Brief on Sustainable Agriculture

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This brief discusses the potential for sustainable agriculture to contribute towards sustainable development with a particular focus on developing countries. It briefly describes different sustainable agricultural practices and the extent of their adoption, identifies constraints to their further adoption, and presents some actions and policy options that could accelerate the widespread adoption of sustainable agricultural practices.

Why sustainable agriculture?

The past decades have witnessed a dramatic change in agriculture with food production soaring due to the Green Revolution. The Green Revolution entailed the use of improved technologies (particularly the breeding of high yielding food crop varieties), the expansion of irrigation, mechanization, specialization and the use of chemical fertilizers, and pesticides. While the Revolution led to dramatic production increases especially in Asia and Latin America in the 1960s, the increase in production was not sustainable. For example, evidence indicates that rice yield growth in Asia declined sharply in the 1980s, from an annual growth rate of 2.6% in the 1970s to 1.5% during the period beginning in 1981 (Pingali and Rosegrant,1994), owing partly to increasing prices of chemical fertilizer and agrochemicals (pesticides and herbicides). More importantly, despite the productivity gains associated with the Green Revolution, poverty and hunger persist while land degradation and agriculture-driven environmental damage are prevalent and unabated. FAO's most recent estimates indicate that 848 million people suffered from chronic hunger worldwide between 2003 and 2005, 98% of which lived in developing countries (FAO, 2008).

Decreasing hunger requires increased food production which in turn requires farmers' access to productivity-enhancing inputs, knowledge and skills. However, the majority of the chronically hungry are smallholder farmers in developing countries who practice subsistence agriculture on marginal soils, lack access to inputs and product markets, as well as financial resources to procure costly chemical fertilizer and other agrochemicals that might enhance the productivity of their land.

Moreover, the Green Revolution has been criticized for its adverse human health and environmental impacts. For example agricultural intensification, through excessive and inappropriate use of chemical fertilizers and pesticides, has polluted water bodies and degraded soils, led to biodiversity loss by killing beneficial plants, insects and other wildlife, and in some cases poisoned farm workers. Irrigation has led to salinization (build-up of salt within the soil) and retreating of groundwater levels in areas where more water is pumped for irrigation than can be replenished by rainfall. Monoculture systems have, through crop and biodiversity loss, led to a treadmill of resistance that requires more or stronger agro-chemicals to sustain yield levels. All these costs have not been properly internalized in the calculation of production costs of the Green Revolution model. In addition, inorganic fertilizer loses effectiveness when the organic matter of soil is low, which is of particular concern in developing countries due to continuous cultivation and soil degradation.

Sustainable agriculture has emerged as an alternative agricultural system that addresses the many constraints faced by resource-poor farmers and at the same time ensures environmental sustainability. It refers to the capacity of agriculture over time to contribute to overall welfare by providing sufficient food and other goods and services in ways that are economically efficient and profitable, socially responsible, while also improving environmental quality (Crosson, 1992). This system involves a combination of inter-related soil, crop and livestock production practices in conjunction with the discontinuation or the reduced use of external inputs that are potentially harmful to the environment and/or the health of farmers and consumers. Instead, it emphasizes the use of techniques that integrate and are adapted to local natural processes such as nutrient cycling, biological nitrogen fixing, soil regeneration and natural enemies of pests, into food production processes (Pretty et al., 2003) (see Box 1).

Principles of sustainable agriculture

Economic sustainability. In order to be truly sustainable, a farm must be economically profitable. Farms that are not economically viable are replaced by alternative uses of land that that are more profitable. Sustainable agriculture can improve the economic viability of a farm in a number of ways. In the short term, improving soil management and crop rotation can increase yields, while in both the medium and long term, improved soil quality and water availability as well as other environmental benefits from sustainable practices, may raise the value of the farm and provide for payments for environmental services. Economic viability can also be achieved through, for example, reducing machinery, chemical fertilizer and pesticide costs (for farmers who can afford these inputs), depending

Box 1. Examples of some the most prominent sustainable agriculture practices

Category	Examples of practices
Soil and water management	• Terraces and other physical and biological structures to prevent soil erosion • Contour planting • Hedgerows and living barriers • Conservation tillage • Mulches, cover crops including biological nitrogen fixing legumes • Water harvesting practices
Soil fertility management	• Manures and composts • Biomass transfer and green manures • Agro-forestry • Integrated soil fertility management
Crop establishment	• Planting pits • System of rice intensification (SRI) • Intercropping • Alley cropping
Controlling weeds and pests	• Intercropping and rotation (diversity) • Integrated pest management

Source: *Tripp, 2006.*

on the specific characteristics of the production system. Of course, economic sustainability is also conditioned by many factors aside from crop production methods, e.g. household characteristics such as managerial ability, institutions, infrastructure, and market access among others.

Environmental sustainability. Sustainable agriculture is frequently described as ecologically sound practices that have little to zero adverse effect on natural ecosystems, or even enhance environmental quality and the natural resource base upon which the agricultural economy depends. Typically this is achieved through protecting, recycling, replacing and maintaining the natural resources base such as land (soil), water and wildlife that contribute towards conservation of natural capital. While synthetic fertilizers can be used to supplement natural inputs, they are applied on a needs basis. Under sustainable agriculture, synthetic chemicals known to harm soil organisms, soil structure and biodiversity are avoided or reduced to minimum use.

Social sustainability. Social sustainability relates to the quality of life of those who work and live on the farm, as well as those in the surrounding communities. It includes ensuring equitable revenue or returns to different stakeholders of the agricultural production chain. In context of high unemployment, sustainable agriculture can promote sharing of agricultural value added by more members of the community through more extensive use of available labor, at least for some techniques, thus contributing to social justice and cultural cohesion. Fair treatment of workers and choosing to purchase supplies locally rather than from more distant markets are also elements of social sustainability.

Although the abovementioned elements are often discussed separately, they are not mutually exclusive: sustainable agriculture meets environmental, economic, and social objectives simultaneously. In many cases, sustainable agriculture practices are not new, but draw on traditional knowledge and practices, some of which have now been positively evaluated by scientific methods (Box 1).

Can Sustainable Agriculture ensure food security over time?

A key question is whether sustainable agriculture can be productive enough to ensure food security. While there is a clear consensus as to the environmental and social benefits of sustainable agriculture (see examples below), there are still fears that it might not address the future demands for food. There is growing evidence, however, that sustainable agriculture practices have been able to increase productivity with minimum damage to the environment compared to conventional agriculture. Although it may not be fully representative, a review of 286 sustainable agricultural projects carried out between 1999 and 2000 across eight categories of farming systems in 57 developing countries in Africa, Asia, and Latin America (Pretty et al. 2006) revealed that farmers increased yields by an average of 79% by adopting sustainable agricultural practices (Box 2). In those projects, many practices were used but three types of technical improvements are argued to have played substantial roles in yield increases: 1) more efficient water use in both dryland and irrigated farming; 2) improvements in organic matter accumulation in soils and carbon sequestration; and 3) pest, weed, and disease control emphasizing on farm-biodiversity and reduced pesticides.

The Tigray region of Ethiopia illustrates how sustainable agriculture can ensure sustainable development by raising yields and household income, improving the environment and attracting the much needed community and government support (Box 3).

Box 2: Impact of sustainable agriculture practices on food production and carbon sequestration (in soils and above-ground biomass)*

FAO farm system category	Average increase in crop yields (%)	Carbon sequestered (ton C/ha/year)
Smallholder irrigated	129.8 (±21.5)	0.15 (±0.012)
Wetland rice	22.3 (±2.8)	0.34(±0.035)
Smallholder rainfed humid	102.2 (±9.0)	0.46 (±0.034)
Smallholder rainfed highland	107.3 (±14.7)	0.36 (±0.022)
Smallholder rainfed dry/cold	99.2 (±12.5)	0.26 (±0.035)
Dualistic mixed	76.5 (±12.6)	0.32 (±0.023)
Coastal artisanal	62.0 (±20.0)	0.20 (±0.001)
Urban-based and kitchen garden	146.0 (±32.9)	0.24 (±0.061)
All projects	79.2 (±4.5)	0.35 (±0.016)

*Standard errors in parenthesis
Source: *Pretty et al. (2003, 2006)*.

Box 3: A success story in sustainable agriculture: the Tigray region in Ethiopia

A sustainable agriculture project has been carried out since 1996 in the Tigray Region in northern Ethiopia. The main technologies promoted under the project include composting, biological and physical water and soil conservation, and crop diversification.

Empirical evaluation of the project demonstrates the superiority of compost over chemical fertilizer in terms of productivity. Specifically, the data collected in 1998 indicated that using compost gave similar yield increases as chemical fertilizers while data collected from 2001 through to 2006 showed that, on average, composted fields gave higher yields, sometimes double than those treated with chemical fertilizers. In contrast to chemical fertilizers, composted soil remains productive for up to four years so compost does not need to be applied every year. In addition, the fact that compost increases the moisture retention capacity of soil is of crucial importance to the region, given its susceptibility to drought. Other documented benefits include improved hydrology with raised water tables and permanent springs, reduced weeds, pests and diseases, rehabilitation of degraded lands and increased incomes. Overall, between 2003 and 2006, grain production for the region almost doubled from 714 thousand to 1,354 thousand tons while use of chemical fertilizer decreased steadily from 13.7 thousand to 8.2 thousand tons since 1998. These numbers clearly testify to the success of sustainable agriculture practices in the region.

Increased yields have raised farmers' incomes and enabled them to avoid debts from buying chemical fertilizer on credit. This has further empowered local communities who have taken an active role in the implementation and management of the project, lending support to its social sustainability. The success of the project has also led to its expansion to many communities in other parts of the country. The Ethiopian government has now included this approach as part of its strategy for combating land degradation and poverty.

Source: *Third World Network, 2008.*

Box 4 below presents selected case studies from developing countries to illustrate benefits of sustainable agriculture.

In Box 5 below we focus on the System of Rice Intensification (SRI) as a sustainable agriculture practice and discuss some selected evidence demonstrating its benefits. The SRI, developed in Madagascar in the late 1980s by a French priest working with Malagasy farmers, is a method of rice cultivation that combines less water, less seeds and more organic fertilizer. It is associated with healthier, more productive soil and plants by supporting greater root growth and promoting the abundance and diversity of soil organisms. Empirical evaluation of SRI systems shows that, among other benefits, SRI reduces production costs; enables farmers to overcome the problems associated with water scarcity; is especially accessible to the poor since it has practically no capital requirements; and is more resistant to other biotic and abiotic stresses besides drought, thereby reducing farmers' risks (Uphoff, 2005).

Adoption of sustainable agriculture practices: where do we stand?

There is a growing body of literature documenting the extent of sustainable agriculture practices adoption. The projects reviewed in the survey by Pretty et al (2006) mentioned above made use of a variety of packages of resource-conserving technologies and practices, including: integrated nutrient management, conservation tillage, agro-forestry, water harvesting in dryland areas, livestock integration, and integrated pest management. About 12.6 million farmers had adopted sustainable agricultural practices on 37 million hectares (see Box 6). This was equivalent to 3% of the 960 million hectares of arable and permanent crops in Africa, Asia and Latin America.

The extent of adoption of sustainable agriculture presented in Box 6 is based on surveys carried out between 1999 and 2000. Although the general trend since 2000 have not been thoroughly documented, we would expect adoption to have increased as benefits of sustainable agriculture have become

Box 4. Specific examples of the impact of sustainable agriculture practices

Selected Evidences from Africa

- Soil and water conservation in the drylands of Burkina Faso have combated land degradation, resulting in the average family shifting from being in cereal deficit of 650 kg per year to producing an annual surplus of 150 kg.
- Soil fertility management using a range of biological pest management methods together with legumes, cover crops and green manures have doubled beans and groundnut yields from 300 to 600 kg/ha in western Kenya.
- In Nigeria, alley crops of *Gliricidia* and *Leucaena* reduced soil erosion by 73 and 83%, respectively.
- In low rainfall areas of Ethiopia, reduced tillage without chemical fertilizer increased gross crop revenue by US$ 106 per hectare. Moreover, this productivity impact was superior to that of chemical fertilizers with conventional tillage (US$ 13 per ha). Lower impacts of reduced tillage without chemical fertilizer were found in high rainfall areas (US$ 6 per ha).

Selected Evidences from Asia

- In North Vietnam, contour planting of hedgerows on sloping lands reduced soil loss from 18 to 7.4t/ha/year.
- In Pakistan, yields of citrus fruits increased by 150-200% after adopting sustainable agriculture practices such as mulching, no till production, and composting.

Selected Evidences from Latin America

- 45,000 families in Honduras and Guatemala have increased crop yields from 400-600 kg/ha to 2000-2500 kg/ha using green manures, cover crops, contour grass strips, in-row tillage, rock bunds and animal manures.
- Soil and water conservation using contour grass barriers, contour ploughing and green manures has raised maize yields from 3 to 5 tons/ha and soybeans from 2.8 to 4.7 tons/ha in the states of Santa Caterina, Paraná and Rio Grande do Sol in Brazil.
- Some 2000 farmers in Bolivia have improved potato production from about 4 tons/ha to 10-15 tons/ha in particular by using green manures to enrich the soil.

Sources: Pretty *et al. 2003; Graves et al. 2004; Kassie et al. (2008a, 2008b); Third World Network, 2008.*

better understood and articulated in the scientific literature and global support for environmentally friendly agricultural practices has been growing. Available figures for specific practices at the national level seem to point to an increase in areas cultivated under sustainable agriculture practices. For example Bolliger et al (2006) report that in Brazil the minimum tillage system has spread from less than 1,000 hectares in 1973/74 to 22 million hectares by 2003/04. In Argentina, there are more than 11 million hectares under zero-tillage, from less than 100,000 hectares in 1990. Baudron (2005) reported 10% adoption rates of conservation tillage among smallholder farmers in Zambia. In Cambodia, the number of SRI users grew from 28 farmers in 2000 to at least 16,884 in 2004.

Box 5. Impacts of the System of Rice Intensification (SRI)

- In Bangladesh an evaluation of SRI on 487 farmers revealed a 7% reduction in costs of production and a 58% average increase in farmers' net return per hectare with SRI.
- In Cambodia, a 51% reduction in costs of production for 120 farmers who had practiced SRI for three consecutive years, and a 76% increase in their net income/ha was reported.
- Research conducted by the Sichuan Academy of Agricultural Sciences in China over 100 farms in 2004 shows that using modern, high-input methods gave an average of 7.5 tons/hectare, while SRI plots gave an average of 10.5 t/ha.
- A cold spell in Andhra Pradesh, India, in February 2004 had no effect on SRI plots, while it had an adverse impact on conventionally-grown rice.
- The Tamil Nadu Agricultural University evaluation of SRI in Tamiraparani delta of India found that SRI reduced water requirements by 40-50%. In addition significant decreases in rice pests have been documented.
- Application of the rainfed version of SRI in Madagascar in 1999 led to a yield of 4 ton/ha, which was 2.5 to 5 times more than normally produced with upland rice in the area.

Source: *Uphoff, 2005.*

Box 6. Summary of adoption of sustainable agriculture in developing countries

FAO farm system category	Number of adopting farmers (million)	Hectares covered under Sustainable Agriculture (million)
Smallholder irrigated	0.18	0.36
Wetland rice	8. 71	7.00
Smallholder rainfed humid	1.70	1.08
Smallholder rainfed highland	0.40	0.73
Smallholder rainfed dry/cold	0.60	0.74
Dualistic mixed	0.54	26.85
Coastal artisanal	0.22	0.16
Urban-based and kitchen garden	0.21	0.16
All projects	12.56	36. 95

Source: *Pretty et al. (2006)*

Main constraints to the adoption of sustainable agriculture practices

The adoption by farmers of any technology depends on its net economic benefits in relation to other options, but also on external constraints that may impede the adoption of profitable technologies. Given evidences indicating that sustainable agriculture practices can in fact create multiple benefits, including reduction in production costs, environmental benefits and at the same time increased food production, it is crucial to understand what drives or constrains resource-poor farmers from adopting such technologies.

Heterogeneity in agro-climatic environments implies that no single approach can be applied all over the world in a uniform manner. Different techniques and systems are applied, and adapted, in different agro-ecological conditions, giving different results. For example, Kassie et al (2008a, 2008b) found that in Ethiopia, reduced tillage and stone terraces perform better in semi-arid areas compared to high rainfall areas. Local or regional biophysical factors such as land quality and plot characteristics have been found to be key determinants of adoption of soil conservation technologies (Zikhali, 2008 and Lee, 2005). This indicates that heterogeneity of environment will condition the need to adapt and the type of sustainable agriculture practice adopted. Similarly, the same technologies may not fit all households equally because of different endowments in resources and imperfect or non-existing markets such as credit markets.

Biomass availability. The adoption of sustainable agricultural practices by resource-poor farmers depends on the amount and availability of biomass (e.g., crop residues, animal dung). This is because benefits of most sustainable agriculture practices (e.g., erosion control, moisture conservation, soil fertility enhancement, carbon sequestration) are directly related to the amount of biomass used as soil amendments. The quantity of biomass available to smallholder farmers is commonly insufficient because resource-poor farmers have limited resource endowments (e.g., land, livestock and/or labor). Kassie et al. (2008c) found evidence that livestock ownership limited the adoption of compost, while a household's total landholdings and labor availability limited the adoption of conservation tillage. Adoption of techniques such as cover crops and crop residues incorporation in the Ethiopian highlands depend on farm size and availability of labor (Amede, 2001 cited in Graves et al., 2004). Thus although resource-poor farmers might be aware of soil and environmental degradation caused by not using biomass as soil amendment, they may still choose to divert scarce biomass to use either as cooking fuels or as fodder for the cattle because they do not have alternatives (Lal, 2007).

Economic incentives are crucial in determining the economic viability of sustainable agriculture. The profitability (both in the short and long term) of sustainable agriculture practices will affect their broader diffusion. The adoption and economic returns of a technology are a function of several factors such as prices, consumers demand for food type, physical infrastructure, market access and development, agro-ecology, and household characteristics (e.g. rich versus poor and male versus female headed households). Importantly, the profitability as well as social acceptability of a given practice depends on prevailing agro-ecologic conditions. Increasing prices of purchased inputs are expected to encourage adoption of sustainable practices as farmers substitute external inputs with practices that are often more labor- intensive and utilize locally available resources.

Final demand also drives adoption of technologies. Greater knowledge and improved channels of communication are leading consumers to demand food increasingly produced through organic methods in many developed countries. At the same time, consumers are increasingly demanding that their food be produced using techniques that conserve natural resources, limit environmental pressures and pay greater attention to rural viability and animal welfare. This could be an opportunity to adopt sustainable agriculture practices by developing countries.

Farmers in developing countries are not well integrated into input and output markets. This affects promotion and adoption of technologies. Some studies (e.g., Pender et al., (2001) in Ethiopia and Place et al. (2006) in Kenya and Hwang et al. 1994 in the Dominican Republic) found that better infrastructure and market access impacts positively the adoption of sustainable agriculture practices. The upfront investment costs and transition costs in learning, in developing or adapting old technologies is also a barrier to adoption of these practices, particularly in developing countries where capital markets are imperfect (Bekele and Drake, 2003).

Access to information is crucial in creating awareness and attitudes towards technology adoption. Inadequate information on availability, net benefits of adoption, and technical details of implementation of sustainable practices are barriers to adoption. Kassie et al. (2008c) found that access to agricultural extension services impacted adoption of compost and reduced tillage positively, while formal education (as opposed to no education at all) increased the probability of using compost in Ethiopia. Boyd and Turton (2000) found that lack of awareness of the extent of soil erosion problems as well as lack of knowledge of conservation technologies partly due to weak extension systems were the two major constraints to farmers' adoption of soil and water conservation technologies in Tanzania. Improved education, access to information, and technical assistance could thus encourage investments in soil and water conservation in that country.

Land issues. Insecurity of land tenure has been proven to be a constraint to any investment whose returns are weighted toward the future, while requiring immediate cash outlays. This is the case with sustainable agriculture practices. However, the impact of tenure insecurity on investment in sustainable practices has been found to be country- and site-specific. In the Philippines and Honduras tenure security positively and significantly influences adoption of hedgerow and minimum tillage, respectively (Arellance, 1994; Sureshwarna et al., 1996). In the highlands of Tigray, northern Ethiopia, insecure land tenure is an important factor inhibiting investment on soil conservation practices and tree planting (Gebremedhin et al, 2003). However, Pender et al. (2006) in Uganda and Holden and Yohannes (2002) in Southern Ethiopia argue that land tenure insecurity does not significantly constrain investments on land.

Fragmentation of land can affect adoption of sustainable agriculture practices since it implies that farmers have to transport inputs to several isolated plots in different locations. This is particularly important in the case of biomass transfer techniques, where several tons of biomass per hectare may be required. Furthermore, fragmentation of land may result in decreasing plot size, which makes certain practices impractical.

Institutions are important in facilitating the promotion and adoption of sustainable agriculture practices. Applied research, extension services, and NGO networks, could typically serve as a vehicle for the development, implementation, and adaptation of these practices. It is important not to undermine the role of social capital in facilitating technology adoption (Nyangena and Sterner, 2008). Penning de Vries (2005) identified participatory approaches in implementing technologies as one of the key factors influencing adoption of sustainable agriculture practices.

Lack of proper ***extension services*** has been identified as constraining adoption of productivity-enhancing technologies (Lee, 2005). Lack of skills of extension workers, particularly on sustainable agriculture practices, has been recognized as a key shortcoming of many extension delivery systems. In order to ensure that correct and up-to-date information is efficiently disseminated by extension workers, there is need for a system of training and organizational development that constantly upgrades the capacity of extension workers to ensure their technical competence, particularly in 'unconventional' farming practices such as sustainable agriculture practices.

Given the limited governments' resources and the subsequent pressure imposed on existing extension services, it is important to recognize the value to be gained in encouraging farmer-to-farmer extension through proper training of selected farmers. Informal networks among farmers have always been powerful channels for exchanging information and spreading knowledge. In Cambodia, for example, the number of SRI users grew from 28 farmers in 2000 to at least 16,884 in 2004, mainly through informal dissemination mechanisms. An evaluation of 120 farmers who had used SRI methods for at least 3 years found that, all together, they had informed 969 households within their respective villages, and 967 households outside (Uphoff, 2005). However, although such diffusion of sustainable agriculture is encouraging, it does not replace the need for properly trained extension workers. They are still needed to provide farmers with reliable information on these practices, thereby ensuring sustainability.

A large number of developing country farmers remain outside the cash economy because of high risks and transaction costs. This means that rural institutions have a huge potential in addressing these imperfections by for example surmounting information, credit, and marketing constraints. It has been argued that farmer associations and unions constitute important sources of information available to farmers (Caviglia and Kahn 2001). Kassie et al. (2008c) in northern Ethiopia found that a household's membership in at least one farmers' organization significantly increased the likelihood that conservation tillage and/or compost use are practiced on the farm. Pender et al. (2001) show that credit services and associated technical assistance from micro-finance institutions was associated with increased use of compost, and investments in soil bunds, trees, and live fences in Ethiopia.

Political constraints. At the national and international level, the policy environment may be more or less conducive to the widespread adoption of sustainable agricultural practices. A first factor affecting the design of agricultural policies is the degree of awareness of policy-makers on the benefits of sustainable agricultural practices, some of which represent significant departures from previously accepted paradigms. In addition, sustainable agriculture, by discouraging the use of external inputs such as chemical fertilizers and chemicals for weed management and pest control, might face resistance from agrochemicals industries and other traditional actors in intensive agricultural supply chains. For sustainable agriculture to be feasible at scale, it needs to be anchored on a clear understanding of the interactions of different layers of local and global institutions, as well as of political and economic factors that might threaten its sustainability.

Conclusion

Given persistent hunger and malnutrition and the high costs associated with traditional intensive models of agriculture, sustainable agriculture has received a growing attention from farmers, the research community and development organizations, as an agricultural system that can ensure sustainable food production while at the same time increasing farmers' incomes and minimizing the damages to the environment and the health of farmers and consumers. Given the empirical evidence on the potential benefits of sustainable agriculture, the main policy question is what changes in policies, institutions, research and development are required to encourage broader adoption of sustainable agricultural practices? Some answers can be drawn from the scientific and applied body of knowledge that has been analyzed in this Brief.

As a first requirement, in order to develop, sustainable agriculture practices need to benefit from an enabling policy environment at the national level. Policy changes that promote sustainable agriculture practices on a par with more conventional technologies are needed to create a platform for the development of initiatives promoting sustainable agriculture.

The adoption and economic performance of sustainable agriculture is determined by different factors such as agro-ecological conditions, household types, farm types, supporting institutions, among others. This makes blanket recommendations and promotion of agricultural practices inadequate in many contexts. Instead, policies seeking to promote adoption of sustainable agriculture technologies should be based on an understanding of how different factors condition the performance of those particular technologies. Stable and remunerative market prices for agricultural products produced using sustainable practices can help enhance the economic viability of adopting sustainable agriculture, as well as provide important safety nets for resource-poor farmers.

The role of institutions (both formal and informal) in facilitating the promotion and adoption of sustainable agriculture practices cannot be overemphasized. Up-scaling sustainable agriculture requires raising farmers' awareness and understanding of the potential benefits of sustainable agriculture practices. This in turn requires improving access to as well as the quality of information and education and training programs on sustainable agriculture for farmer and extension workers. It also requires institutional support to formal and informal farmer networks. Applied research, extension services, and development practitioners could serve as vehicles for the development and implementation of these practices. However, finding ways to create closer links between applied research and farmers on the ground, through improved extension systems or other channels, is still an area where much work is needed.

One of the major constraints facing the adopters of sustainable agriculture practices is biomass availability. To ease biomass constraints, policies have to be developed that: provide modern cooking fuel to rural households (e.g., via rural electrification, improved energy saving technologies, *locally produced biofuels*); encourage incorporating forage legumes in the cropping systems and rotation cycle to improve livestock productivity; encourage using integrated nutrient management; and encourage the strengthening and structuring of available rural labor sharing mechanisms.

Lastly, policies that seek to address market imperfections may be conducive to agriculture in general, and to sustainable agriculture in particular. For example, social capital-based connections and rural institutions could ease market imperfections arising from the fact that farmers in developing countries are not well integrated into input and output markets. Support to those institutions would be important in that context. In the same vein, policies should strive to improve security of tenure among farmers, thereby decreasing the risks associated with undertaking long-term investments in the presence of insecure tenure.

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