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13 Farmer Decisions about Adopting Environmentally Beneficial Practices

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Farmers hugely influence the mix of ecosystem services that rural landscapes provide. Their management choices about crop and livestock production practices affect services linked to water, soil, climate, and wild species. Apart from cropland and pastures, farmers also control woodlots, wetlands, and meadows that can keep groundwater clean, actively mitigate greenhouse gas (GHG) emissions, and provide habitat for beneficial insects (Power 2010, Swinton et al. 2007; Swinton et al. 2015, Chapter 3 in this volume). Given that farmers have such influence over rural ecosystems, it is important to ask how they decide whether and how much to adopt environmentally beneficial practices.

These questions about farmer behavior take us inside the Social System section of the Kellogg Biological Station Long-Term Ecological Research (KBS LTER) conceptual model (Fig. 1.4 in Robertson and Hamilton 2015, Chapter 1 in this volume). The model shows that humans respond to flows of ecosystem services as well as to other drivers of change. Yet human behavior is tremendously variable, and farmers are no exception. Their individual objectives and how they experience external stimuli affect how they respond. For professional farmers, income generation is a major objective. They experience all sorts of ecosystem services, but they are in business to produce and sell provisioning services such as food, fiber, and bioenergy products. Incentives, rules, perceptions, personal values, and social norms (Chen et al. 2009) all shape how they manage agricultural ecosystems.

In this chapter, we examine patterns in U.S. agriculture over the past century to understand how present-day patterns evolved. We then draw on research with crop farmers about their decisions to adopt agricultural practices that provide environmental benefits. We close by reviewing the means to encourage greater environmental stewardship both within current U.S. legal structures and beyond.

Managed Ecosystems and Human Impacts

The impact of human domination of Earth's ecosystems is well documented (Vitousek et al. 1997). Our large ecological footprint owes much to the effects of intentional ecosystem management (Farber et al. 2006). Among managed ecosystems, agricultural systems cover the largest area, with estimates ranging from 25 to 38% of Earth's land area (Wood et al. 2000, Millennium Ecosystem Assessment 2005), and arguably have the greatest environmental impact (Robertson and Swinton 2005). Not only does agriculture compose over half of the land area that is not either desert or permafrost, but also agricultural systems are increasing in area. Indeed, the prospect of a growing reliance on biofuels is likely to drive greater global growth in cultivated land area than even the ~20% growth that Tilman et al. (2001) predicted by 2050.

Agricultural impacts on global ecosystem services are significant. Smith et al. (2007) estimate that 10–14% of total global GHG emissions originate from agriculture, and that does not include land-use change. Land-use change, mostly associated with deforestation for agriculture, is responsible for another 12–17%. Watershed biogeochemical models supported by empirical evidence suggest that agriculture is responsible for over 70% of the phosphorus and nitrogen carried by the Mississippi River to the hypoxic zone of the Gulf of Mexico (Alexander et al. 2008), and similar dead zones exist in other coastal regions around the world (Diaz and Rosenberg 2008). Groundwater reserves that serve drinking water wells and recharge surface streams have been significantly contaminated by agriculture during the twentieth century (Böhlke 2002). On the plus side, carbon reserves in U.S. agricultural soils are estimated to have risen during 1982–1997 due to the replacement of moldboard plowing by conservation tillage practices (i.e., reduced or no tillage), land retirement from agriculture, and reduced use of bare-soil fallow periods (Eve et al. 2002). The magnitude of changes in ecosystem services across air, water, and land indicates the importance of agricultural management effects on services at global, regional, and local scales. The recent evolution of U.S. agriculture helps to explain these environmental impacts.

Trends in United States Agriculture

The past half century of U.S. agriculture has seen rising economic efficiency at producing marketed products. Particularly striking has been the trend of rising productivity (Fig. 13.1). During 1948–2001, the 1.9% annual increase in total factor productivity permitted the real value of agricultural output to rise steadily without the use of additional inputs (Ball et al. 1997, Dumagan and Ball 2009). For example, fertilizer and pesticide use have remained essentially constant

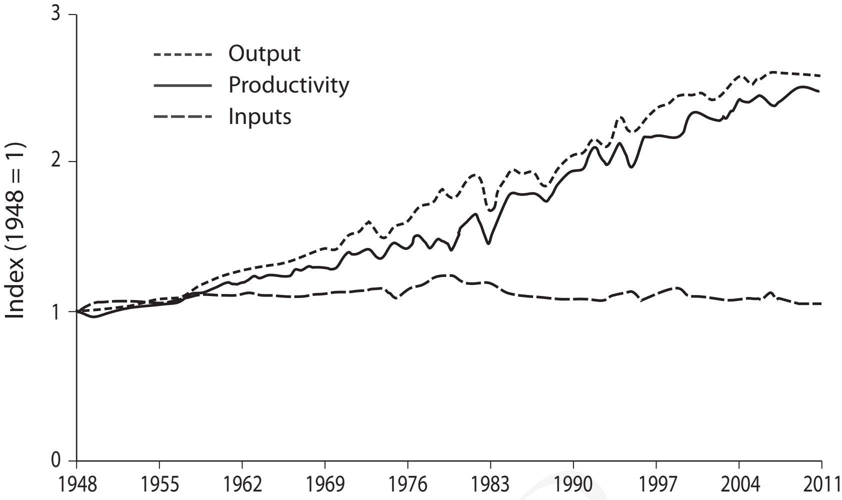

Figure 13.1. Changes in agricultural output, inputs, and total factor productivity in the United States, 1948–2011. Total factor productivity refers to gains in output that were not embodied in added inputs. Redrawn from ERS (2012a).

since 1980 (Gardner 2002). Rises in productivity combined with farm consolidation have contributed to both a sharp growth in the number of consumers supported by each U.S. farmer and some of the world's lowest food expenditures as a proportion of income.

Rising agricultural productivity has, however, been accompanied by environmental harm. In particular, large quantities of agrochemicals applied to farm fields miss their targets (Snapp et al. 2010), escaping to cause environmental damage elsewhere. To farmers, these wasted input costs are offset by the value of increased output. But the cost to society is large, as documented for pesticides (Paul et al. 2002) and nitrogen (Secchi et al. 2007) in ground and surface waters, including hypoxia in the Gulf of Mexico (Alexander et al. 2008). Agricultural mechanization has been another driver of productivity gains. Yet the removal of field borders to facilitate mechanized farming has resulted in fewer field edges and reduced biodiversity in areas of highly productive farmland (Meehan et al. 2011).

Evidence of environmental damage from agriculture, especially to water quality, led to a series of U.S. environmental programs for agriculture during the 1980s and 1990s. For croplands, these programs either paid to remove environmentally sensitive land from crop production (e.g., the Conservation Reserve Program [CRP]) or shared farmer costs of improving environmental performance (e.g., Environmental Quality Incentives Program [EQIP], Wildlife Habitat Incentives Program [WHIP], and Conservation Reserve Enhancement Program [CREP]).

The potential for agriculture to provide beneficial ecosystem services (Daily 1997) was increasingly recognized during the first decade of the 2000s. Managing agriculture as an ecosystem means not only managing for marketed products but also for socially valued ecosystem services (Antle and Capalbo 2002, Robertson et al. 2004, Farber et al. 2006, Swinton et al. 2006, 2007; Swinton et al. 2015, Chapter 3 in this volume). Examples of such services include farm management for GHG mitigation via carbon sequestration and reduced greenhouse gas emissions (Robertson 2004), water-quality improvement via reduced nutrient and pesticide leaching and runoff (Hamilton 2015, Chapter 11 in this volume), and biodiversity habitat that enables enhanced biocontrol of agricultural pests by natural enemies and crop pollination by wild pollinators (Landis et al. 2008; Landis and Gage 2015, Chapter 8 in this volume).

Some environmentally beneficial agricultural practices have low and uneven levels of adoption by U.S. farmers. For example, more complex crop rotations are known to provide environmental benefits related to pest protection and nutrient conservation. Yet in 1997, 53% of U.S. corn (*Zea mays* L.) and soybean (*Glycine max* L.) acreage was in a simple 2-year corn–soybean rotation, with only 10% in a rotation that included small grains (Padgitt et al. 2000). Only 31% of U.S. corn farmers practiced soil testing in 2002 (Christensen 2002). In California, by 2007 the adoption of organic farming remained under 2% of farmers and less than 1% of the state's agricultural value; the number of California farmers becoming organic-certified was nearly offset by the number allowing their certification to lapse (Serra et al. 2008).

Agricultural research over several decades, including 20 years at KBS LTER, has identified clear environmental benefits of rotations of corn, soybean, and wheat (*Triticum aestivum* L.) with a winter cover crop and reduced fertilizer application. Nonetheless, the 2008 Crop Management and Environmental Stewardship Survey linked to the KBS LTER (Jolejole 2009, Ma et al. 2012) found that Michigan corn and soybean farmers devoted only 8% of their land to wheat and 5% to winter cover crops, while only 22% reported applying fertilizer at rates below those recommended by university extension and only 21% applied pesticides at rates below label recommendations (Ma et al. 2012).

Some environmentally beneficial practices have been readily adopted by farmers. In the same 2008 Michigan farm survey, 82% of farmers reported that they practiced reduced tillage (compared to moldboard plow), including 55% who practiced no-till in some years (Jolejole 2009). Eighty-seven percent also reported scouting for insect pests to guide pesticide decisions. At the national scale, U.S. conservation land set aside through the CRP was fully enrolled shortly after its inception in 1985 (ERS 2012b). And a high enrollment rate has persisted in spite of increasingly stringent environmental criteria. Since EQIP was created in 1996, it too has seen more farmer interest in environmental cost share programs than its budget or acreage caps allow.

Notwithstanding the success of these programs, the combination of national and local patterns of low adoption of many (but not all) environmentally beneficial cropping practices raises the questions: Why are rates of adoption of environmentally beneficial farming practices not higher? Why are some practices adopted but not others?

Drivers of Farmer Adoption of Environmental Technologies

For a new agricultural technology about which farmers are knowledgeable, the determinants of its adoption fall into two basic categories: barriers and incentives. As Nowak (1992) observed,

> Farmers do not adopt production technologies for two basic reasons: they are either unable or unwilling. These reasons are not mutually exclusive. Farmers can be able yet unwilling, willing but unable, and, of course, both unwilling and unable. (p. 14)

The barriers and incentives paradigm offers a compelling explanation for much of observed farmer behavior with respect to environmental stewardship. A national study based on 2001–2003 data found that when farmers see a conservation technology as advantageous and not costly to adopt, adoption can proceed rapidly (Lambert et al. 2006). For example, adoption of seed-embodied conservation technologies like herbicide tolerance and transgenes that encode for the *Bacillus thuringiensis* (Bt) toxin reached high levels in just a few years. The rapid signups and overenrollment of CRP fit this model because lease payments were a clear incentive for which there were no barriers other than knowledge of the program and time available to apply for it.

Technologies embodied in equipment and other capital goods, on the other hand, tend to face high cost as a barrier to adoption. As a result, attractive but capital-intensive technologies are adopted more slowly. They tend to be more quickly adopted by large-scale farmers who can spread fixed costs over more land and may be able to hire staff with the necessary skills. For example, conservation tillage has been widely adopted in the United States (Lambert et al. 2006), but its adoption was much slower than improved seeds because it became cost-effective to adopt only when the time came to replace equipment (Krause and Black 1995).

Uncertainty can be another barrier to farm technology adoption. Farmers may be reluctant to invest when significant uncertainty (including the uncertain costs of learning by trial and error) accompanies an investment in a new technology. For example, free-stall dairy barns offer improved manure handling as well as operational efficiencies, but they were adopted slowly on account of uncertainty about future returns on investment (Purvis et al. 1995). Organic farming technologies have been adopted slowly largely because of the time lag to certification and a degree of management complexity that can make future earnings uncertain (Musshoff and Hirschauer 2008).

Demands on management time can also be a barrier to technology adoption, especially for small and part-time farmers (Lambert et al. 2006). In contrast, full-time farmers are more likely to invest the management time or hire a specialized employee who can do so.

National Trends in Adoption of Cropping Practices Used at KBS LTER

Adoption of the conservation technologies included in the KBS LTER Main Cropping System Experiment (MCSE) row-crop systems (Robertson and Hamilton 2015, Chapter 1 in this volume) is high in some areas of the United States but low in others. The Agricultural Resource Management Survey—begun by the USDA in 1996 and most recently conducted in 2010—offers online data summaries for tracking adoption of crop production practices (ERS 2012c)

Although over 80% of U.S. row crops are grown in rotations (Wallander 2013), there has been a trend toward simplified crop rotations that focus on the most profitable crops. In 1996–2006, the most recent decade for which preceding crop data are available, the corn–soybean rotation was increasingly adopted at the expense of both continuous corn and rotations with small grains. Over that period, corn following small grains dropped from 10% to less than 8% of U.S. corn acreage. By contrast, corn following soybean expanded from 54 to 60% of corn area. That pattern appears to have continued in the early 2000s, as corn and soybean displaced over 10 million acres of wheat and hay, in response to market price signals (Jekanowski and Vocke 2013).

Winter cover crops such as clover and rye are planted in the fall following harvest and plowed under prior to the following summer's primary crop. Winter cover crops are more common after soybean than after corn, mainly due to an earlier soybean harvest that provides a longer planting time in the fall. In 1997 winter cover crops were grown on 1% of U.S. corn land and 5% of U.S. soybean land (Padgitt et al. 2000). As of 2010, 3 to 7% of U.S. farms planted cover crops, but the area remained small, roughly 1% of cropland (Wallander 2013).

By contrast, acreage under conservation tillage increased from 26 to 41% between 1990 and 2004 (Sandretto and Payne 2006). This is likely linked to the availability and rapid adoption of herbicide-tolerant crop varieties that simplify herbicide decisions and reduce the need for tillage to control weeds. Between 1996 and 2006, the percentage of U.S. soybean acreage planted with genetically modified, herbicide-resistant seed rose from 7 to 97% (ERS 2012c). Over that same period, the mean number of tillage operations in soybean fell from three to one, and mean number of herbicide applications from three to two.

Corn farmers consistently applied nitrogen fertilizer to 96–99% of planted acres during 1996–2010 at annual average rates that grew from 151 to 160 kg N ha^{-1} yr^{-1} from 2000 to 2010 (134 to 143 lb $acre^{-1}$ yr^{-1}) (ERS 2012c). Over that same period, the percentage of corn land area that underwent soil nitrogen testing rose from 21% in 1996 to 28% in 2005, and then fell back to 22% in 2010. Plant tissue nutrient testing crept upward from 2 to 4% of planted area. Using the same USDA survey data, Ribaudo et al. (2011) found that only 35% of U.S. corn land met best management practice norms for rate, timing, and method of nitrogen fertilizer application in 2006.

In summary, the adoption of conservation technologies like those used at KBS LTER has occurred in the case of conservation tillage practices and (to a lesser extent) small grains in the crop rotation, but not for cover crops or reduced nitrogen rates (Table 13.1). Given the documented ecosystem service benefits from all these technologies, it is important to ask what impedes adoption of the full set of them.

Attitudes toward Adopting Conservation Practices

Direct questioning of farmers can shed light on the motives behind their adoption patterns. We gathered both qualitative and quantitative data on how Michigan corn

Table 13.1. KBS LTER technologies and adoption trends among U.S. corn and soybean farmers.

Technology	U.S. Land-Area Trend among Corn/ Soybean Farmers	Source
Small grain in crop rotation	Declined in corn rotations from 10% to 8% in 1995–2005; wheat area down 2000–2002 to 2010–2012	ERS (2012c)[a]; Jekanowski and Vocke (2013)
Conservation tillage	Rose from 26% to 41% in 1990–2004	Sandretto and Payne (2006)
Fertilizer-reduced rates	Nitrogen use on corn stable, but excessive rates declined from 41% to 35% in 2001–2005	Ribaudo et al. (2011)
Soil nitrogen testing on corn	Trended 21, 28, and 22% in 1996, 2005, and 2010, respectively	ERS (2012c)[a]
Cover crop	Declined from 5% to 2% of soybean land in 1997–2006	Padgitt et al. (2000), C. Greene (personal communication)

[a]Data retrieved by Swinton from the Agricultural Resource Management Survey online database, but these fields not accessible in online tailored reports tool (ERS 2012c).

and soybean farmers view various conservation practices. Qualitative data came from 39 full-time corn and soybean farmers interviewed in six focus groups held in south-central and central Michigan during February and March 2007. Three of the 39 were organic farmers. In 2006 the participants had farmed between 273–2750 acres. Focus group participants were recruited by Michigan State University Extension agricultural educators and were financially compensated for their participation. The farmers completed short questionnaires about their farms, current management, and attitudes toward specific conservation practices. After discussing their views about these practices, they took part in a series of experimental auctions that were designed to reveal what it would cost them to adopt various conservation practices.

The quantitative data come from the 2008 Crop Management and Environmental Stewardship Survey, a statistically representative survey of Michigan corn and soybean farmers, described previously (Swinton et al. 2015, Chapter 3 in this volume). Farmers were asked specific questions about current farming practices and their attitudes toward conservation. They were also asked hypothetical questions about adopting new practices, and their willingness to adopt was used to estimate the potential supply of ecosystem services in exchange for payments.

Some conservation practices of interest to ecological researchers had already been adopted by the farmers surveyed. Figure 13.2 ranks 11 practices and the percentage of farmers currently using them. Two practices were used by over 80% of the farmers. These included reduced tillage (as compared to moldboard plow) and scouting for pests to guide pesticide decisions. What did these practices have in common? Both either saved labor (for tillage and pesticide application operations) or input costs (pesticide and fuel) without reducing expected crop revenue. They were largely viewed as win-win choices, helping both the environment and farm profitability.

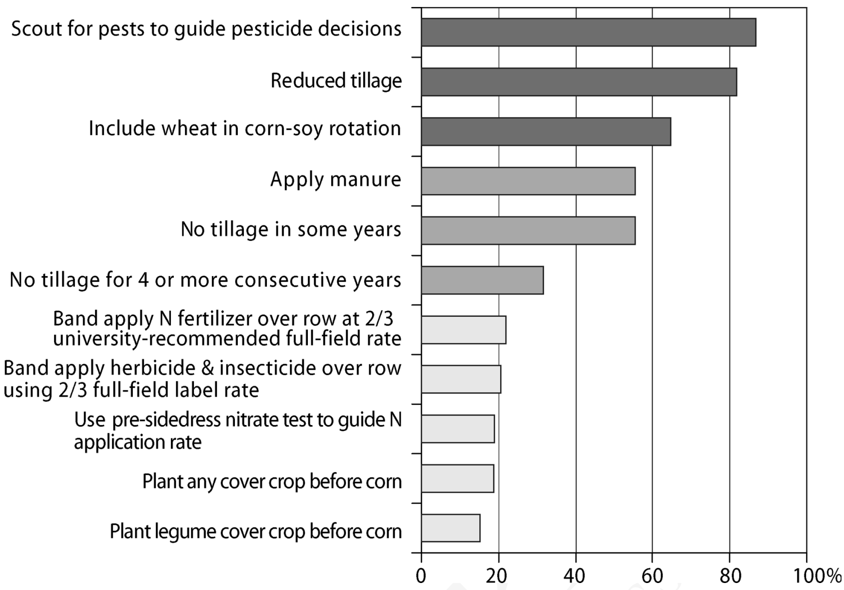

Figure 13.2. Percentage of Michigan corn-soybean farmers reporting current use of selected practices (n = 1408).

A second group of conservation practices were used by 55–65% of the farmers (Fig. 13.2). These included no-till in some years (but not continuously), applying manure, and including wheat in rotation with corn and soybean crops. What made this second category of practices slightly less attractive? No-till planting reduces weed control options (particularly for farmers not using glyphosate-tolerant crops, still a notable number at the time of the survey). Applying manure can compete for time with other farming tasks. As for why a third of respondents opted not to include any wheat in the corn–soybean rotation, three explanations came from the focus group participants: (1) wheat can be less profitable than corn or soybean, (2) wheat diseases in Michigan can reduce yield and grain quality, and (3) demand for white winter wheat had declined at local grain elevators. The common element among these three common but not ubiquitous practices is that under certain circumstances, all had the potential for reduced revenues, higher costs, or greater labor demand during busy periods.

A third group of conservation practices appealed to less than a third of the focus group farmers (Fig. 13.2). These practices were viewed by many as fundamentally problematic for one reason or another. Winter cover crops were widely perceived to delay or complicate spring planting by two mechanisms: (1) the need to allow cover crops sufficient time to accumulate spring biomass without reducing soil moisture excessively, and (2) the need to kill the cover crop prior to crop planting. The pre-sidedress nitrate test, a just-in-time test to estimate nitrogen fertilizer needs after the corn is up and growing, also confronted the timeliness problem—soil must be sent to a laboratory for analysis, which can delay fertilizer decisions and make equipment scheduling more difficult, especially when weather is poor for field work. As for continuous no-till cultivation (for more than 4 years consecutively), farmers observed that when fields went several years without tillage, they were invaded by perennial weeds that were difficult to control with herbicides. Reducing fertilizer, insecticide, and herbicide use was viewed by most farmers as having two serious negatives: potentially sacrificing crop yield and boosting the risk of herbicide-resistant insects and weeds. The least attractive practices were perceived to involve the risk of significant income loss. In the words of one focus group participant,

> "I think if you're going to get a good yield on anything you have to use the full rate of fertilizer and the full rate of pesticide . . . . Otherwise you're not getting the profits that you should have, and I don't think you're doing a service to the future crops you're planting either."

Many farmers expressed their commitment to environmental stewardship, but typically they saw it in a trade-off relationship with profitability and gave a higher priority to profitability and business viability. Said one focus group participant, "I always try to choose practices that have environmental benefits but if it's going to cause me to lose money then I can't take that choice."

Farmers' willingness to adopt stewardship practices was also influenced by their perception of how much they would benefit directly. Such benefits might be monetary, such as a greater profit margin or higher future land value, or nonmonetary, such as safer groundwater for family use. The survey respondents were asked to consider six environmental benefits from conservation agriculture and to rate the relative importance of these services "to me" on a three-point Likert scale of (1) highly important to me, (2) somewhat important to me, and (3) unimportant to me. Benefits included less global warming, less pesticide risk, less phosphorus and nitrate pollution, more soil conservation, and more soil organic matter. A parallel set of questions followed asking respondents to rate importance "to society" instead of "to me."

Upon taking differences between their answers for the relative importance "to me" versus "to society," paired difference *t*-tests revealed clear statistical differences ($p < 0.01$). Figure 13.3 shows that farmers rated soil organic matter, soil conservation, and reduced nitrate leaching as much more important to themselves than to society. To a lesser degree, they also found less phosphorus runoff and less pesticide risk to be more beneficial to themselves than to society at large. In contrast, they found reduced global warming to be much more important to society than to themselves. These responses conform to the economic distinction between private and public goods. The first three benefits are largely private: benefits to soil organic matter and soil conservation contribute directly to crop productivity. Reduced nitrate leaching protects the quality of groundwater, which most Michigan farms rely on for drinking, and it keeps fertilizer nitrogen in the field where it can contribute to crop productivity. Less markedly, the survey respondents also found themselves to benefit more than society from reduced phosphorus runoff and reduced pesticide risk to human health; both help farmers as well as neighbors in the region. By contrast, reduced global warming was clearly viewed as more beneficial to society at large, which is characteristic of a public good.

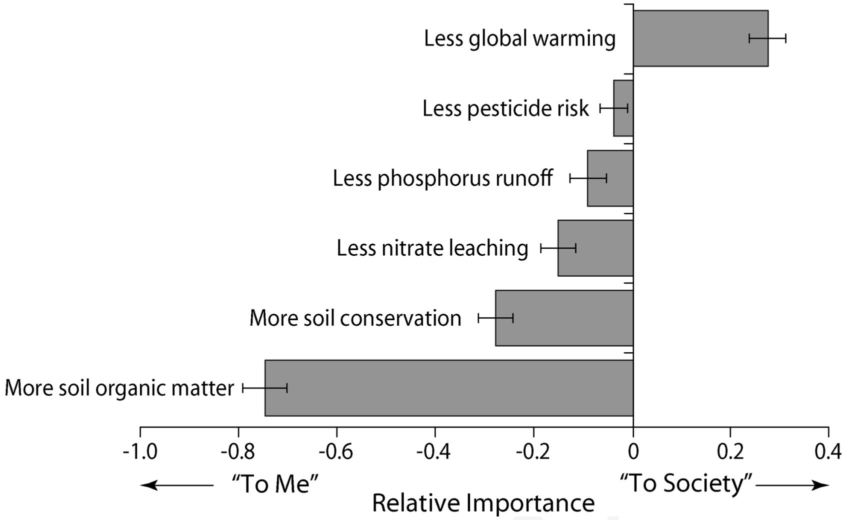

Figure 13.3. Michigan corn-soybean farmer ratings of the importance of the environmental benefits "to me" minus importance of the benefits "to society," in 2008 (n=1443). Error bars = 2 standard errors based on paired difference t-test. Negative values imply the service was rated more important "to me" than "to society"; positive values indicate the converse. Redrawn from Robertson et al. (2014).

Both survey respondents and focus group participants expressed familiarity with the management practices presented in the questionnaire, so knowledge of the practices was present. Those practices that they had adopted, or were willing to adopt, were ones that offered clear private benefits. Conservation tillage practices are a case in point. Reduced tillage was adopted by 82% of Michigan corn and soybean farmers surveyed, with 65% adopting no-till in some years. According to Sandretto and Payne (2006), reduced tillage lowers expenses for labor, fuel, and equipment and may improve yields. Among the four MCSE annual crop systems, reduced tillage is represented both by the Conventional chisel-till system and by the No-till system, the latter being both the most profitable (Swinton et al. 2015, Chapter 3 in this volume) and the provider of lowest greenhouse gas emissions (Gelfand and Robertson 2015, Chapter 12 in this volume). So conservation tillage appears to offer farmers private profitability benefits at the same time that it provides beneficial environmental externalities.

Most of the farmers surveyed and interviewed reported that environmental traits of the potential cropping systems were secondary to profitability traits. This ranking explains farmers' reluctance to reduce herbicide use by using more costly mechanical weed control or to reduce nitrogen fertilizer use by substituting more costly winter cover crops—patterns that are also evident at the national scale.

Even when farmers desire to adopt environmental technologies, barriers can impede them from doing so. Of the technologies evaluated in the 2008 Crop Management and Environmental Stewardship Survey, reduced tillage, especially no-till, has the greatest capital requirements because it requires special equipment.

Prior research has found that the practice of no-till cultivation was delayed by the normal capital replacement process because it requires purchase of an expensive no-till planter (Krause and Black 1995). Despite this financial hurdle, adoption of conservation tillage has been expanding over the past 15 years. By contrast, reducing fertilizer rates and planting cover crops are generally accessible technologies that most farmers have not elected to practice.

Incentives and Payments for Ecosystem Services

In focus group interviews, farmers made it clear that maintaining profitability is a necessary condition when it comes to deciding which crop management technologies to adopt. Hence, cropping practices that offer public benefits but impose private costs were acceptable to most participants only in exchange for a payment.

The next logical question, then, is what payments would be required to get farmers to adopt practices with greater public benefits but also higher private costs? Farmer focus group participants were invited to participate in three rounds of experimental auctions to elicit their willingness to adopt progressively more costly stewardship practices. The experimental auctions were modeled on USDA CRP procurement auctions in which the low bidder receives the payment contract. However, the experimental auctions differed from the CRP process in two important ways: (1) farmers were presented with pre-set bid amounts and had to decide whether or not to accept them and, if so, on how many acres, and (2) the lowest bidders were enrolled in the program and paid the amount per acre of the second lowest bid. This approach provides participants an incentive to truthfully reveal the minimum amount that they would be willing to accept because no single bid controls both the payment awarded and whether enrollment is successful (Harrison and List 2004, Milgrom and Weber 1982).

Farmers were asked to consider a basic corn–soybean cropping system (System A). Considering their own costs and environmental views, they were asked to determine how much they would need to be paid to replace System A with one of the four lower input systems shown in Table 13.2. All the alternative systems (B to E) included reduced tillage, pre-sidedress nitrate testing on corn, and split nitrogen applications. Beyond these, Systems C to E each added a new level of stewardship: winter cover crop (C, D, E), wheat in rotation with corn and soybean (D, E), and agrochemicals applied at two-thirds of the normal recommended rate (university rate for fertilizer and pesticide label rate for pesticides). In each case, participants were invited to specify the number of acres they would be willing to supply from their own farms at the bid offered.

Experimental auction responses (Table 13.3) showed a clear willingness to adopt environmental stewardship practices if the price is right. As the systems become more complicated with higher direct and opportunity costs, (1) fewer farmers were willing to participate and (2) the average payment the farmers would need to receive increased. In particular, farmers would require higher

Table 13.2. Alternative cropping systems offered to six farmer focus groups, Michigan, 2007.

Cropping System	A	B	C	D	E
Tillage	Mixed	Reduced	Reduced	Reduced	Reduced
Fertilizer timing	At planting	Split	Split	Split	Split
Nitrate test on corn[a]	No	Yes	Yes	Yes	Yes
Winter cover crop	No	No	Yes	Yes	Yes
Rotation	Corn–soybean	Corn–soybean	Corn–soybean	Corn–soybean–wheat	Corn–soybean–wheat
Mineral fertilizer rate	Full	Full	Full	Full	2/3 recommended
Pesticide rate	Label	Label	Label	Label	2/3 label[b]

[a]Pre-sidedress nitrate test, which requires split nitrogen fertilizer application after corn is growing.
[b]Full rate added within rows, mechanical cultivation between rows.

Table 13.3. Farmer willingness to implement low-input cropping practices in exchange for payment.[a]

Cropping System	B	C	D	E
Rotation/Management	Corn–soybean	Corn–soybean, winter cover	Corn–soybean–wheat, winter cover	Corn–soybean–wheat, winter cover agrochemicals at 2/3 rates
Participated (%)	90	85	72	59
Average payment offered if participated ($US)	37	57	44	71
Average acres offered	1315	1203	947	877
Average acres offered if participated	1470	1436	1274	1353

[a]Results are compared to Cropping System A in Table 13.2 and are based on an experimental auction involving 39 Michigan farmers in six 2007 focus groups.

payments to grow wheat and a winter cover crop. Beyond that, they would require yet a higher payment to reduce agrochemical rates from university extension recommendations (F. Lupi, unpublished data). Admittedly, the small sample size calls for caution in drawing quantitative inferences. However, the subsequent 2008 Crop Management and Environmental Stewardship Survey of 1688 corn–soybean farmers found a similar pattern: although farmers' willingness to consider enrolling in a payment-for environmental-services program was determined by their environmental attitudes, experience, education and equipment owned, the amount of land they would enroll depended more on the payment level and other income-related factors that would compensate the costs of participation (Ma et al. 2012).

What We Can Conclude about Incentives for Ecosystem Service?

Farmer adoption of conservation practices depends on awareness, attitudes, barriers, and incentives. The low-input practices studied at KBS LTER offer documented environmental benefits, including greenhouse gas mitigation (the permanent No-till, Reduced Input, and Biologically Based systems) and reduced nitrate leaching (the Reduced Input and Biologically Based systems). Michigan farmers have been adopting conservation tillage practices, as have farmers nationally. However, management that includes permanent no-till, rotation with small grains, winter cover crops, and reduced agrochemical input rates has not been widely adopted, which is also consistent with national patterns. Evidently, where a management option is win-win for both private profitability and the environment at large, farmers will adopt the practice. But where there are trade-offs that affect profitability, most farmers are reluctant to shoulder what they perceive as a private burden for the benefit of the public at large.

In focus group interviews and a statewide survey, Michigan farmers expressed familiarity with the conservation practices used at KBS LTER, but they were generally inclined to adopt only those practices that are profitable. Farmers generally believed they should be compensated to undertake practices that benefited a wider public than the farm. In experimental auctions and a subsequent mail survey, they expressed willingness to adopt low-input cropping practices in exchange for payments that would increase with the complexity and cost of the practices to be undertaken.

Similar findings internationally have led to an explosion of interest in payments for environmental services (Pagiola et al. 2002, Lipper et al. 2009). The ideal for sustainable financing of such projects is that they emerge from markets between willing buyers and sellers. However, designing such an exchange for agricultural ecosystem services can be extremely demanding, even when external start-up funding is involved (Bohlen et al. 2009). Alternatively, government programs can offer payments, although in the past, budgetary and political limitations have constrained U.S. programs such as the Conservation Stewardship Program and EQIP. Moreover, EQIP is not a true payment for ecosystem services program because its payments share input costs; they do not pay for ecosystem service outcomes per se.

Although funding payment for ecosystem service programs in the United States may be politically difficult to expand through existing farm bill mechanisms (Batie 2009), there exist alternative avenues for inducing farmers to adopt costly practices that generate wider environmental benefits. Tradable pollution permits have been inspired by the cost-effectiveness of tradable emissions permits within the Clean Air Act cap on sulfur dioxide from U.S. electrical power plants. Similar cap and trade programs have been proposed for water-borne nutrients (Hoag and Hughes-Popp 1997, Stephenson et al. 1999, Ribaudo et al. 2011, Millar and Robertson 2015, chapter 9 in this volume); greenhouse gas emissions (Konyar 2001, Post et al. 2004); and nitrous oxide abatement (Millar et al. 2010, Ribaudo et al. 2011). Such programs potentially offer farmers a market-based incentive to offer ecosystem services. However, tradable permit programs for water pollution and GHG emissions have failed to gain traction because they lack legally binding caps on emissions needed to motivate significant payment rates.

Taxes on polluting inputs are another incentive avenue. Agrochemical input taxes have been implemented at low levels in many U.S. states. While these taxes generate revenues often directed toward financing more environmental improvements, they have not led to widespread adoption of reduced agrochemical use. The literature suggests that tax rates would have to be very high in order to trigger significant reductions in agrochemical application rates (Swinton and Clark 1994, Claassen and Horan 2001, Ribaudo et al. 2011).

The adoption of environmental stewardship practices can also be made a precondition for farmers to gain access to desirable opportunities. In the government sector, conservation compliance is already required for farmers to access many farm subsidy programs, and those requirements could be expanded (Ribaudo et al. 2011). In the private sector, a number of large food companies have mandated certain management practices in the name of corporate social responsibility (Maloni and Brown 2006). For example, McDonald's requires that contracted poultry farmers meet certain animal welfare requirements. By making market access contingent on the adoption of environmental practices, the incentive for farmer adoption is tied to the value of being in that market.

To put this recent incentive research into a broader perspective, U.S. farmer attitudes and adoption behavior emerge from a legal institutional setting under which farmers have broad latitude to use their land, so long as there is no directly traceable harm done to someone else. This U.S. legal precedent evolved from English common law during a time when no scientific basis existed to demonstrate links between farm input use and outcomes that were unimaginable at that time, such as hypoxia in the Gulf of Mexico or changes in the global climate. Even when those links are acknowledged, the nonpoint source nature of much agricultural pollution impedes tracing outcomes to individual sources. Moreover, much of the damage from agricultural pollution results from the combined effect of individual contributions, making it difficult to tie aggregate impacts to individual actions.

Property rights hinge on the relationship between the person and the property. The judicial interpretation of that relationship has evolved over time (Williams 1998, Merrill and Smith 2001). Mainly in nonagricultural settings has it come to provide greater protection for the interests of persons other than the property owner. Nuisance law does recognize certain property rights of neighbors, but the law has yet to recognize the attenuation of agricultural property rights based on nonpoint source pollution. This matters both to decisions about agricultural production practices and to resultant environmental quality.

The assignment of property rights affects the very definition of production costs (Coase 1960, Norris et al. 2008, Schmid 2004). Because most U.S. farmers hold the implicit right to allow excess nutrients and greenhouse gases to move into off-farm water and air, they expect to be compensated for internalizing these disposal costs. This definition of property rights is coming under challenge from a view based on relations among members of society (Singer 2000). Kling

(2011) has argued that in a populous world with greater scientific understanding of off-farm emission effects, property rights should change so that farming is subject to the same "polluter pays" principle as industry. Were that to occur, farmers would be responsible for pollution mitigation costs for which they now expect to be compensated. Given that most of the conservation technologies discussed in this chapter would abate such pollution, voluntary adoption would be more likely.

Apart from policy and market incentive programs, technological change offers another potential avenue for a greater voluntary provision of ecosystem services from agriculture. Conservation tillage in association with herbicide-tolerant, genetically modified crops has been adopted in the United States chiefly because farmers find it to be efficient and profitable. Arguably, this phenomenon has provided important benefits via both reduced greenhouse gas emissions and reduced pesticide runoff from farm fields (NRC 2010). However, these two benefits have come with the potential for risks associated with gene release as well as perceived health risks (Uzogara 2000), which has led to the banning of genetically modified crops in Europe. The development of more win-win technologies that are profitable to farmers while offering public benefits remains possible. Incentives to generate such technologies could be enhanced by payment programs that would induce innovation of environmental technologies for agriculture (Swinton and Casey 1999) or by changes in property rights that hold farmers responsible for reducing the release of excess agrochemicals and greenhouse gases from agricultural activities (Norris et al. 2008).

Summary

Agricultural ecosystems are managed directly for human benefit. Farmers make decisions with the knowledge and resources they command to meet their goals in a complex, risky setting. Working ecosystems like agriculture are managed chiefly to provide farm income, while producing food, fiber, and biofuels to meet human needs. During the twentieth century, U.S. farmers became increasingly efficient at producing food and fuel through more reliance on agrochemical inputs. Recent calls for a rebalanced, more diverse mix of ecosystem services from agriculture raise a fundamental question: What will induce farmers to adopt more environmentally beneficial practices? By what avenues will they balance food, fiber, and fuel production with ecosystem services like carbon sequestration, improved water quality, and functional biodiversity?

Farmer adoption of new management practices depends on awareness, attitudes, available resources, and incentives. Research with Michigan farmers indicates that they are largely aware of the low-input systems studied at KBS LTER. Yet few row-crop farmers have chosen to adopt these systems in their entirety. Focus group interviews, experimental auctions, and a statewide mail survey suggest that farmer reluctance to adopt low-input practices stems from a perception of lower profitability and higher labor requirements. While no-till farming with conventional fertilization was profitable and attractive for many farmers, reduced chemical inputs appealed only in the presence of special incentives such as an organic price premium. However, farmer focus group participants and mail survey respondents expressed willingness to adopt low-input practices in exchange for payments for ecosystem services. Apart from existing government cost-share programs like the USDA Environmental Quality Incentives Program, there appear to be opportunities for payments that could compensate farmers for providing added ecosystem services, such as global warming mitigation and water-quality improvements. Payment programs or changes in legal responsibility for agricultural pollution will likely be necessary to create incentives for technological innovation with environmental benefits.

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