructure economies as well as research in science and technology to achieve sustainable societies "low in carbon" (OECD, 2011a). Asian countries signed a unified vision toward green growth in 2005 at the Ministerial Meeting on Environment and Development in Asia and the Pacific. Several countries have developed concrete green growth and low-carbon policies, including Brazil (Zanella, 2011), China, Korea, Malaysia, and Thailand; and countries in the Near East and North Africa, Latin America, and Africa are ready to follow suit. Korea's green-growth strategy integrally promotes sustainable agriculture with innovation, policies, and financing (Kim, 2010).

Korea: policy measures for green growth in the agricultural sector[4]

Korea has seen a continual expansion of environmentally friendly agriculture, with an annual growth of about 70% since 2000 and with a strong government support through a five-year plan. In April 2010, the president enacted the Framework Act on Low-Carbon, Green Growth.

Strategies for green growth in agriculture, forestry, fisheries, and food sectors included six implementation projects:

- Green life: comprehensive plan for fostering urban agriculture
- Green energy: activating energy of livestock manure and expanding use of biomass to generate renewable energy. Innovations in energy efficiency for agriculture include geothermal heat pumps, light, bio-energy, and plant factories
- Low-carbon policy: carbon labeling system; target management of GHGs
- Infrastructure of green industry: green R&D investment, environmentally friendly agriculture infrastructure
- Sustainable resource management: ecosystem conservation
- Strengthening international cooperation: global partnership

The agro-green strategy required a paradigm shift to *low-carbon and resource circulation agriculture* with a vision to *Reduce, Recycle, and Reuse*. It also required a shift from a productivity-oriented quantitative approach to a qualitative approach based on ecological efficiency (*maximized* production to *optimized* agricultural production) with green technologies as well as a policy mix through integrating agricultural and environmental policy programs.

The programs implemented the expansion of environmentally friendly farming practices in districts and the establishment of a Regional Circulation Agricultural Support Center. The government promoted environmentally friendly agribusiness (biopesticides, organic fertilizers, natural enemies), established a special district of organic agriculture, and promoted the consumption and marketing of organic products.

The development and dissemination of green technologies involves all kinds of innovations – from reduction of methane from irrigated rice

[4] SOURCE: Presentation of Chang-Gil Kim from the Korea Rural Economic Institute (KREI) at the UN Regional Symposium of Low-Carbon Economy in Bali, Indonesia, 2010.

fields to the production of bioethanol energy crops as well as plant factories, vertical farms, and biorefineries.

The green agriculture strategy involves financial mechanisms as well as substantial investment and support for education and training programs.

Brazil: Agriculture and the low-carbon economy

The Brazilian parliament adopted a voluntary goal of reducing emissions in 2020 by about 37% against current projections. Brazil's GHG emissions per person each year are less than half the global average. However, the biggest source of GHG emissions comes from deforestation, mainly from the expansion of livestock farming, maize cultivation, and ethanol biofuel production from sugarcane. Agriculture accounts for a quarter of Brazil's emissions.

In 2010, the Brazilian Ministry of Agriculture announced a new credit line of R$2 billion (approximately US$1.1 billion) over the next 10 years to finance rural agriculture activities that use technologies to reduce GHG emissions. The Low-Carbon Agriculture (ABC) Program aims to reduce carbon-equivalent emissions from Brazilian agriculture by up to 176 million tons by the year 2020.

The investment is intended to encourage the increased use of sustainable practices in the Brazilian agricultural sector, considered the fastest-growing in the world (OECD/FAO, 2010). One of the sustainable practices to be funded by the ABC program is the no-tillage system, which dispenses with the traditional, intensive use of soil grids and plows by instead sowing directly over the crop residues left from the previous harvest. The procedure preserves nutrients in the soil, thus increasing crop yields. Through the ABC program, the Ministry of Agriculture plans to expand the use of this technique to cover a land area of 33 million ha, up from the current 25 million ha. This increase would reduce emissions by 16–20 million CO_2-equivalent tons over the ten-year period.

A crop–livestock–forestry system also ensures carbon retention in the soil, allowing farmers to alternate from pastures to agriculture to forestry on the same piece of land, thus restoring the soil and increasing income. The program aims to increase use of the system in Brazil by 4 million ha over the next decade, while reducing CO_2-equivalent emissions by 18–22 million tons over the same period.

Brazilian farmers often plant commercial forests to supplement their income, and the Ministry of Agriculture has set a target to increase Brazil's planted forest area from 6 to 9 million ha by 2020. This will result in a reduction of approximately 8–10 million tons of CO_2-equivalent emissions over ten years.

"Brazil is a leader in using efficient, productive systems that respect the environment. This is evidenced by the expansion of grain production in Brazil by almost 24 million tons since 2003, while the planted area grew by only 3.6 million ha," said Brazil's former Minister of Agriculture, Wagner Rossi.

The ABC program is consistent with Brazil's National Plan on Climate Change, a set of integrated programs to curb emissions generated by the Brazilian economy and to reduce Amazon deforestation by 80% by 2020, compared to 1996–2005 average deforestation levels. In December 2009, Brazil approved its National Policy on Climate Change, which established goals to cut projected emissions between 36.1 and 38.9% by 2020.

Water availability, use, and pricing instruments

The agricultural sector consumes nearly 70% of available fresh water, compared with 22% used for manufacturing and energy, and 8% used for drinking, sanitation, and recreation (WWAP, 2009). Increasing demand from all sectors and likely changes in supply resulting from climate change will increase strains on existing supplies.

Table 1. Low-carbon agriculture targets in Brazil, 2010–2020.

	Current Land Area: 2010 (in million ha)	Target Land Area: 2020 (in million ha)	Reduction of GHG Emissions by 2020 (in million CO_2-equivalent ton)
Planted forests	6	9	8 – 10
Crop–livestock–forestry integration	2	6	18 – 22
No-tillage system	25	33	16 – 20
Recovery of degraded areas	40	55	83 – 104
Biological nitrogen fixation	11	16.5	16 – 20

SOURCE: The Secretariat of Social Communication of the Presidency of Brazil (SECOM).

Large irrigation systems were the models in the 1970s, with investments that were later challenged for being inefficient, generating corruption schemes and degrading the environment without achieving reasonable long-term use of water. At the same time, individual water schemes from aquifers increased the ease of having pumps and extraction mechanisms, depleting and contaminating much of the world's aquifers. In the face of increasing food consumption, production systems need to ensure a water supply to meet global production needs.

Water sources such as rivers, lakes, and aquifers rarely lie within the boundaries of single nations, and hence managing water resources will require international cooperation and international and regional policy measures. Hermans et al. (2005) note several regional schemes that provide funds for improving the management of water catchments and therefore the long-term water supply.

Furthermore, techniques for the efficient use of water for agriculture exist in various forms. A prime example exists in Israel, where drip irrigation developed on the kibbutz in the 1960s was exploited as an export opportunity. In Italy, the open irrigation systems were converted into irrigation pipes, reducing the evaporation and loss from the inefficient system. There are also individual control systems of irrigation with computer models that allow one to reduce the volume, while making more equitable use of water by various users (OECD/FAO, 2010).

Measuring water footprint will be critical. Agricultural industries will have to take into account estimates of their water usage and implement measures to minimize it (Segal and MacMillan, 2009). For example, following a series of water-footprint studies, Coca-Cola is seeking to reduce its water footprint by developing and encouraging more-sustainable agricultural practices that benefit suppliers, customers, consumers, and local watersheds (The Coca-Cola Company and The Nature Conservancy, 2010).

Eco-agri-"culture"

Solutions to poverty, hunger, and the climate crisis require agriculture that promotes producers' livelihoods, knowledge, resiliency, health, and equitable gender relations, while enriching the natural environment and helping to balance the carbon cycle (IAASTD, 2009). In line with this, some governments currently rethinking agriculture have placed those who produce, distribute, and consume food at the heart of food systems and policies, rather than the demands of markets and corporations. Connecting producers and consumers through fair-trade and green production chains is emerging as a win–win policy to address poverty issues, feed the world, and have a healthier planet.

Consumers are increasingly demanding transparency about origins of food products, trading conditions, and carbon footprints, leading to a rise in eco-labeling and certification schemes in global agricultural markets. Supermarket chains supporting these processes, such as Sequoia in Belgium and Whole Foods and Trader Joe's in the United States, have gained favor with consumers and grown comparatively faster than competitors who have been slower to embrace these schemes (Marquis et al., 2009).

Reducing postharvest losses and food waste would go a long way towards reducing the ecological impact of food production. It is estimated that more than 30% of the food produced is wasted, especially by the final consumer in developed countries (Gooch et al., 2010). Much of the loss in developing countries is due to poor storage, packaging, and transport. Improvements in storage and transport infrastructure, packaging, and marketing would reduce losses and reduce the environmental impact of food production.

The Common Challenge: Science and Technology towards Eco-efficiency

Developing policies that encourage adoption of new agricultural technologies that can increase productivity, while preserving environmental resources, is a key strategy for governments that seek to reduce the negative environmental externalities caused by agricultural activities (Fuglie and Kascak, 2001).

The recent International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) conducted by the World Bank in collaboration with a group of agencies of the United Nations called for technological development through networks and associations, and development of capabilities across borders and regions. Our future food security will depend on sharing research and development results and on increasing budgets for research, science, and technology.

The European Union (EU) is taking an unprecedented leap in establishing a green growth policy for the agricultural sector. Several EU countries have been pioneers in this field. For example, the Netherlands has a long tradition in policies promoting sustainable agriculture, including restricting the use of pesticides, management of soil and water acidification, landscape management, and biodiversity. Their strategy to remain one of the world's largest agricultural producers as a small country is to differentiate themselves in environmental management and general innovation.

Green growth has become one of the highest priorities of the Organisation for Economic Co-operation and Development (OECD) governments. A press release from the agriculture ministers meeting at OECD in 2010 notes that "Ministers recognized that green growth offers opportunities to contribute to sustainable economic, social, and environmental development; that agriculture has an important role to play in the process, as do open markets that facilitate the sharing of technologies and innovations supportive of green growth, and that, in this context, care needs to be taken to avoid all forms of protectionism. Climate change presents challenges and opportunities for the agricultural sector in reducing GHG emissions, in carbon sequestration, and the need for adaptation" (OECD, 2011b).

There is increasing international coordination of research addressing climate change issues facing agriculture, such as:

- The CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) – a strategic partnership between CGIAR and the Earth System Science Partnership (ESSP) – brings together researchers in agricultural, climate, environmental, and social sciences to identify and address the most important interactions, synergies, and trade-offs between climate change and agriculture. (http://ccafs.cgiar.org/)
- The Global Research Alliance on Agricultural Greenhouse Gases was launched in December 2009, and now has more than 30 member countries from around the world (www.globalresearchalliance.org).

Similar partnerships are needed on shared ecosystem services management, biodiversity management, second and third generation bioenergy, green production chains, and health and food security management.

Finally, all this will be possible only if there is a fundamental shift in food consumption, from foods with high input demands to less resource-intensive foods, and if waste and postharvest losses are reduced.

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