Chapter 7

Sustainable Agriculture and Natural Resource Management: A Policy Perspective

Gerald Shively and Dileep Birur

Forests, soils, grazing lands, and water provide the necessary foundation for agricultural activity and sustain the rural economies of most developing countries. At a conceptual level, the connections between rural populations and their natural resource base include an interlinked set of biophysical, economic, and social systems. These systems co-evolve in response to human desires and needs on the one hand and to environmental health and resilience on the other. At a more practical level, the ways in which land managers adapt to their physical environment are influenced by a policy environment defined by explicit or implicit incentives and constraints. These are determined by local, regional, and national policy makers. Policy makers establish the rules for legitimate behavior, observe outcomes, and subsequently adjust policies in light of competing interests and whatever mandate they may possess. For their part, farmers adjust their behavior in response to changing needs and in reaction to shifts in prices and policies. Of course, sometimes the extent to which farmers can respond may be quite limited. Equally important is that natural systems respond to human activity, sometimes abruptly, sometimes slowly, and sometimes in unanticipated ways. The aggregate patterns we observe are jointly created and evolve through this interplay, suggesting that an essential element of any strategy aimed at promoting sustainable agriculture and natural resource management must be flexible and adaptive at its core. It is quite important to recognize that pure subsistence is rare, and few, if any, smallholders operate completely detached from the market. As a result, the choices and tradeoffs made by national governments and international actors establish the incentives and constraints that farmers face and, ultimately, the crops and cropping systems they choose. Patterns of innovation, adoption, and adaptation reflect the social and economic fabric of rural communities and therefore differ markedly across time and space.

This rural fabric of farmers, their natural environment, and the policy setting in which farmers operate constitute a complex system. The key feature of a complex system, as underscored by Arthur (1999), is that outcomes are not deterministic and cannot always be easily predicted. Instead, outcomes are process-dependent and evolve over time. The policy part of this complex system includes three key components: (1) prices and markets, (2) public institutions and the rules and norms under which farmers operate, and (3) the spectrum of agricultural technologies created and made available both publicly and privately. Because most forms of agricultural production lead to degradation of resources in some way and because poverty reduction, food security, and unemployment are major challenges faced by developing countries, the problem of finding flexible and adaptive policies to ensure sustainable agricultural development is not easily solved. Nevertheless, environmental concerns and economic goals can be approached together through an adaptive learning process. Ideally, such a process will specifically acknowledge markets for what they are: a filter through which incentives for adaptation and change are transmitted.

It will be clear to the reader that policies related to agricultural prices and markets—for example, domestic price support programs—often directly influence smallholder performance. By extension, these policies also influence a range of important outcomes. These include rates of deforestation, water pollution, land degradation, and biodiversity loss on the one hand and rates of forest protection, soil and water conservation, and biotic conservation on the other. What may not be so clear is that policies not specifically directed at agriculture also play an important role in shaping agricultural outcomes because they influence the ways in which resources such as land, labor, and capital are used. Moreover, many cases of resource degradation in the developing world can be traced either to a lack of clearly defined and enforceable property rights or to the lack of implementation or enforcement of existing rights. For this reason, land tenure institutions are an integral part of the agricultural policy system. As Stiglitz (2003) points out, developing countries often suffer from limited competition in markets and imperfect information on the part of decision makers. As a result, Adam Smith's oft-celebrated "invisible hand" may not align private and social interests; therefore, institutions—including regulatory institutions and other functions of the state that shape the market—take on considerable importance in the realm of promoting sustainable development.

Moreover, because the technology of agricultural production, like that of most productive activities, is subject to innovation and adaptation, technology policy plays an important role in shaping the conditions under which smallholders operate. As Ascher and Healy (1990) have argued, many developing countries have adopted a policy bias in favor of agricultural modernization, taking the view that traditional peasant agriculture should be replaced by a more scientific, market-oriented, and specialized form of production. In some cases, the key to sustaining rural livelihoods may indeed be found in technological progress. However, as the experience of the Green Revolution has shown, the promotion of specialized monocultural systems has sometimes led to overexploitation of land and water resources and has sometimes generated unintended local and off-site effects. Thus technology cannot be viewed as an easy fix to smallholders' problems but rather as a component to be managed in a strategic and adaptive way.

Agriculture and Natural Resources: An Overview

Agricultural Expansion and Deforestation

Agricultural expansion is one important factor influencing rates of tropical deforestation and biodiversity loss. Global tropical deforestation exceeds 130,000 square kilometers a year and poses an enormous threat to biodiversity and the resilience of local and global environmental systems (Sterner 2003). Forest degradation, defined as a decrease in density or a disturbance in the forest ecosystem, is also a serious ongoing problem. Table 1 provides an overview of global trends in forest degradation. Forest loss over the three decades covered by the data in table 1 has been most acute in Central America (where the share of forest in total land area declined by 6.5%), East and Southeast Asia (6.5%), and Central Africa (2.8%).

Deforestation has many causes. In some settings, rates of deforestation are closely linked to changes in agricultural input and output prices, timber prices, tenure security, credit availability,

Table 1. Forest degradation and agricultural expansion (www.faostat.fao.org).

Region	Share of forest area to all land			% change in agricultural area (1961 to 2002)
	1961	1994	Change	
Africa	24.81	24.05	-0.75	4.97
Central Africa	56.05	53.25	-2.79	2.50
Eastern Africa	28.36	28.36	0.00	-1.63
Southern Africa	27.22	27.20	-0.02	-0.24
Western Africa	16.21	15.15	-1.06	10.74
Asia	21.99	20.71	-1.28	59.41
East and Southeast Asia	48.46	41.99	-6.47	8.22
South Asia	17.49	20.54	3.05	6.34
North and Central America	39.34	38.55	-0.79	-3.01
North America developed	40.85	40.77	-0.08	-7.34
Central America	35.48	28.99	-6.48	13.57
South America	54.24	53.13	-1.10	29.61
Europe	30.15	—	—	—
Eastern Europe	29.24	30.37	1.13	-8.89
Western Europe	30.44	34.33	3.90	-14.20
Australia	18.95	18.87	-0.08	-3.16
Summary				
Developed countries	36.50	34.86	-1.64	-3.25
Developing countries	31.36	29.88	-1.48	21.34
World	33.50	31.96	-1.55	11.06

and technological progress (Barbier and Burgess 2001). Macroeconomic policies are also implicated in deforestation. The textbox below highlights three important cases of agriculture-induced deforestation, providing examples of how economic policies have influenced rates of deforestation in Brazil, Cameroon, and Indonesia.

Deforestation in Brazil, Cameroon, and Indonesia

Binswanger (1991) and Hecht (1993) examined the complex interplay of major government polices such as tax exemptions, special tax incentives, land allocation rules, and agricultural credit and their effect on deforestation in the Amazon. The tax exemption policies for the agricultural sector in Brazil led private and corporate sectors to invest heavily in agriculture. With very high land ceilings, investments in agriculture resulted in accumulation of large land holdings. Because forestland was considered unused, a farm containing forests was taxed at higher rates than the one containing pastures or cropland. This provided an incentive for farmers to convert forested property into large pasturelands, leading to large-scale deforestation. A number of regional and sectoral tax breaks also encouraged investments in enterprises using cleared forestland. These structural changes in agriculture (reduced labor demand, increased mechanization) marginalized small farmers.

Gbetntom (2005) studied the causes and consequences of deforestation in Cameroon over three decades. An average of 130,000 hectares of forest was cleared each year in Cameroon during this period. Deforestation increased faster after Cameroon's boom, the adoption of structural adjustment policies, and the devaluation of the CFA franc. During the oil boom in the late 1970s, higher international prices for coffee and cocoa encouraged farmers to clear forests to plant these crops. Also, the oil boom stimulated construction, which generated greater domestic demand for timber. While structural adjustment policies reduced coffee and cocoa prices by 60% and 40%, respectively, and led farmers to eventually abandon these crops, food crop expansion led to even greater rates of deforestation. The prices paid to producers of coffee, cocoa, and food crops, as well as to exporters of timber, effectively influenced the speed of forest clearing in Cameroon. However, Gbetntom's results show that short-run responses to changes in perennial prices were weaker than responses to changes in food crop prices, indicating more rapid forest clearing for annual crops than perennials.

Indonesia also illustrates how economic policies influence rates of deforestation. Sunderlin et al. (2001) examined the effect of Indonesia's economic crisis in the 1990s on small farmers' welfare, their agricultural practices, and natural forest cover. Because of a drastic decline in real household income during the East Asian economic crisis, farmers relied on nearby forest resources rather than waiting for additional income from agricultural production. An increase in timber and rattan harvesting was observed during the crisis due to combined effects of economic hardship, favorable timber prices, and reduced forest policing. Despite a decline in rubber prices, forest clearing to establish rubber production increased because rubber provided a safety net for farmers. Higher prices also increased the area under pepper.

Land Degradation and Soil Erosion

Land degradation is a major problem facing agriculturally dependent populations in the developing world. Table 2 provides data on rates of land degradation worldwide. Soil erosion in tropical and subtropical watersheds leads to siltation, water flow irregularities, a decline in irrigation efficiency, and water pollution through soil and agrochemical runoff. One estimate suggests that during the early history of agriculture (beginning roughly 10,000 years ago) approximately 25

Table 2. Land degradation due to agricultural activities (FAO, http://www.fao.org/ag/agl/agll/terrastat/).

Region	Total area (1,000 km²)	Total degradation (1,000 km²)	Degradation due to agriculture (1,000 km²)	Total area degraded (%)	Degradation due to agriculture (%)
Asia and Pacific	28,989	8,407	3,506	29.0	41.7
Europe	6,889	3,274	727	47.5	22.2
North Africa and Near East	12,379	4,260	759	34.4	17.8
North America	19,237	3,158	2,427	16.4	76.9
North Asia, east of Urals	21,033	4,421	1,180	21.0	26.7
South and Central America	20,498	5,552	1,795	27.1	32.3
Sub-Saharan Africa	23,754	5,931	1,996	25.0	33.7
World	134,907	35,005	12,391	25.9	35.4

million metric tons of soil was lost each year worldwide. This annual loss rate has accelerated to 300 million tons in the past 300 years and to 760 million tons in the past 50 years (McNeely and Scherr 2003).

Approximately 550 million hectares of land globally are degraded due to agricultural mismanagement—primarily due to water erosion and soil loss. Another 40 million hectares are affected by soil salinization and water logging (UNEP 2002). The extent of soil erosion depends on the complex interaction of a number of factors such as the resilience of the natural resource base, institutional conditions, population growth, and the policy environment (Ananda and Herath 2003). (Of course, population growth need not necessarily lead to land degradation. As Boserup [1981] pointed out, population growth can promote more intensive practices and more favorable technological and organizational innovation that will not only increase productivity but also improve environmental quality.)

The drive among smallholders to achieve food security (or profit) often leads to high rates of chemical use and soil depletion. The relative prices for inputs and outputs are often facilitating factors. For example, Barbier and Burgess (1992) show how higher crop prices in Thailand led to agricultural expansion and how government subsidies of fertilizer in Malawi encouraged overuse of fertilizers by smallholders without providing complementary improvements in cropping systems and resource conservation. Yet the logic of input subsidization is sometimes supported. For example, Fan et al. (2008) demonstrate how subsidies for credit, fertilizer, and irrigation were crucial for small Indian farmers to adopt new technologies, particularly during the initial stage of the Green Revolution in the late 1960s and 1970s. But they also show that investments in agricultural research, education, and rural roads were the three most effective public spending items in promoting agricultural growth and reducing poverty, suggesting that expensive subsidies that crowd out these other forms of public investment may be counterproductive in the long run. Similarly, looking across three continents, Rios, Masters, and Shively (2008) find that improvements in agricultural productivity are more conducive to participation in agricultural markets than are improvements in market infrastructure and access.

Biofuels also illustrate how economic policies affect the environment. Interest in biofuels has been growing at a rapid pace in recent years. Rising concerns over energy security and mitigation of greenhouse gases has led many developed countries to undertake biofuel programs supported in large part with massive subsidies. The US Energy Independence and Security Act of 2007 mandates the use of biofuels to increase to 36 billion gallons by 2022 from 7 billion gallons in 2007. The European Union biofuels directive requires its member states to realize a 10% share of biofuels on the liquid fuels market by 2020 from the current share of about 3%. These ambitious mandates depend on large-scale production of feedstock that directly or indirectly competes for land and water resources. Although, biofuels are considered by many observers to offer some economic benefits, they also pose enormous challenges to the environment. Accounting for emissions from land-use change, Searchinger et al. (2008) found that use of corn-based ethanol nearly doubles greenhouse gasses over 30 years instead of producing a 20% savings, as widely perceived. The same study argues that biofuels from switchgrass, if grown on US lands, would increase emissions by 50%. The environmental effects of biofuel programs largely depend on the type of feedstock used for production. Fargione et al. (2008) assert that the net effect of biofuel production through clearing of carbon-rich habitats such as rainforests and grasslands would result in an increase in CO2 emissions relative to fossil fuel use. While these findings are still being debated, concerns about deforestation and land degradation are also being voiced across the world, a synthesis of which is given in the textbox below.

Impact of biofuel programs on the environment

Rising interest in crop-based biofuels in developed countries, particularly the European Union and the United States, has spurred the demand for feedstock. The demands have been transmitted to a number of other locations, including Brazil and Southeast Asian countries, which have comparative advantages in producing these crops. While the United States mainly produces corn-based ethanol, the European Union countries have been focusing on vegetable oil-based biodiesel. Expansion of corn area in the United States has been displacing soybean production to the Brazilian Amazon. Altieri and Bravo (2007) report that soybean cultivation has already resulted in the loss of 53 million acres of forests in Brazil, 35 million acres in Argentina, 5 million acres in Paraguay, and 1.5 million acres in Bolivia. Oil palm is another feedstock, grown mainly in Southeast Asia. It is gaining in popularity because it is cheap and efficient for biodiesel production. EU imports of palm oil have escalated in recent years, resulting in expansion of oil palm plantations in Indonesia, Malaysia, and Thailand. The Friends of Earth (2005) reports that about 8 million acres of forest were cut for oil palm cultivation in Indonesia, and about 1.9 million acres were converted in Malaysia by 2003. Rapid increases in palm oil prices in recent years (from an average of $479 per metric ton in 2006 to a peak of $1,390 per metric ton in March 2008) have exacerbated the rate of deforestation in oil palm-growing regions.

Another potential problem associated with crop-based biofuels is land degradation. For example, higher corn prices in the United States could induce farmers to withdraw lands from the United States Department of Agriculture's voluntary Conservation Reserve Program (CRP) to increase corn production (Dufey 2007). The USDA reports that about 37 million acres are under CRP, of which 7 million acres are suitable for corn production. Other land could be used to support production of non-food crop biofuel feedstocks. However, conversion of these lands could result in high rates of soil loss and reductions in soil quality, highlighted by the extent to which subsidy policies for biofuel programs play a crucial role in determining the scope of agriculture's impact on the environment.

Water Use and Management

Globally, about 250 million hectares are under irrigation for agriculture, a major portion of which is in India, China, and Pakistan. Many developing country governments provide irrigation water either free or at highly subsidized prices. This has led to inefficient and unsustainable patterns of water use and depletion of water resources. Although water scarcity typically reflects inadequate rainfall, even rain-abundant countries experience scarcity because flawed policies undermine efficient water use and management. Pingali (2001) argues that, in Asia, government policies aimed at food self-sufficiency have led to degradation of water resources and reduced agricultural productivity. Estimates suggest that water tables have been falling by up to 1 m annually in the North China Plain and by 25 to 30 m per decade in parts of India (McNeely and Scherr 2003).

Externalities from Agricultural Chemicals

Agricultural advancement and market-oriented production is generally accompanied by intensified use of chemical inputs, particularly fertilizers and pesticides. Indiscriminate use of these chemicals has serious repercussions for the environment. High rates of chemical fertilizer use tend to decrease soil organic matter and pesticides can pollute water, air, soil, and even alter the ecosystem by harming non-target organisms. The misuse of agrochemicals in many developing countries reflects two facts. First, policies have only in recent years been formulated and legislated in many countries, and not all countries have the regulations to implement the policies that have been promulgated. Second, in places where it is possible, there has often been a lack of implementation of environmental regulations and policies governing agrochemical use.

Chemical inputs are widely perceived to benefit agricultural production. But some studies question the value of indiscriminate use of agrochemicals. For example, in a study of rice production in the Philippines, Antle and Pingali (1994) concluded that reduced use of insecticides would have a small overall effect on productivity because crop losses from reduced pest control would be offset by labor productivity improvements from the better health of farmers. They concluded that policies aimed at reducing insecticide use in rice production, including reduction or elimination of subsidies, would likely improve overall farmer welfare. Garcia and Shively (2008) measured the impact of pesticide reductions on the efficiency of smallholder coffee producers in Vietnam and found that modest restrictions on pesticide intensity had very small deleterious effects on overall productive efficiency. Their finding largely reflects the fact that the least efficient farms in the sample were generally those that were applying pesticides at rates above those that were optimal.

Role of Policy

As stated above, the perspective of this chapter is that the policy system has three distinct points of entry to smallholder agriculture: markets, institutions, and technologies. We illustrate the basic conceptual linkages among these in figure 1 and further explain the key relationships suggested by this schematic in table 3. The entries in table 3 aim to highlight the ways in which each policy dimension influences particular smallholder decisions that influence natural resource management. We elaborate below.

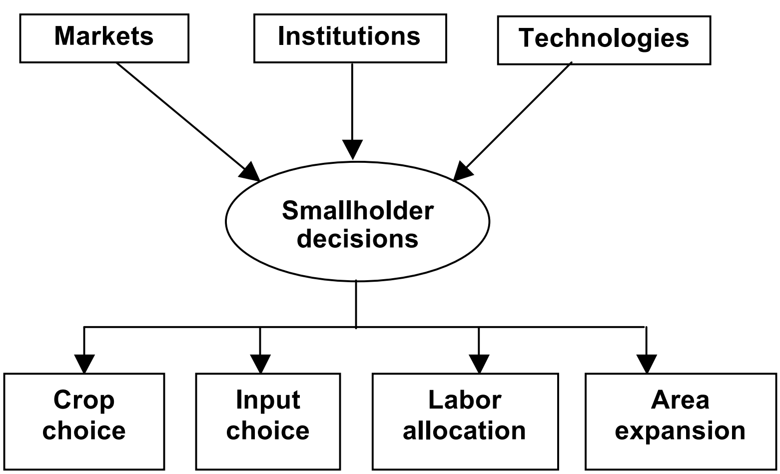

Figure 1. Smallholder decisions and the policy system.

Table 3. Policy focus and smallholder decisions.

Policy focus	Choice of crops	Input choices	Labor allocation	Area expansion
Markets	Producer prices drive cropping patterns	Input intensity depends on subsidies, credit, insurance, etc.	Off-farm opportunities influence on-farm labor allocation	Markets for agri-products influence decisions for agri-expansion vs. agri-intensification
Institutions	Institutional framework (e.g., property rights) influence planning horizons and incentives to invest in strategies with long-term payback	Banks, co-operatives, market agencies influence input use	Property rights and tenure security influence rates of urban/rural migration	Tax and legal framework may influence forest conversion to agriculture
Technology	Crops choice will reflect profitable and easily adoptable technologies that favor particular crops	Some technologies may favor certain inputs (labor or chemicals) and may be input-intensive or input-saving	Technologies may be labor-intensive or labor-saving	Profitable technologies may promote intensification or expansion depending on their scale characteristics

In traditional smallholder production systems, optimal resource allocation is frequently determined year by year, with farmers adjusting to changing conditions over time through trial and error (Tomich et al. 1995). Typically, and conditional on biophysical and socio-cultural factors, a farmer's crop choice is strongly influenced by current market prices and expectations for future prices. Concerns regarding price variability also influence crop choice. In thinking about how policies influence crop choice by way of prices, it is important to recognize that price support programs may encourage farmers to plant some crops rather than others and that trade and import restrictions, including phytosanitary regulations in many countries, may indirectly raise the domestic price of a commodity and encourage its production. Moreover, policies that reduce the uncertainty or variability of crop prices will, other things equal, make those crops more attractive to farmers (Coxhead et al. 2002; Shively 1998).

The institutional framework can also influence crop choice. Farmers tend to produce only those commodities for which markets are well established. Furthermore, secure property rights regimes have been widely shown to influence farmers' decisions to plant perennial crops, which are generally more environmentally desirable than annual crops (due to less soil disturbance and greater year-round canopy) but also require long planning horizons and some incentive to invest in strategies with long-term payoffs. Many improved agricultural technologies have been criticized for being biased towards large farms and unaffordable for smallholders. Available technology may influence the choice of crop, for example, if the availability of irrigation or germplasm causes some crops to be favored over others.

The input choices of smallholders depend on the relative cost of inputs, as well as access to financing in cases where farmers must borrow to purchase inputs at the beginning of the cropping season. As a result, the overall intensity of input use may depend on specific input subsidies (e.g., for fertilizer), access to credit, and access to insurance, remittances, or other sources of income, for overuse of inputs is often a strategy employed to reduce risk. Even farm size, largely under the influence of policymakers in areas with active land reform programs, may influence the intensity of input use. Land constraints tend to encourage higher cropping intensity, which can reduce forest clearing but also lead to intensive use of inputs.

Labor availability and labor allocation have been shown to be important factors influencing natural resource management by smallholders. While abundant labor is a stylized feature of rural areas of developing countries, labor shortages, especially at peak times in the agricultural calendar, often undermine labor-intensive resource management schemes. In contrast, abundant labor may depress wages, and as the opportunity cost of rural labor falls, incentives to engage in environmentally degrading activities with short-run payoffs increase. Using data from Colombia, Heath and Binswanger (1998) show that intensification-led resource management is not automatic. Instead, it arises as an outcome of investment decisions made by farmers and requires enabling policies and institutional support. Using data from the Philippines, Shively and Fisher (2005) demonstrate how competition for labor off farm can strongly influence a farmer's decision to intensify or expand production on farm.

Technology choice can also influence outcomes. Other things equal, as agricultural commodity prices rise, smallholders have incentives to expand agricultural area. If available technologies favor adoption of machinery, then the agricultural sector will shift from labor-intensive to capital-intensive forms of production. In turn, economies of scale in mechanized production may favor agricultural expansion. The effectiveness of the legal framework in a country also influences incentives for area expansion. In Brazil, for example, individuals seeking tax shelters available to agricultural producers helped to precipitate deforestation. Area expansion also depends on whether the available agricultural technology promotes intensification or expansion. Shively (2001) relates data from the Philippines showing that irrigation of lowland farms acted as a magnet to pull labor away from forest margins, thereby reducing local rates of deforestation to some extent. Tomich et al. (1995) argue that specialization and technological change are the primary driving forces available for transforming an agrarian economy into a diversified and highly productive economy.

Toward a Framework for Policy Analysis and Design

"Getting prices right" has been a foundation for economic development policy over the past four decades. Allowing farmers to participate in markets and allocate resources on the basis of market signals has been a powerful mechanism for achieving food sufficiency in many countries. However, agricultural development has failed to alleviate poverty in many settings. As a result, increasing attention has come to be placed on market failures, in particular on the weakness or absence of institutions to support market development. Bator (1958) defined market failure as "the failure of a more or less idealized system of price-market institutions to sustain desirable activities or to stop undesirable activities." In fact, many of the policy failures reflected in very low or negative national income growth in sub-Saharan African countries since 1970 have come to be blamed as much on institutional failures as on market imperfections manifested in "incorrect" prices (Bruce and Mearns 2004; Gabre-Madhin and Haggblade 2001).

But what, exactly, are institutions? Different disciplines tend to define the term differently. Among economists, Bromley (1989) building on Matthews (1986) and the early work of Commons (1934) defines institutions as rights and obligations. These may be general conventions (regularities in human behavior) or specific entitlements (sets of legal ordered relations). In this sense, many of the organizations that one might regard as "institutions" (banks, informal credit markets, government ministries) may be more accurately thought of as entities created and defined by underlying institutionally ordered relations. In examining links between policies and natural resource use, Sterner (2003) highlights institutional failure as a key causal factor precipitating resource degradation. Institutional failure is typically equated with a lack of enforced rights of access to and use of an environmental resource, resulting in degradation of the resource (primarily because agents do not internalize the costs of damage to the resource). Yet institutional failure can be construed more broadly. Governments and government agencies, whether national, provincial, or local, are frequently the primary institutions through which policies are implemented. Faulty policies, an absence of policies, or the failure to enforce policies and laws all constitute institutional failure. Though many norms exist in rural communities with respect to water sharing, community grazing, and use of fisheries, there is always a threat of losing these norms in the process of development if communities and governments fail to maintain, adapt, and enforce policies and practices consistent with goals of sustainable development. Arguably, effective adaptive management requires effective governance, and institutional failure is therefore somewhat synonymous with ineffective governance.

Equally important to failures to achieve agricultural development, let alone sustainable agricultural development, is a shortage of appropriate technologies for smallholders operating in challenging or "least favored" environments. Where markets and institutions have been seen to fail, attention has been refocused on the possibility that new technologies might increase agricultural production while simultaneously conserving natural resources. Of course, new technologies alone are insufficient. Complementary policies are needed to stimulate an innovative learning environment, disseminate new technologies, evaluate and monitor their adoption and effectiveness, and modify both the technologies and the policy environment. When these complementary policies are in place, one might then regard technology policy as adaptive and therefore consistent with the aims of sustainability.

Our perspective is that single strategies to pursuing sustainable development—whether through markets, institutions, or technologies—are good. But single strategies are unlikely to succeed. In figure 2 we combine and intersect the three spheres of the policy system as a way of encouraging

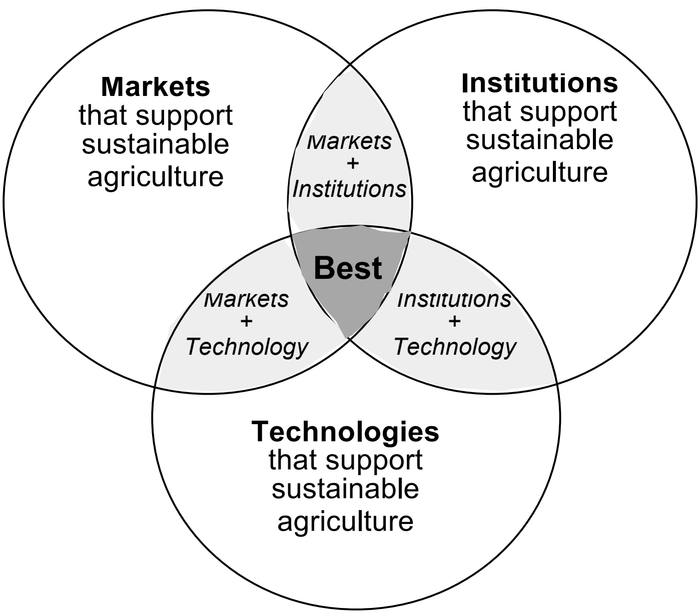

Figure 2. Schematic diagram of the market-institution-technology nexus.

Table 4. Examples of economic polices influencing the environment in selected developing countries.

Country	Economic policies	Findings and example
Brazil	Tax policies, land ceiling legislation, credit and subsidies for livestock production	Tax exemptions in agriculture led private and corporate sectors to invest in the agricultural sector. Very high land ceilings resulted in accumulation of huge holdings by a few companies, marginalizing small farmers. Regional tax credit schemes encouraged uneconomical corporate livestock production, leading to conversion of forest land into large-scale ranches. (Binswanger 1991; Hecht 1993; Mertens et al. 2002)
Cameroon	Structural adjustment policies and devaluation of CFA franc	High international coffee and cocoa prices during the late 1970s encouraged forest clearing. Though policies gave greater importance to food crops, devaluation of the CFA franc in 1994 doubled timber prices, which stimulated timber production. (Gbetntom 2005)
Philippines	Policies on support prices, import reduction, trade interventions, and R&D support to develop yield-raising and pest-resistant technologies	As a result of the policy mix, the area under corn and vegetables expanded in Manupali River watershed, leading to a steady decline in forest cover, an increase in soil erosion and sedimentation, and an increase in pesticide use. (Shively 1998; Coxhead 2000)
	Agricultural intensification	Irrigation development led to labor absorption and a reduction in forest clearing in Palawan. (Shively and Pagiola 2004)
Morocco	Trade liberalization and water policies	The water allocation system existing before liberalization favored area expansion in water intensive crops such as sugarcane, leading to an unsustainable pattern of water use. A low urban water tariff is projected to produce a water deficiency in Morocco by 2020. A rise in the water tax would reduce real GDP slightly but reduce water use significantly. (Munasinghe and Cruz 1995; Tyner 2004)
Vietnam	Trade liberalization, greater access to the world market	Higher coffee prices in the 1990s brought more barren and forested land under coffee production, and increased migration. Forest cover decreased from about 90% in the 1960s to less than 50% in the late 1990s (Oxfam 2002b).

the reader to consider interactions among the three. Our view is that, to move toward sustainable use of resources, the best development strategy will be one that aims to get all three mechanisms working together, that is, one that aligns incentives through adaptive processes in ways that are individually and together consistent with the goal of sustainable use of resources.

The ways in which each policy sphere can affect behavior, decisions, and adaptation on farms is further articulated in table 3. It is important to note that one key aspect of complex adaptive systems is that agents acting in those systems adapt as conditions (i.e., policies) change. These adaptations in turn create a policy environment in which other agents may make further reactive behavioral changes and so on. In such dynamic settings, it is not just that multiple "strategies" are important for successful adaptation on the part of agents but also that the policy process itself must become iterative to deal rapidly with unintended consequences, on the one hand, and the responsiveness of agents on the other. This is one reason why many observers regard local, democratic institutions as most desirable.

Table 4 provides examples of situations in which specific economic policies have been linked to environmental outcomes. We summarize the basic linkages below.

Markets

Several studies have analyzed the relationship between policies, the market for agricultural goods, and the natural environment. Trade policy reforms are the most noteworthy example of policies that can directly or indirectly affect agricultural producers. Trade reforms tend to boost income and production. By relocating production globally, they can also lead to positive environmental changes (Anderson 1998). However, trade policies rarely embody environmental considerations. Because agricultural producers may not have to pay for damages to the environment, international trade that promotes agricultural expansion in environmentally sensitive areas can lead to an increase in environmental damage.

In evaluating the effects of economic liberalization, Thorbecke (2000) makes a distinction between two types of policies: those that focus on "getting the prices right," such as currency devaluation and elimination of subsidies, and those that focus on "getting the prices and institutions right," thereby improve market efficiency. So, for example, removing agricultural subsidies is advocated by many economists based on the principle that scarce resources ought to be allocated based on their "true" prices (ideally the shadow values of those resources). Lifting output prices or reducing input prices below market levels can lead to overuse of natural resources in agricultural production, thereby contributing to environmental degradation. By reducing input subsidies and thereby increasing prices for modern inputs, policies can discourage the cultivation of crops requiring heavy use of machinery and chemicals, leading smallholders instead to increase the intensity of labor use (Young and Bishop 1995). Getting prices right by correcting market distortions caused by input subsidies can promote a more efficient and sustainable use of resources. In many cases, inputs such as fertilizer are subsidized on the grounds that lower prices are required to generate their use, in some cases because farms lack access to credit to purchase the inputs. But in these cases, it may be far preferable to eliminate the original distortion (the credit constraint) rather than introduce a new distortion (a subsidy) to compensate.

In evaluating the effects of trade liberalization on natural resource use in agriculture, it is important to consider what are referred to as scale, composition, and technique effects. (The Environmental Kuznets Curve purports that economic growth and environmental pollution typically follow an inverted "U" shape. At early stages of economic growth, economic development tends to induce increased pollution. As incomes rise, environmental degradation may reach a peak and then start to decline, due to increased demand for higher quality environmental services and to changes in the composition and technique of production.) The scale effect refers to whether the scale of production in a specific location or country increases as a result of new trade patterns. Other things equal, if output increases, then any environmental impacts associated with production will increase also. The composition effect, sometimes called the structural effect, refers to the change in the composition of activities toward those sectors with comparative advantage. So, for example, a trade liberalization policy might increase the comparative advantage of a country in producing a certain good by tilting relative prices in favor of that good. If the favored good replaces one that is more environmentally damaging, then liberalization would have an environmentally beneficial impact, judged on the basis of the composition effect. For example, a policy that caused smallholders to replace annual crops with perennials might be judged beneficial on the grounds that perennial systems provide greater year-round ground cover, less soil disturbance, and greater biodiversity opportunities.

Finally, changes in the regulation of markets that lead to technology transfer can generate shifts in the composition and location of production and consumption. The technology effect refers to a nation's access to resource-efficient production processes due to trade liberalization. For example, during the 1990s Vietnam experienced a change in the composition and scale of agricultural activity as a result of trade liberalization. Production of modern varieties of coffee expanded, as did other export-oriented agricultural activities. However, rather than replacing annual crops, in Vietnam coffee tended to expand into previously forested areas. The textbox below highlights this process and underscores the importance of local features in shaping whether trade liberalization has positive or negative environmental effects. In contrast, Shively (1998) analyzed the influence of changes in agricultural prices on land-use decisions and environmental outcomes in the Philippines, focusing on agricultural households that were choosing among a portfolio of crops and making investment decisions regarding tree crops. That analysis found that pricing policies favoring perennial crops and policies aimed at liberalizing agricultural trade would tend to encourage tree planting, which was judged less environmentally damaging than the production of annual crops. Crop diversification was shown to have beneficial impacts on both soil erosion rates and species diversity.

Trade liberalization and coffee expansion in Vietnam

Vietnam experienced rapid growth in coffee production and coffee area during the 1990s. Two studies looked carefully at the growth in Vietnam's coffee sector: International Institute for Sustainable Development (1999) and Oxfam (2002b). One of the main reasons for the rapid increase in coffee cultivation in Vietnam was a sudden rise in the world coffee price in the early 1990s and government response through market and trade liberalization. Due to severe frost in 1994, Brazil lost a substantial portion of its production, and global coffee prices rose. The higher profitability of coffee made it popular in Vietnam, and the area expanded to cover about 21% of total crop area by 2000, compared with less than 2% of crop area in 1994. This area expansion came directly at the expense of forest and arose in response to both spontaneous and state-sponsored migration to upland coffee-growing areas. Among the difficulties generated by the rapid expansion in coffee production have been indiscriminate use of chemical pesticides and high rates of water extraction for irrigation.

Focusing on a range of Asian countries, Young and Bishop (1995) argue that removal of price distortions in input and output markets would enable farmers to allocate the resources more judiciously, which would encourage diversification away from rice and wheat. For example, gradually dismantling pesticide subsidies would result in decline in use of pesticides for cereals compared with higher value crops (Pingali 2001). Predicted impacts, even within a country, are rarely uniform, however, and overall environmental effects tend to hinge on whether new agricultural activities will be more or less damaging than those they replace (Coxhead 1997).

Achieving food security is a primary concern of any developing country. Climatic challenges are often a significant obstacle to food production and also compromise attempts to manage natural resources. In the case of arid lands, Tyner (2004) reports a significant increase in production of common wheat in Morocco during the past two decades. This increase is credited to government pressure on farmers, higher price incentives, greater use of improved seeds and fertilizer, and expansion of area under irrigation. While successful from the perspective of food production, this increase came at a high cost for the agriculture sector, rural development, and the environment. In another study of Morocco, Karaky and Arndt (2002) cite the tariff policy for wheat, which is set based on world prices with the objective of minimizing domestic price fluctuations around a target price. Similar kinds of distorting policies have persisted in sugar and meat products, which have increased the production of high-value crops and marginalized area under traditional crops such as barley. The latter tends to be less intensive in the use of water and chemical inputs. These policies have transformed Morocco from a net exporter to a net importer of barley and have undermined environmental quality.

Institutions

Domestic rules and international agreements can be very important in fostering or hindering sustainable agricultural development. Investment in research and development, market infrastructure, and dissemination of advanced technologies all influence environmental outcomes in the long run. Although many factors contribute to the global movement of production, including the cost of labor, raw materials, and transport, in the case of both agriculture and industry it is sometimes the case that a combination of strict environmental regulations in developed regions and weak environmental standards in developing regions can encourage the movement of polluting industries across borders—the "pollution haven" hypothesis. Conversely, institutions to support and create identity around environmentally sound cropping practices (whether through organic labeling, fair trade labeling, or environmental branding) can provide both markets and—through higher prices—incentives for farmers to participate in new activities and adapt to new opportunities.

Environmental clauses of the World Trade Organization agreements also influence natural resource use in the agriculture sector. World Trade Organization guidelines typically prevent trade restrictions based on the method of production, thereby making it difficult to use environmental considerations to block trade. However, sanitary and phytosanitary (SPS) regulations may still apply to exporting companies. Damodaran (2002) studied coffee enterprises in India, examining those companies' attempts to comply with SPS regulations and other national and international environmental rules. SPS-complying farms were found to have experienced an increase in labor input per unit of land, largely as a result of replanting and altering the intensity of cultural operations. Compared with non-SPS complying farms, complying farms were found to engage in more biodiversity-depleting activities. These included felling of endemic trees, stumping of non-endemic trees, and converting tanks and ponds for wastewater storage. Such evidence suggests a strong need to create formal institutions that can harmonize such disparate issues as SPS and biodiversity conservation, and to do so in ways that fit within the terms of national laws and international agreements.

The institutional feature most widely acknowledged in playing a local and fundamental role in promoting sustainable activities is security of land tenure. Security of tenure helps to reinforce a farmer's long-term perspective in his land and also often provides a form of collateral that facilitates borrowing and investment in productive activities such as tree planting. (Raintree [1987] provides a comprehensive catalog of empirical evidence regarding the influence of tenure on natural resource management.) Although security of tenure is often equated with private property rights, a private property rights regime is neither necessary nor sufficient to ensure the sustainability of activities. Indeed, the literature contains many examples of sustainable systems built on common property regimes (Bromley 1992).

Technology

In the past, the bulk of attention on technological approaches to agriculture has focused on promoting particular specialized types of innovations, either with narrow applications or with clear benefits for outsiders who are responsible for developing and marketing the technologies, such as improved varieties. In recent years, however, new thinking on the topic of innovation and technology adoption has arisen. This thinking acknowledges that there are roles for policies that promote innovation in general (for example, Douthwaite 2006) and for policies that promote innovations that more specifically hold out promise to be developed locally in an adaptive management context. The latter may especially improve local—and possibly global—competitiveness and profitability of highly localized (and sometimes specialized) production processes.

Of course, the application of biotechnology is fundamentally changing the structure of agriculture in the 21st century, especially in industrialized countries. The introduction of genetically modified (GM) crops and their possible economic and environmental implications has emerged as a subject of contentious debate. Much of the early literature on this subject focuses on developed countries because many of those have been relatively slow in opening up to GM crops. Qaim and Zilberman (2003) analyzed the yield effects of GM crops in developing countries based on the example of Bt-cotton in India. As indicated in table 5, the yield effect of GM crops is high in tropical and subtropical regions, largely because the pest pressure is also high in those regions compared with temperate areas.

Though trials indicate some positive yield effects and also reductions in pesticide use, concern over potential environmental and health risks associated with GM crops has resulted in limited acceptance of GMs by policy makers in developing countries. It has been argued that, because many GM crops are developed for pest resistance, they would be easier to manage at the farm level and could increase smallholder yields while reducing pesticide use. At this time, greater public investments are justified to evaluate the spillovers of the technology and the potential effects on natural resource management.

Integrated pest management (IPM) involves control of pests and diseases through the use of eco-friendly methods aimed at reducing (not always eliminating) pesticide usage. Cuyno et al. (2001) analyzed the environmental benefits of IPM in the Philippines using contingent valuation and found that practicing IPM proved to be a win-win situation. Farmers' willingness to pay to reduce pesticide risk was quite high, and the savings in direct pesticide costs were almost twice the environmental benefits. The study called for public policies to encourage IPM adoption and also institutional support for research and information dissemination.

Table 5. Expected effects of pest-resistant genetically modified crops (adapted from Qaim and Zilberman 2003).

Region	Effect on pest pressure	Incentive to adopt chemical alternatives	Effect on yields
Developed countries	Low to medium	High	Low
Latin America (commercial)	Medium	High	Low to medium
China	Medium	High	Low to medium
Latin America (non-commercial)	Medium	Low	Medium to low
South and Southeast Asia	High	Low to medium	High
Africa	High	Low	High

Summary

There are few strict lessons for adaptive management of complex adaptive systems. However, tradeoffs and opportunities do emerge in various settings.

In the case of markets and pricing policies, innovations that can be sustained over time will have to serve the interests of both agricultural producers and policy makers. Those that will tend to support sustainable agriculture and natural resource management will be those that accomplish the following:

- Remove input subsidies, especially on chemical inputs. In settings where subsidies have been justified to correct policy failures, the original market failure should be addressed.
- Encourage perennial crops over annual crops. To the extent that perennial crops can compete financially with annual crops and provide reliable income for farmers, they often are a better option for provision of environmental services and protection of natural resources.
- Promote resource-conserving methods rather than area expansion. Where area expansion has occurred as a reaction to limited access to other productive resources or specific markets, policies should aim to facilitate farmers' access to resources and markets and—importantly—aim to increase rates of on-farm productivity to alleviate poverty-led area expansion.
- Encourage labor use where labor is abundant and discourage labor intensity where labor is scarce. To be successful, policies must be aligned with the economic logic of household production. It should also be emphasized that the economic logic of household production is itself a moving target.

Institutional innovations that will tend to support sustainable agriculture and natural resource management will be those that accomplish the following:

- Reduce smallholder production and income risk, either by reducing yield risk at the farm level or by reducing price risk at the market level.
- Strengthen local institutions, especially in ways that promote local accountability for resource use.
- Support property rights and establish mechanisms through which those secure rights can be mobilized in support of forward-looking investments to make resource use more efficient and sustainable.
- Support the building of human, social, and physical assets so that natural forms of capital are transformed into more productive forms of capital, rather than merely consumed or squandered.
- Expand the scope for combining and coordinating the efforts of national line agencies such as ministries agriculture and the environment (such efforts will help to ensure resource allocation patterns serve the broadest set of interests).
- Link smallholders to markets to support rural livelihoods, keeping in mind that "market linkages" are more than just roads and bridges but include communication, education and training, and support to help farmers realize the gains in efficiency that result in marketable surpluses.

Technology innovations to support sustainable agriculture and natural resource management must accomplish the following:

- Aim to be favorable to smallholders and cognizant of scale efficiencies and possible resource constraints that limit adoption and/or adaptation.

- Be consistent with market and institutional incentives, especially in situations where markets for particular products are thin or seasonal.
- Where possible, promote perennial crops, especially when such promotion serves to improve environmental conditions through soil and water conservation or biodiversity protection.
- Where possible, encourage agroforestry or multi-species systems over monocultural systems to increase the resilience of the overall system and help moderate economic variability.

Opportunities on the Horizon

We close this chapter by briefly highlighting three emerging areas of policy for those interested in sustainable agriculture and natural resource management. Each represents a potential opportunity to align the economic interests of smallholders more closely with concerns regarding environmental management.

Clean Development Mechanism of the Kyoto Protocol

It has been widely argued that industrialized economies, which constitute only one-fifth of the world's population, are causing disproportionate environmental damage through their emissions of carbon dioxide and other greenhouse gases (Oxfam 2002a). As described by the United Nations Framework Convention on Climate Change (UNFCC 2006), the 1997 Kyoto Protocol is the main legally binding instrument for carbon emissions in the developed countries. The protocol identifies annex I (industrial) countries that pledged to reduce their emissions of greenhouse gases to 5.2% below 1990 levels. (Substantial literature addresses the potential for increased energy prices due to the Kyoto Protocol. The higher energy prices would lead to changes in acreage of irrigated and dry land crops, their yield, total output, and prices of both output and inputs. The increase in variable cost due to energy price might cause farmers to substitute inputs and alter cropping patterns. See Manne and Richels [2004].)

Annex II countries (developing) were not assigned caps on their emission of greenhouse gases. The clean development mechanism provides for high-income countries to implement project activities that reduce emissions in low-income countries in return for certified emission reductions that could be used to meet their emissions targets under the Kyoto Protocol. These provisions enable technical cooperation between developed and developing countries resulting in sustainable development. The development of biomass fuels is one area where the aims of the clean development mechanism closely align with the goals of sustainable agriculture and natural resource management.

Payments for Environmental Services

Command-and-control policy instruments existing to conserve environmental and ecological resources have rarely succeeded in their purpose. The main principle behind PES is that those who provide valuable environmental services should be compensated for doing so, and those who benefit from environmental services should pay for them (Pagiola et al. 2005). Wunder (2005) defines PES as a voluntary transaction where a well-defined environmental service is being bought from a provider if and only if the provider secures the provision. Unlike command-and-control regulations, which aim directly at protecting resources, PES schemes use economic incentives to conserve or restore resources of concern (USAID 2007).

PES programs have been implemented in several Latin American countries, including Costa Rica, Colombia, Ecuador, El Salvador, and Mexico (Pagiola and Platais 2006). To slow deforestation, PES programs in these countries rely on the governments offering cash to communities in exchange for agreeing to conserve forest resources. Costa Rica introduced Pago por Servicios Ambientales, a PES program under which private landowners are paid by the Costa Rican society, water users, and carbon buyers, for conservation of native forest and reforestation (Pagiola and Platais). In Mexico, under Pago por Servicios Ambientales Hidrologicos—Payment for Hydrological Environmental Services—water users pay *ejidos* in priority watersheds for avoiding deforestation. In Heredia, Costa Rica, and in Quito, Ecuador, water users pay an additional fee to private landowners for protecting the town's water supplies. Similarly in Cauca Valley, Colombia, local municipalities pay private landowners for protecting water supplies. In Yamabal, El Salvador, municipalities pay for enhancing recharge of water sources by practicing land uses that promote infiltration in the aquifer recharge area (Pagiola and Platais).

Pagiola et al. (2005) elucidate several potential applications of PES in the Philippines. A current program requires operators of hydroelectric power facilities to pay a small fee per kilowatt-hour of electricity sales, a portion of which goes into a special fund to assist with watershed reforestation and management. In most settings, however, PES systems are very new, and their overall effectiveness remains uncertain, however promising. Rather than being a drawback to their implementation, though, they offer an exciting opportunity for adaptive management to ascertain what kinds of incentives elicit desired behavior on the part of resource managers and what kinds of environmental services can be expected as a result.

Ecoagriculture and Organics

McNeely and Scherr (2003) define ecoagriculture as the management of landscape for food production while conserving the ecosystem, particularly the wild biodiversity. Today, agricultural expansion likely poses a greater threat to wild biodiversity than agricultural intensification on existing agricultural lands. Converting native forests into pastures, croplands, or even agroforestry leads to the loss of most native plant species and the animals that depend on them. For example, one-fourth of North America's wild domestic honeybees have disappeared since 1988, due mainly to an epidemic of mites that prey on the bees. This loss costs American farmers $5.7 billion a year in crop yield losses (Nabhan and Buchmann 1997).

Because trade and agricultural polices directly affect smallholder agriculture, they indirectly affect the prospects for biodiversity conservation in ecologically fragile areas. Producer price supports and input subsidies encourage agricultural production and land conversion while promoting economically and environmentally degrading resource exploitation. Reducing subsidies for agricultural chemicals can often indirectly benefit biodiversity in agricultural regions. In Indonesia, for example, banning of 56 brands of rice pesticides in 1986 and establishing a national IPM program reduced pesticide use by more than half while increasing rice yield by 0.5 tons per hectare. Re-colonization of plant and animal species was also observed in rice fields.

Trade directed toward developed-country demand for perennial crops such as coffee, cocoa, rubber, cashew, and palm oil may also benefit biodiversity to some extent if the shift is away from annual crops. Land conversion from forests to perennial crops is undesirable, however, and a significant challenge is finding ways to promote land conversion from annuals to perennials while at the same time not creating incentives to establish perennials on forest land.

In the context of the European Union, Dabbert (2003) analyzed the environmental impact of organic farming compared with conventional farming. Organic farming uses no synthetic pesticides and nitrogen fertilizers, which helps to conserve the soil fertility and lower leaching rates by 50% or more. (The same study found that CO_2 emissions were 40% to 60% lower in organic farming systems, with similar results for N_2O and CH_4 emissions.) Although organic farming can underperform conventional farming in terms of yields, lower input costs can be an offsetting advantage. The overall scope for organic production by smallholders in developing countries is relatively unexplored.

Note

We use the term "land managers" deliberately here. In most developing country contexts, discussions regarding sustainable agriculture necessarily focus on smallholder farmers, and for most of this chapter we will accordingly focus our attention on policies aimed at benefiting smallholders. However, we readily acknowledge that a more comprehensive, hence more realistic and effective, approach to the policy system must take into account other primary producers—not just smallholders—as well as other active and passive players in the policy system, including those with a stake in markets and institutions, and not necessarily agriculture per se.

References

Altieri, M.A. and E. Bravo. 2007. The Ecological and Social Tragedy of Crop-based Biofuel Production in the Americas. http://www.foodfirst.org/node/1662.

Ananda, J. and G. Herath. 2003. Soil erosion in developing countries: A socio-economic appraisal. Journal of Environmental Management 68:343-353.

Anderson, K. 1998. Agricultural Trade Reforms, Research Initiatives, and the Environment. *In* Agriculture and the Environment: Perspectives on Sustainable Rural Development, ed. E. Lutz, 71-82. Washington, DC: World Bank.

Antle, J., and Pingali. 1994. Pesticides, productivity, and farmer health: A Philippine case study. American Journal of Agricultural Economics 76(3):418-430.

Arthur, W.B. 1999. Complexity and the economy. Science 284:107-109.

Ascher, W. and R. Healy. 1990. Natural Resource Policymaking in Developing Countries: Environment, Economic Growth, and Income Distribution. Durham, NC: Duke University Press.

Barbier, E., and J.C. Burgess. 1992. Agricultural Pricing and Environmental Degradation. Working papers. WPS 960:1-15. Washington, DC: World Bank.

Barbier, E.B. and J.C. Burgess. 2001. The economics of tropical deforestation. Journal of Economic Surveys 15(3): 413-421.

Bator, F.M. 1958. The anatomy of market failure. Quarterly Journal of Economics 72(3):351-379.

Binswanger, H.P. 1991. Brazilian policies that encourage deforestation in the Amazon. World Development 19(7):821-829.

Boserup, E. 1981. Population and Technological Change: A Study of Long-term Change. Chicago: University of Chicago Press.

Bromley, D. 1989. Economic Interests and Institutions: The Conceptual Foundations of Public Policy. New York, NY: Blackwell Publishing.

Bromley, D. 1992. Making the Commons Work: Theory, Practice and Policy. Ithaca, NY: ICS Press.

Bruce, J.W., and R. Mearns. 2004. Natural Resource Management and Land Policy in Developing Countries: Lessons Learned and New Challenges for the World Bank. Washington, DC: World Bank.

Commons, J.R. 1934. Institutional Economics. New York, NY: MacMillan.

Coxhead, I. 1997. Induced innovation and land degradation in developing country agriculture. Australian Journal of Agricultural and Resource Economics 41(3):305-332.

Coxhead, I. 2000. Consequences of a food security strategy for economic welfare, income distribution and land degradation: The Philippine case. World Development 28(1):111-128.

Coxhead, I., G. Shively, and X. Shuai. 2002. Development policies, resource constraints, and agricultural expansion on the Philippine land frontier. Environment and Development Economics 7(2):341-364.

Cuyno, L.C.M., G.W. Norton, and A. Rola. 2001. Economic analysis of environmental benefits of integrated pest management: A Philippine case study. Agricultural Economics 25:227-233.

Dabbert, S. 2003. Organic agriculture and sustainability: Environmental aspects. *In* OECD Organic Agriculture: Sustainability, Markets and Policies. CABI 407. Wallingford, Oxfordshire, UK: CABI.

Damodaran, A. 2002. Conflict of trade-facilitating environmental regulations with biodiversity concerns: The case of coffee farming units in India. World Development 30(7): 1123-1135.

Douthwaite, B. 2006. Enabling innovation: Technology- and system-level approaches that capitalize on complexity. Innovations 1(4):93-110.

Dufey, A. 2007. International trade in biofuels: Good for development? And good for environment? Environment for the MDGS—An International Institute for Environment and Development. Briefing.

Fargione, J. et al. 2008. Land clearing and the biofuel carbon debt. Science 319 (5867):1236-1238.

Fan, S., A. Gulati, and S. Thorat. 2008. Investment, subsidies, and pro-poor growth in rural India. Agricultural Economics 39(2): in press.

Friends of Earth. 2005. The Oil For Ape Scandal: How Palm Oil is Threatening Orangutan Survival. Friends of Earth.

Gabre-Madhia, E., and S. Haggblade. 2001. Successes in African Agriculture: Results of an Expert Survey. Washington, DC: International Food Policy Research Institute.

Garcia, A. and G. Shively. 2008. Do Environmental Restrictions Reduce Economic Efficiency? Evidence from Coffee Farms in Vietnam. West Lafayette, IN: Department of Agricultural Economics, Purdue University.

Gbetnkom, D. 2005. Deforestation in Cameroon: Immediate causes and consequences. Environmental and Development Economics 10:557-572.

Heath, J., and H.P. Binswanger. 1998. Policy-induced effects of natural resource degradation: The case of Colombia. *In* Agriculture and the Environment: Perspectives on Sustainable Rural Development, ed. E. Lutz, 22-34. Washington, DC: World Bank.

Hecht, S.B. 1993. The logic of livestock and deforestation in Amazonia. Bioscience 43(10): 687-695.

International Institute for Sustainable Development. 1999. Trade and Sustainable Development in Vietnam. Winnipeg, Manitoba, Canada: International Institute for Sustainable Development.

Karaky R. and Arndt C. 2002. Climate variability and agricultural policy in Morocco. Proceedings of the Fifth Annual Conference on Global Economic Analysis, 2B-13 through 2B-22, Taipei, Taiwan, June 5-7, 2002.

Manne, A. and R. Richels. 2004. US Rejection of the Kyoto Protocol: Impact on Compliance Costs and CO2 Emissions? Energy Policy 32:447-454.

Matthews, R.C.O. 1986. The economics of institutions and the sources of growth. Economic Journal 96:903-18.

McNeely, J.A. and S.J. Scherr. 2003. Ecoagriculture: Strategies to Feed the World and Save Wild Biodiversity. Washington, DC: Island Press.

Mertens, B., R. Poccard-Chapuis, M.G. Piketty, A.E. Lacques, and A. Venturieri. 2002. Crossing spatial analyses and livestock economics to understand deforestation processes in the Brazilian Amazon: The Case of São Félix do Xingú in South Pará. Agricultural Economics 27(3):269–294.

Munasinghe, M., and W. Cruz. 1995. Economywide Policies and the Environment: Lessons from Experience. World Bank Environment Paper No.10. Washington, DC: World Bank.

Nabhan, G.P., and S. Buchmann. 1997. Services provided by pollinators. *In* Nature's Services: Societal Dependence on Natural Ecosystems, ed. G.C. Daily, 133-150. Washington, DC: Island Press.

Oxfam. 2002a. Rigged Rules and Double Standards: Trade, Globalization, and the Fight against Poverty. Oxford, UK: Oxfam.

Oxfam. 2002b. The Impact of Global Coffee Trade on Dak Lak Province, Viet Nam: Analysis and Policy Recommendations. ICARD and Hong Kong: Oxfam.

Pagiola, S., M.D. Angeles, and G. Shively. 2005. Using payments for environmental services to assist in watershed management. *In* Land Use Change in Tropical Watersheds: Evidence, Causes, and Remedies, ed. I. Coxhead and G.E. Shively, 163-175. Cambridge, MA: CABI.

Pagiola, S., and Platais G. 2006. Payments for Environmental Services: From Theory to Practice. Washington, DC: World Bank.

Pingali, P. 2001. Environmental consequences of agricultural commercialization in Asia. Environment and Development Economics 6:483-502.

Qaim, M., and D. Zilberman. 2003. Yield effects of genetically modified crops in developing countries. Science 299:900-902.

Raintree, J.B. 1987. Land, Trees and Tenure: Proceedings of an International Workshop on Tenure Issues in Agroforestry, Nairobi, Kenya, May 27-31, 1985. Madison WI: Land Tenure Center.

Rios, A., W. Masters, and G. Shively. 2008. Linkages between Market Participation and Productivity: Results from a Multi-country Farm Household Sample. West Lafayette, IN: Department of Agricultural Economics, Purdue University.

Searchinger, T.R., et al. 2008. Use of US croplands for biofuels increases greenhouse gases through emissions from land-use change. Science 319(5867):1238-1240.

Shively, G.E. 1998. Economic policies and the environment: The case of tree planting on low-income farms in the Philippines. Environment and Development Economics 3(1):83-104.

Shively, G.E. 2001. Agricultural change, rural labor markets, and forest clearing: An illustrative case from the Philippines. Land Economics 77(2): 268-284.

Shively, G.E., and M.M. Fisher. 2004. Smallholder labor and deforestation: A systems approach. American Journal of Agricultural Economics 86(5):1361-1366.

Shively, G.E., and Pagiola, S. 2004. Agricultural intensification, local labor markets, and deforestation in the Philippines. Environment and Development Economics 9:241-266.

Stern, D.I., M.S. Common, and E.B. Barbier. 1996. Economic growth and environmental degradation: The Environmental Kuznets Curve and sustainable development. World Development 24(7):1151-1160.

Sterner, T. 2003. Policy Instruments for Environmental and Natural Resource Management. Washington, DC: Resources for the Future and World Bank.

Stiglitz, J.E. 2003. Globalization and its Discontents. New York, NY: W.W. Norton and Co.

Sunderlin, W., et al. 2001. Economic crisis, small farmer well being, and forest cover change in Indonesia. World Development 29(5):767-782.

Thorbecke, E. 2000. Agricultural markets beyond liberalization: The role of the state. *In* Agricultural Markets beyond Liberalization, ed. Aad van Tilburg, H.A.J. Moll, and A. Kuyvenhoven, 19-53. Kluwer Academic Publishers.

Tomich, T.P., P. Kilby, and B.F. Johnston. 1995. Transforming Agrarian Economies: Opportunities Seized, Opportunities Missed. Ithaca, NY: Cornell University Press.

Tyner, W.E. 2004. Agricultural Policy Reform in the Context of Trade Liberalization and Climatic Variability—the Case of Morocco. Paper presented at an ICARDA conference on Obstacles to Technology Transfer for Small and Medium Sized Farmers in Arid and Semi-Arid Zones of North Africa, Algiers, Algeria, December 2004.

UNEP. 2002. Global Environmental Outlook 3. Nairobi, Kenya: United Nations Environment Programme.

USAID. 2007. Global Assessment of Best Practices in Payments for Environmental Ecosystem Services Programs. Blacksburg, VA: SANREM CRSP, OIRED/Virginia Tech.

UNFCC. 2006. The Mechanisms under the Kyoto Protocol: Joint Implementation, the Clean Development Mechanism and Emissions Trading. United Nations Framework Convention on Climate Change. http://unfccc.int/kyoto_mechanisms/items/1673.php.

Wunder, S. 2005. Payments for Environmental Services: Some Nuts and Bolts. Jakarta, Indonesia: Centre for International Forestry Research Occasional Paper No. 42.

Young, C.E.F. and J. Bishop. 1995. Adjustment Policies and the Environment: A Critical Review of the Literature. CREED Working Paper Series No 1. London: IIED.