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Benefits and barriers to perennial forage crops in Iowa corn and soybean rotations

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Abstract

The transition away from forage-based cropping systems in Iowa to corn and soybean rotations since World War II has corresponded with degraded economic and environmental conditions in the state. Falling net incomes for farmers and concern over global warming and the effects of agriculture-related pollution on water, wildlife and human health have increased interest in diversified cropping systems. This paper reviews the benefits of diversifying Iowa corn and soybean rotations with perennial forage species such as alfalfa and red clover. Perennial forage crops improve soil quality, decrease NO_3-N leaching and soil erosion, increase carbon sequestration and decrease pesticide and herbicide needs by controlling weed and insect pests. Forage legumes reduce N fertilizer needs for succeeding corn crops at a higher rate than soybeans, and corn crops following forages have higher yields than after corn or soybeans. Farmers who add alfalfa to corn and soybean rotations could realize significant economic gains. A simulated 5-year rotation in Iowa including corn–soybeans–oats/alfalfa–alfalfa–alfalfa would result in a 24% net income increase over 5 years of corn–soybean–corn–soybean–corn, even with government farm support payments for the row crops. Farm policies that encourage commodity production create little incentive for Iowa farmers to diversify their cropping systems beyond corn and soybeans, despite the clear economic and ecological benefits. We recommend increasing federal support for conservation programs that reward environmentally beneficial farm practices such as the Conservation Securities Program and we encourage land grant universities to hire researchers interested in alternative agricultural systems.

Key words: forages, alfalfa, corn, cropping systems, alternative agriculture, farm policy

Introduction

Prior to World War II, forage species, used for pasture, silage and hay, were routinely included in Iowa crop rotations. By providing feed for livestock and work animals, cash income to farmers from hay sales and crucial ecological benefits to the farming system, these multi-functional crops mitigated risk on the farm. The post-war influx of cheap, abundant chemical fertilizers and synthetic pesticides, along with a shift from animal to machine-based labor, caused a decrease in forage-based cropping sequences[1,2], in part because farmers did not need to rely solely on forage legumes to supply nitrogen nor did they need feed for draft animals.

Since 1950, Iowa agriculture has increasingly focused on intensive corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] production, an effort that produced impressive results—corn and soybean yields nearly quadrupled and more than doubled, respectively, between 1950 and 2004[3]. Ironically, these yield increases did not represent improved welfare for Iowa farms or farmers. During the same period of time, the number of farms in Iowa decreased by more than 50% and crop prices plummeted[4]. After adjusting for inflation, average net income per Iowa farm in 2001 was 9% lower than it was in 1960, despite a more than twofold increase in the number of acres per farm[4].

Meanwhile, the environmental implications of intensive corn and soybean production are cause for concern. Runoff and artificial drainage from corn and soybean fields are

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well-documented causes of non-point source contamination of surface and groundwater bodies with sediment, nutrients (especially NO_3-N and P)[5–8], and pesticides[9–13]. NO_3-N loading to the Mississippi River from agricultural operations in the Mississippi River Basin has been linked to a hypoxic zone in the Gulf of Mexico that is growing in size and severity[14]. Further, pesticide and herbicide use in corn and soybean production may have negative effects on human and wildlife health[15–17].

We hypothesize that diversifying Iowa corn and soybean rotations by including forage crops would offer farmers a way to mitigate negative environmental impacts caused by corn and soybean production while providing a lucrative source of income not dependent on government subsidization. In this paper, we review the literature on the agronomic and ecological effects of forage incorporation into Iowa and Midwestern cropping systems. We also look at the economic effect of incorporating forages into corn and soybean rotations in Iowa and assess socio-political barriers that discourage farmers from including forage species as part of their agricultural systems. Finally, we make recommendations for policy changes that would encourage the adoption of forages by corn and soybean farmers, a goal that has the potential to greatly improve not only the ecological health of Iowa waterways and soil but also the economic health of the state's farmers. Although this analysis primarily focuses on Iowa, the discussion and conclusions can likely be generalized to other agroecosystems as well.

Forage Production

Forage is defined as the edible part of a plant, other than the separated grain, that is generally above ground and that can provide feed for grazing animals or can be harvested for feeding[18]. In Iowa, several grass and legume species are cultivated as forages, including smooth bromegrass (*Bromus inermis* Leyss.), orchardgrass (*Dactylis glomerata* L.), switchgrass (*Panicum virgatum* L.), red (*Trifolium pratense* L.) and white clover (*Trifolium repens* L.), birdsfoot trefoil (*Lotus corniculatus* L.), and most commonly, alfalfa (*Medicago sativa* L.)[19]. Forages can be harvested by animals in pasture-based systems or mechanically harvested throughout the growing season as silage/haylage, hay or pellets for use as year-round livestock feed.

Precise estimates of the amount of perennial forage crops grown in Iowa are not available. Iowa has between 1 and 2 million ha of pastureland, encompassing cropland, permanent and woodland pastures[19]. An additional 650,000 ha of hay were harvested in Iowa in 2004, 525,000 ha (81%) of which was alfalfa[20]. This represents 7% of Iowa's crop harvest, which also includes corn, soybeans, oats (*Avena sativa* L.) and wheat (*Triticum aestivum* L.).

Relative to corn and soybeans, perennial forage crops have high caloric and protein yields, and high output/input energy ratios. Based on energy data from production in Ohio, alfalfa yields nearly twice as many calories and protein per hectare as soybeans and more than 40% more protein than corn per hectare. The energy output/input (energy inputs include labor, machinery, fuel, fertilizers, pesticides, electricity and transportation) ratios for alfalfa, soybeans and corn are 6.17 : 1, 4.15 : 1 and 2.5 : 1, respectively[21]. The relative energy efficiency of alfalfa over a corn and soybean rotation is mainly the result of the high energy cost of nitrogen fertilizer applied primarily to corn.

Agronomics

Rotational yield benefits

Little debate exists over the yield benefits arising from diversifying crop rotations, particularly those combining legume and grass crops in succession. A rotation of corn and soybeans yielded 10% more than continuous corn and 8% more than continuous soybeans in Minnesota, evidence for a 'rotation effect'[22]. Adding perennial forage legumes, particularly alfalfa, to the system creates more substantial benefits to corn yield, a trend that has been observed for over 50 years and in many regions of North America[23–33] (Table 1). In Minnesota, a single year of alfalfa increased succeeding corn yields by 19%[24] to 84%[22] compared to corn following corn and by 33% compared to corn following soybeans[22]. Even when nitrogen is applied to the corn crop, corn following alfalfa typically yields more than corn following soybeans[34]. These studies demonstrate that rotations including at least 1 year of alfalfa would produce higher corn and soybean yields than the typical corn–soybean rotation. Because the preceding alfalfa crop supplies nitrogen to the corn for free, the higher yield is produced at lower input cost as well. Yield benefits conferred by alfalfa occur in sub-humid regions like the Midwest or in areas under irrigation. When water availability is restricted, alfalfa, which uses large quantities of water, can decrease subsequent corn yields[35].

Weed effects

In recent years, Iowa farmers have sprayed more than 95% of corn and soybean fields annually with herbicides[36]. Evidence of human and animal toxicity of the most frequently applied herbicides—atrazine for corn and glyphosate for soybeans—has raised concerns about their widespread use[15–17]. In particular, the widespread adoption of Roundup Ready® soybeans and corn has resulted in a large increase in the application of Roundup® (glyphosate), which is now present in many water samples in the Midwest[37]. Further, herbicide-tolerant crops do not solve the weed control problem; resistance has developed in many weed species to herbicides like Roundup®, diminishing the value of the technology[38]. In other words, the technological fix of herbicide-resistant crops is transient, requiring continual reinvigoration by more advanced technology.

Table 1. Corn yield following corn, soybeans or alfalfa across ten environments.

Preceding crop						
Corn	**Soybeans**	**Alfalfa**	**Alfalfa–corn as % of corn–corn**	**Location**	**Year**	**Reference**
-----------------kg ha^{-1}	-----------------	-----------------				
267	–	748	280%	IA	1948	31
1599	–	4792	300%	GA	1970	32
1670	–	5170	310%	ON	1976	25
3700	5100	6800	184%	MN	1986	27
852	–	1642	193%	PA	1988	29[1]
8709	9126	9031	104%	MN	1994	33[2]
7860	8130	9270	118%	MN	1997	23
5084	7015	7966	157%	ON	2003	30
3830	6140	7300	191%	SD	2005	24
7407	7407	9416	127%	MN	2005	26

[1] The corn yield values come from Table 1, with the comparison being corn following corn with no nitrogen application versus corn following alfalfa in 1984.
[2] Comparisons from Table 2 and crop yields in 1994, which is the only year with corn grown directly after all three crops.

In contrast, alfalfa and other forages planted in rotation with corn and soybeans offer non-chemical means of controlling weeds. When grown in monoculture, alfalfa stands decrease or eliminate populations of several weed species, including milkthistle [*Silybum marianum* (L.) Gaertn.], field bindweed (*Convulvulus arvensis* L.), white campion [*Silene latifolia* subsp. *alba* (Mill.) Greuter & Burdet; syn. *Silene alba* (Mill.) E.H.L. Krause], and common lambsquarter (*Chenopodium album* L.)[39–42]. By their second year, alfalfa stands can often be weed-free without any herbicide use[43,44]. Without decreasing yields of succeeding crops, alfalfa has been shown to reduce weed densities to a comparable degree as herbicides[45–47]. A recent demonstration of one alternative system has shown that diversifying crop rotations to include triticale and either red clover or alfalfa is nearly as effective as herbicide use in controlling velvetleaf (*Abutilon theophrasti* Medik.) and foxtail (*Setaria faberi* Hermm.), two of the most prevalent weed species found in corn and soybean crops in the Midwestern US[48].

Soil nutrients

All plants require nitrogen for growth. Corn, like most grass species, cannot fix its own nitrogen and must mainly rely either on synthetic fertilizer or animal manure nitrogen inputs or on nitrogen that has been fixed by a legume species planted before it. Soybeans are legumes, and hence fix nitrogen, but in quantities insufficient to fully meet the N demands of themselves or of successive corn crops. In contrast, alfalfa can fix up to nine times more N than soybeans, birdsfoot trefoil up to four times as much, and red clover up to five times more[49]. Sweetclover (*Melilotus* spp.), once widely planted throughout the Midwest and Great Plains, can produce even more N than these species[50]. The value of alfalfa for increasing soil nutrient levels has been documented since at least the time of the Roman agronomist Columella, who wrote sometime around 100 CE that alfalfa 'dungs the land'[51]. The decomposing alfalfa crop results in more mineralizable N than either soybean or corn crops[52], further demonstrating the value of the crop in providing nitrogen for crop production.

Alfalfa's superior nitrogen fixation rate enables it to reduce the economically optimum N fertilizer rate needed for corn production by a greater magnitude than soybeans. Iowa State University recommends a reduction in the application rates of N fertilizer to corn following alfalfa by 80–85% compared to 0–25% for corn following soybeans[53]. Alfalfa in rotation with corn contributes an 18–50 kg ha^{-1} larger nitrogen credit than soybeans, depending on the condition of the stand when rotated out of alfalfa[54]. In addition to cost savings for nitrogen fertilizer, this credit also results in a considerable reduction in the amount of nitrogen leaving the agroecosystem[33,55,56].

Soil quality

Forage legumes and grasses improve soil quality as determined by multiple indicators, including improved soil organic matter (SOM) and physical properties[26,57–66] (Table 2). Additionally, 5 years of continuous alfalfa increased the mean weight diameter of water-stable aggregates (an indicator of soil quality) from 1.5 to 2.3 mm and C content increased from 26 to 30 g/kg[67]. In comparison, 5 years of corn and fallow resulted in neither an increase nor decrease in soil quality[68]. Alfalfa, bromegrass and red clover increased soil structural quality, as indicated by a decrease in dispersible clay and an increase in wet aggregate stability, compared to continuous corn grown under either conventional or no-till conditions, which showed either no improvement or some decline in soil structural quality[57].

Table 2. Soil quality and ecological benefits contributed by forages.

Ecological indicator	Data	Reference
SOM	148% greater SOM with C-S-O/A-A-A than C-S-C-S-C	26
Soil organic C (SOC)	24% greater SOC in C-C-O-A than C-S	66
Subsurface drainage	54% less subsurface drainage in A-C-C than C-S	33
Nitrogen loss	14% less NO_3-N loss in A-A-A-C-O-S than C-S	55
Nitrogen loss	37% less NO_3-N loss in A-C-C than C-S	56
Nitrogen loss	23–77% lower N loss in A-C-C than C-S	33
Wildlife habitat	Eighteen times more wildlife in A than in a field by chance	67

C, corn; S, soybeans; O, oats; A, alfalfa.

Ecological benefits

Recent decades have seen growing concern over the widespread damage caused by row cropping, including soil erosion, nutrient contamination of waterways and contribution to excess greenhouse gas emissions[33,69,70]. Cropping systems that reduce or mitigate these problems are essential if agricultural systems are to be environmentally sustainable in the long term. Crop rotations that include forages can help reduce negative impacts of agriculture on the environment, as compared to rotations that only include corn and soybeans, through decreased NO_3-N leaching and water drain flows[33,55,56,71] and by increased C sequestration[59,66,68,72–77] (Table 2). Additionally, forage crops can also play an important role in providing critical wildlife habitat for many species of migratory birds and small mammals[51,67] (Table 2).

Economics

Few formal economic comparisons exist that calculate production costs and profits on Midwestern farms with corn and soybean rotations as compared to those with alternative rotations including forage crops such as alfalfa[65,78–81]. Case study economic analyses, however, often show alternative rotation schemes to be economically competitive with, or frequently advantageous over, rotations of only corn and soybeans[65,78,79,81,82]. Additionally, a number of analyses show that forage-based livestock production systems are economically advantageous over grain-based livestock systems or row-crop systems[83,84].

To illustrate the economic differences between a corn–soybean rotation and two alternative rotations in Iowa, we compared estimated production costs and incomes on an average-sized Iowa farm. This analysis does not pretend to be exhaustive or to take into consideration the complexity of factors influencing production costs and income on Iowa farms. Variables such as yield differences between farms, the effects of precipitation and pest stress, management differences, or the complexity and variation of incomes from government payments will affect any given farmer's bottom line. This analysis seeks solely to compare production costs and farm incomes based on average farm size, management practices, input costs, prices and government payments.

According to 2005 statistics from the Iowa Department of Agriculture[20], average farm size in Iowa is 143 ha, so we set our generalized farm size equal to that figure. This analysis could be scaled up or down for other farm sizes and the income differences between the systems would change proportionally. According to 2002 statistics on land tenure rates, Iowa farmers on average rent 59% of the land they farm, so on our generalized farm we assumed 81 ha were rented and 62 ha were owned[85]. The cropping systems analyzed were as follows:

Conventional: corn–soybean
Alternative 1: corn–soybean–oat/alfalfa
Alternative 2: corn–soybean–oat/alfalfa–alfalfa–alfalfa

The *conventional* system, an annual corn and soybean rotation, represents the most common cropping system found in Iowa. For our purposes, we assumed that 1/2 of the farm was planted to each crop each year. *Alternative 1* includes an oats/alfalfa mix. Thus, in any given year, 1/3 of the farm is in corn, 1/3 in soybean and 1/3 in oat/alfalfa; crops would be rotated year-to-year in that order on each of the thirds. Oats would be harvested for grain and the straw baled; a single alfalfa harvest would be taken one month after oat harvest. Alfalfa regrowth would be plowed down, adding value as an N fertilizer to the succeeding corn crop, but not considered in our economic analysis. For the *Alternative 2* rotation, the farm is divided into five fields, with one in corn, one in soybeans, one in oats and establishing alfalfa and two in established alfalfa in any given year. During the two post-establishment years of alfalfa production, four harvests are made each season.

Crop production costs were obtained from Iowa State University Extension estimates, which include fixed and variable expenses such as machinery and fuel, seeds, chemical inputs (including pesticides and fertilizers), labor and land[86]. Actual crop prices were obtained from the Iowa Department of Agriculture[20] (except for the average price of oat straw, which was obtained from the *Hay and Forage Grower* Web site[87]) (Table 3). Government payments, including direct and counter-cyclical payments (DP and CCP), were estimated as described below using formulas and figures provided by the Farm Services Agency of the United States Department of Agriculture (USDA)[88]. DP

Table 3. Assumed crop yields (kg ha^{-1}) and average crop prices (US\$ Mg^{-1}) for the years 2001 through 2005.

	Assumed yield[1]					Average price[2]				
Crop	**2001**	**2002**	**2003**	**2004**	**2005**	**2001**	**2002**	**2003**	**2004**	**2005**
Corn	8467	8467	9408	9408	9408	$75	$87	$93	$75	$73
Soybeans	3024	3024	3024	3024	3024	$160	$204	$105	$186	$197
Oats	2867	2867	2867	2867	2867	$106	$123	$106	$103	$117
Oat straw	907	907	907	907	907	$66	$66	$66	$66	$66
Alfalfa (established)	5442	5442	5442	5442	5442	$100	$94	$90	$95	$89
Alfalfa (first-year)	907	907	907	907	907	$100	$94	$90	$95	$89

[1] kg ha^{-1} for corn, soybeans, and oats, and kg ha^{-1} cutting^{-1} for oat straw and alfalfa.
[2] US\$ Mg^{-1}.

Table 4. Simulated production costs, gross returns and net returns for three cropping systems on an 'average' 143 ha Iowa farm for the years 2001 through 2005.

		Cropping system		
Year		**Conventional**[1]	**Alternative 1**[2]	**Alternative 2**[3]
2001	Cost	$91,568	$84,314	$93,670
	Gross return	$79,822	$85,479	$128,383
	Net return	−$11,745	$1165	$34,712
2002	Cost	$90,896	$83,214	$90,922
	Gross return	$96,899	$98,416	$131,062
	Net return	$6003	$15,202	$40,140
2003	Cost	$94,786	$86,823	$95,659
	Gross return	$117,628	$109,624	$135,245
	Net return	$22,842	$22,802	$39,586
2004	Cost	$100,013	$91,887	$100,099
	Gross return	$90,412	$91,421	$127,288
	Net return	−$9601	−$465	$27,189
2005	Cost	$105,799	$97,435	$109,177
	Gross return	$91,471	$93,516	$124,309
	Net return	−$14,328	−$3919	$15,132

[1] C-S.
[2] C-S-O/A.
[3] C-S-O/A-A-A.
C, corn; S, soybeans; O, oats; A, alfalfa.

were estimated with the formula, DP = DP rate × base acreage × 85% × DP yield, where the DP rate was set in the US Farm Bill, the base acreage is based on the historical acreage in crop production (assumed to be the entire program crop area on our generalized farm), and the DP yields are equivalent to those listed in Table 3. CCP were estimated using the formula, CCP = Target price − Market price × Base acreage × 85% × CCP yield, where the target price was set in the US Farm Bill, market prices are given in Table 3, and CCP yields are equivalent to those listed in Table 3.

Yields used in the analysis for corn, soybeans, alfalfa, oats and oat straw were the average yields used to determine production costs in the Iowa State University Extension publication[86] (Table 3). These yields were used for all of the systems, despite the fact that yields may differ depending on the rotation employed, as we described in earlier sections of this paper. Similarly, the various ecological benefits of a system including forage crops are not accounted in this analysis.

To make our estimates, we obtained average crop production costs and returns in each year for each system (Table 4) and calculated average net income across five years (the length of the longest rotation) from each production system. Government payments were also averaged across years. Net returns are equal to gross income (including deficiency payments when government programs apply) minus all production costs. Average net returns for the entire 5-year rotation were calculated with and without government program payments for each system (Table 5).

Profitability of the cropping systems was based on production costs, prices obtained by farmers for crops, and in some cases government program payments. Our

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Table 5. Whole farm gross and net returns with and without government program payments for three cropping systems on an ‘average’ 143 ha Iowa farm from the years 2001 through 2005.

Cropping system[1]	With government payments		Without government payments	
	5-Year gross returns (rank)[2]	5-Year net returns (rank)	5-Year gross returns (rank)	5-Year net returns (rank)
Conventional	$543,474 (3)	$60,413 (3)	$476,232 (3)	−$6829 (3)
Alternative 1	$525,524 (2)	$81,852 (2)	$478,456 (2)	$34,784 (2)
Alternative 2	$674,527 (1)	$185,000 (1)	$646,287 (1)	$156,760 (1)

[1] Conventional = C-S, Alternative 1 = C-S-O/A, Alternative 2 = C-S-O/A-A-A; C, corn; S, soybeans; O, oats; A, alfalfa.
[2] The rank of 1 is highest value.

calculations clearly show that the Alternative 2 rotation, with 3 years of alfalfa, is the most profitable, whether government payments are included or not. Alternative 1, with only 1 year of alfalfa, ranks second in profitability, both with and without government payments. The conventional system, which does not include forage, is the least profitable system, and results in a net loss without government payments.

Despite the increased costs associated with alfalfa production (which include factors such as additional machinery and labor), the price obtained for the crop makes the system with 3 years of alfalfa very profitable, 43% more than the conventional system even when including government program payments. According to our analysis, adding only 1 year of alfalfa to a corn–soybean rotation (Alternative 1) decreases profitability of the system compared to Alternative 2, due to the relatively high cost of alfalfa seed, costs associated with planting and low yield of alfalfa in the establishment year.

The most profitable cropping system in our analysis contained 3 years of alfalfa. Prices of alfalfa vary with production levels in local markets and are not eligible for government deficiency payments. An increase in alfalfa production due to inclusion of the crop on more Iowa farms could therefore lead to depressed alfalfa prices. Future studies will need to consider the lowest prices for alfalfa at which the producer would have a net income equivalent to conventional systems, both with and without government program payments. A price sensitivity analysis could also indicate the economic feasibility of increased production levels and the need to consider new markets (other than hay) for alfalfa and other forages as production increases. One possibility could be the expansion of pasture-based livestock systems, demanded by a growing consumer sector[89] and offering many ecological services as compared to decoupled row crop and livestock systems[90]. The bottom line from our analysis showed that even without accounting the many positive externalities generated by alfalfa (or forages in general), profitability of the cropping enterprise increased with the inclusion of a forage component during the years 2001–2005.

Table 6. Whole farm gross and net returns with and without government program payments for corn versus alfalfa on an ‘average’ 143 ha Iowa farm in 2006.

Crop	With government payments		Without government payments	
	2006 Gross return	2006 Net return	2006 Gross return	2006 Net return
Corn	$204,525	$70,600	$172,352	$38,428
Alfalfa	$180,030	$53,209	$180,030	$53,209

The rapid expansion of the ethanol industry has caused a recent spike in corn prices that this economic analysis does not account for. Corn prices rose to four dollars per bushel at the end of 2006 and in early 2007[3]. Farmers have responded by increasing planned corn acreage in Iowa for 2007[91]. Although alfalfa (and most other crop) prices have risen along with corn, the high corn prices of 2006 made corn, on average, more profitable than alfalfa. To examine the change to farm income from the corn price increases, we compared net income from corn versus alfalfa, with and without government payments, on our sample farm, using 2006 average prices and government pay rates, 2006 production costs, and the same size and rented versus owned land proportion assumptions as in our original analysis[85,86,88]. With government payments included in net income estimates, 1 year of corn in 2006 was 25% more profitable than alfalfa. When government payments were excluded, however, alfalfa was 38% more profitable than corn in 2006 (Table 6).

Barriers to Forage Incorporation

Our review of the literature and a simple cost–benefit analysis using average input costs and output crop value demonstrate numerous agronomic, ecological and economic benefits that are being attained on Iowa farms that include forages in rotation with corn and soybeans. Why don’t more farmers grow forage crops? We surmise that the combination of government policies, market dynamics,

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time constraints from off-farm employment, and culture has influenced the hesitancy of many farmers to diversify cropping systems.

Perhaps most importantly, US agricultural policies subsidize a narrow set of commodities in Iowa including corn, soybeans and, to a limited extent, oats. USDA subsidies for Iowa farms totaled $12.5 billion between 1995 and 2004, with corn and soybean production receiving 83% of those dollars, while only 15% went toward conservation programs (mainly the Conservation Reserve Program)[92]. These policies are really a means of risk management, guaranteeing farmers a return on commodity crops regardless of the many uncontrollable variables that may impinge on production. Without similar risk avoidance for other crops, farmers would naturally be loath to grow them. Further, the programs essentially reward maximization of commodity production, offering little incentive for diversification of crop rotations or incorporation of perennial crops into agricultural landscapes.

Without policy incentives to encourage cropping system diversity (or at a minimum, policies that do not encourage corn and soybean production), many Iowa farmers are unlikely to take steps to incorporate forages into their cropping systems. A survey of row crop farmers in central Iowa found that 40% of respondents would be ‘not willing at all’ to convert to a cropping system incorporating more forages. However, another 40% said they would be ‘somewhat willing’, and 20% of respondents said they would be ‘very willing’ to add forages. Of those who were not willing at all, reasons cited included preference for their corn–soybean rotation, the need for increased labor, and the need for new equipment. Survey respondents also cited a lack of market incentives as the most serious obstacle to adoption of more ecologically sound farming practices[93].

Until recently, the relatively low cost of synthetic nitrogen fertilizers and fuel has meant that farmers often did not view energy costs alone as a significant incentive to make changes in agricultural systems. Recent increases in non-renewable energy costs, however, may mean farmers will consider alternative crop production systems that require fewer energy inputs, such as forage-based rotations[94].

Conversely, rising energy costs may increase demands for biofuels such as corn-based ethanol and soy biodiesel. Although comprehensive economic analyses for this scenario have not yet been done, projections from the USDA and World Resources Institute show a substantial increase in corn production over the next decade to meet biofuel demands[94,95]. Recent corn price increases fueled by ethanol demand means corn has lately become as profitable as or more profitable than alfalfa (Table 6). Corn acreage will expand in the near future, a scenario that will come with very high environmental costs. On the bright side, with the advent of ethanol from cellulose, many forage crops could be dual use—livestock feed or biofuel feedstock—and thus, could contribute in a sustainable way to a bioenergy future.

Recommendations for Change

Forages offer potential ecological, economic and agronomic benefits to midwestern agricultural landscapes and producers, and many farmers already incorporate forages into their systems. We see three possible avenues toward increasing the role of forage crops in the Midwest and throughout the country: revamped farm policies that stress conservation rather than production, a reinvigorated agricultural research paradigm that recognizes that the public interest is not always served by industry, and a more vocal forage research sector.

Without government policies that encourage alternative agricultural systems, farmers are unlikely to make changes to their crop rotations. Future farm policy should encourage diversification of agricultural landscapes and should reward environmental services provided by farmers. US farm policies should support forage production for hay and pastures, which would increase the numbers of ruminant livestock on the land. Increased pasture-based livestock production could lead to higher net incomes for farmers while simultaneously decreasing N fertilizer use and soil erosion, thereby improving water quality and increasing carbon sequestration[83,96].

We recommend increased funding and support for two programs within US farm policy intended to promote agricultural biodiversity and conservation: the Sustainable Agriculture Research and Extension Program (SARE) and the Conservation Security Program (CSP). SARE is a competitive grant program for research and outreach that funds farmer-, citizen- and researcher-driven projects, and has been shown to be effective at increasing sustainable production practices[97]. The promotion of researcher–farmer collaboration with a goal of increased diversity and sustainability on agricultural landscapes that is supported by SARE is crucial both to encourage positive changes on farms and to influence research priorities within land grant universities.

The CSP offers payments to farmers and landowners for carrying out conservation practices on working agricultural land. Unlike the Conservation Reserve Program (CRP), where the government essentially rents marginal land to establish grasses or wetlands, the CSP seeks to reward farmers whose agricultural practices provide ecological services such as soil erosion reduction and increased biodiversity. While the CRP has resulted in decreased erosion and increased biodiversity on some marginal lands, its costs have included a reduction in the number of working farms as well as reduced rural community vitality[98]. We recommend increased funding and expansion of incentive programs like the CSP that, rather than encourage increased commodity production, promote farming practices that provide both livable incomes for farmers and ecological benefits.

Secondly, because forage-related research currently attracts little funding from the agribusiness industry and is unlikely to receive substantial industry support in the future, agricultural research at the state land-grant institutions and through the USDA Agricultural Research Service (ARS) needs to include a critical mass of forage scientists. Data for public sector forage breeding show that the number of breeders has declined by 26% across all forages and by 46% for alfalfa just in the period from 1994 to 2001[99]. Therefore, encouraging universities and the USDA-ARS to hire scientists willing to investigate the full range of alternative production systems would enable forage crops to gain a higher profile. Land grant universities need to develop alternatives that help farmers remain on the land while being economically stable and environmentally sensitive, rather than simply following the lead of industrialized agriculture. Funding for agricultural research from state legislatures is declining and research support is increasingly based on extramural funds through governmental agencies like USDA or NSF. These programs need to be crafted to enable the long-term nature of perennial forage crop research to compete successfully.

Finally, forage scientists need to do a better job of relaying the importance of their research to funding agencies, the government and to the public. Although we often complain about the limitations constraining our field, we do not often take the initiative to write letters to the editor or to our congressional delegations supporting our field and on the importance of forages to esthetically pleasing, environmentally beneficial and economically sustainable farming systems.

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References

1 Dimitri, C., Effland, A., and Conklin, N. 2005. The 20th century transformation of U.S. agriculture and farm policy. Economic Research Bulletin. Economic Research Service, United States Department of Agriculture.

2 Cardwell, V.B. 1982. Fifty years of Minnesota corn production: sources of yield increase. Agronomy Journal 74:984–990.

3 United States Department of Agriculture, National Agricultural Statistics Service (USDA-NASS). 2007. Crops and Plants Quick Stats. Available at Web site: http://www.nass.usda.gov/QuickStats/indexbysubject.jsp?Text1=&site=NASS_MAIN&select=Select+a+State&Pass_name=&Pass_group-Crops+%26+Plants&Pass_subgroup=Field+Crops (verified 9 April 2007).

4 United States Department of Agriculture, National Agricultural Statistics Services (USDA-NASS). 2006. Economics Quick Stats. Available at Web site: http://www.nass.usda.gov/QuickStats/indexbysubject.jsp?Pass_group=Economics (verified 16 February 2006).

5 Gast, R.G., Nelson, W.W., and MacGregor, J.M. 1978. Nitrate accumulation in soils and loss in tile drainage following nitrogen application to continuous corn. Journal of Environmental Quality 7:258–262.

6 Logan, T.J., Randall, G.W., and Timmons, D.R. 1980. Nutrient content of tile drainage from cropland in the North Central Region. North Central Regional Research Publication 268. OARDC Research Bulletin 1119. The Ohio State University, Columbus, OH.

7 Logan, T.J., Eckert, D.J., and Beak, D.G. 1993. Tillage, crop and climate effects on runoff and tile drainage losses of nitrate and four herbicides. Soil Tillage Research 30: 75–103.

8 Kladivko, E.J., Van Scoyoc, G.E., Monke, E.J., Oates, K.M., and Pask, W. 1991. Pesticide and nutrient movement into subsurface tile drains on a silt loam in Indiana. Journal of Environmental Quality 20:264–270.

9 Buhler, D.D., Randall, G.W., Koskinen, W.C., and Wyse, W.L. 1993. Atrazine and alachlor losses from subsurface tile drainage of a clay loam soil. Journal of Environmental Quality 22:583–588.

10 Cambardella, C.A., Moorman, T.B., Jaynes, D.B., Hatfield, J.L., Parkin, T.B., Simpkins, W.W., and Karlen, D.L. 1999. Water quality in Walnut Creek watershed: nitrate-nitrogen in soils, subsurface drainage water, and shallow groundwater. Journal of Environmental Quality 28:25–34.

11 Hatfield, J.L., Jaynes, D.B., Burkart, M.R., Cambardella, C.A., Moorman, T.B., Prueger, J.H., and Smith, M.A. 1999. Farming systems impacts on water quality in Walnut Creek Watershed. Journal of Environmental Quality 28:11–24.

12 Jaynes, D.B., Hatfield, J.L., and Meek, D.W. 1999. Water quality in Walnut Creek watershed: herbicides and nitrate in surface waters. Journal of Environmental Quality 28:45–59.

13 Kanwar, R.S., Bjorneberg, D.L., and Baker, D. 1999. An automated system for monitoring the quality and quantity of subsurface drain flow. Journal of Agricultural Engineering Research 73:123–129.

14 Rabalais, N.N., Turner, R.E., Justic, D., Dortch, Q., and Wiseman, W.J. 1999. Characterization of hypoxia: Topic 1. Report for the integrated assessment on hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Series No. 15. NOAA Coastal Ocean Program, Silver Spring, MD.

15 Relyea, R. 2005. The impact of insecticides and herbicides on the biodiversity and productivity of aquatic communities. Ecological Applications 15:618–627.

16 Richard, S., Moslemi, S., Sipahutar, H., Benachour, N., and Seralini, G. 2005. Differential effects of glyphosate and Roundup on human placental cells and aromatase. Environmental Health Perspectives 113:716–720.

17 Rohr, J.R. and Crumrine, P.W. 2005. Effect of an herbicide and an insecticide on pond community structure and processes. Ecological Applications 15:1135–1147.

18 Forage Grazing Terminology Committee. 1992. Terminology for grazing lands and grazing animals. Journal of Production Agriculture 5:191–201.

19 Barnhart, S. 2006. Iowa State University Forage Extension Specialist. (Personal communication.)

20 Iowa Department of Agriculture. 2005. Iowa Agricultural Statistics Bulletin. Available at Web site: http://www.agriculture.state.ia.us/2005AgStatsGeneralInfo.htm (verified 12 November 2006).

21 Pimentel, D. and Pimentel, M. 1996. Food, Energy and Society. University Press of Colorado, Niwot, CO.

22 Crookston, R.K., Kurle, J.E., Copeland, P.J., Ford, J.H., and Lueschen, W.E. 1991. Rotational cropping sequence affects yield of corn and soybean. Agronomy Journal 83:108–113.
23 Porter, P.M., Crookston, R.K., Ford, J.H., Huggins, D.R., and Lueschen, W.E. 1997. Interrupting yield depression in monoculture corn: comparative effectiveness of grasses and dicots. Agronomy Journal 89:247–250.
24 Pikul, J.L.J., Hammack, L., and Riedell, W.E. 2005. Corn yield, nitrogen use, and corn rootworm infestation of rotations in the northern corn belt. Agronomy Journal 97:854–863.
25 Bolton, E.F., Dirks, V.A., and Aylesworth, J.W. 1976. Some effects of alfalfa, fertilizer and lime on corn yield in rotation on clay soil during a range of seasonal moisture conditions. Canadian Journal of Soil Science 56:21–25.
26 Gregory, M.M., Shea, K.L., and Bakko, E.B. 2005. Comparing agroecosystems: effects of cropping and tillage patterns on soil, water, energy use and productivity. Renewable Agriculture and Food Systems 20:81–90.
27 Hesterman, O.B., Schaeffer, C.C., Barnes, D.K., Lueschen, W.E., and Ford, J.H. 1986. Alfalfa dry matter and nitrogen production, and fertilizer nitrogen response in legume–corn rotations. Agronomy Journal 78:19–23.
28 Clay, S.A. and Aguilar, I. 1998. Weed seedbanks and corn growth following continuous corn or alfalfa. Agronomy Journal 90:813–818.
29 Fox, R.H. and Piekielek, W.P. 1988. Fertilizer N equivalance of alfalfa, birdsfoot trefoil, and red clover for succeeding corn crops. Journal of Production Agriculture 1:313–317.
30 Ma, B.L., Ying, J., Dwyer, L.M., Gregorich, E.G., and Morrison, M.J. 2003. Crop rotation and soil N amendment effects on maize production in eastern Canada. Canadian Journal of Soil Science 83:483–495.
31 Uhland, R.E. 1948. Grass and the yields of cash crops. In Grass. Yearbook of Agriculture 1948. United States Department of Agriculture, Washington, DC. p. 191–194.
32 Adams, W.E., Morris, H.D., and Dawson, R.N. 1970. Effects of cropping systems and nitrogen levels on corn (*Zea mays*) yields in the southern Piedmont region. Agronomy Journal 62:655–659.
33 Huggins, D.R., Randall, G.W., and Russelle, M.P. 2001. Subsurface drain losses of water and nitrate following conversion of perennials to row crops. Agronomy Journal 93: 477–486.
34 Anderson, I.C., Buxton, D.R., Karlen, D.L., and Cambardella, C.A. 1997. Cropping system effects on nitrogen removal, soil nitrogen, aggregate stability and subsequent corn grain yield. Agronomy Journal 89:881–886.
35 Hesterman, O.B., Griffin, T., Williams, P., Harris, G., and Christenson, D. 1992. Forage-legume small-grain intercrops: nitrogen production and response of subsequent corn. Journal of Production Agriculture 5:340–348.
36 United States Department of Agriculture. 2005. Agricultural Chemical Usage: 2005 Field Crop Summary. Available at Web site: http://usda.mannlib.cornell.edu/reports/nassr/other/pcu-bb/agcs0506.pdf (verified 31 May 2006).
37 Battaglin, W.A., Kolpin, D.W., Scribner, E.A., Kuivila, K.M., and Sandstrom, M.W. 2005. Glyphosate, other herbicides, and transformation products in Midwestern streams. Journal of American Water Resources Association 41:323–332.
38 Cerdeira, A.L. and Duke, S.O. 2006. The current status and environmental impacts of glyphosate-resistant crops. Journal of Environmental Quality 35:1633–1658.
39 Michael, P.W. 1960. The control of thistles (*Silybum* and *Onopordum*) by perennial pasture species. Proceedings of the Australian Weed Conference, 2nd Council of the Australian Weed Science Society, Meredith, VIC, Australia.
40 Derscheid, L.A. 1978. Controlling field bindweed while growing adapted crops. Proceedings of the North Central Weed Control Conference 33:144–150. North Central Weed Science Society.
41 Pearson, J.O. 1969. A life history study of white cockle (*Lynchis alba* Mill.) and some competitive effects in alfalfa (*Medicago sativa* L.). PhD thesis, Michigan State University, East Lansing, MI.
42 Ahmed, M. 1988. Viability of buried seeds of bathua (*Chenopodium album* L.). Bangladesh Journal of Agriculture 13:23–30.
43 Brink, G.E. and Marten, G.C. 1986. Barley vs. oat companion crops: II. Influence on alfalfa persistence and yield. Crop Science 26:1067–1071.
44 Sheaffer, C.C. 1983. Seeding year harvest management of alfalfa. Agronomy Journal 75:115–119.
45 Curran, B.S., Kephardt, K.D., and Twidwell, E.K. 1993. Oat companion crop management in alfalfa establishment. Agronomy Journal 85:998–1003.
46 Caporali, F. and Onnis, A. 1992. Validity of rotation as an effective agroecological principle for a sustainable agriculture. Agriculture, Ecosystems and Environment 41:101–113.
47 Westerman, P.R., Liebman, M., Menalled, F.D., Heggenstaller, A.H., Hartzler, R.G., and Dixon, P.M. 2005. Are many little hammers effective? Velvetleaf (*Abutilon theophrasti*) population dynamics in two- and four-year crop rotation systems. Weed Science 53:382–392.
48 Heggenstaller, A.H. and Liebman, M. 2006. Demography of *Abutilon theophrasti and Setaria faberi* in three crop rotation systems. Weed Research 46:138–151.
49 Francis, C.A., Flora, C.B., and King, L.D. 1990. Sustainable Agriculture in Temperate Zones. Wiley, Hoboken, NJ.
50 Stickler, F.C. and Johnson, I.J. 1959. Dry matter and nitrogen production of legumes and legume associations in the fall of the seeding year. Agronomy Journal 51:135–137.
51 Putnam, D., Russelle, M.P., Orloff, S., Kuhn, J., Fitzhugh, L., Godfrey, L., Kiess, A., and Long, R. 2001. Alfalfa, Wildlife and the Environment. California Alfalfa and Forage Association, Novato, CA. Available at Web site: http://www.calhay.org/environmental.html (verified 3 January 2007).
52 Carpenter-Boggs, L., Pikul, J.L.J., Vigil, M.F., and Riedell, W.E. 2000. Soil nitrogen mineralization influenced by crop rotation and nitrogen fertilization. Soil Science Society of America Journal 64:2038–2045.
53 Sawyer, J.E. 2001. Making Every Fertilizer Dollar Pay. Integrated Crop Management IC-486, 29 January 2001. Available at Web site: http://www.ipm.iastate.edu/ipm/icm/2001/1-29-2001/makenpay.html (verified 22 March 2006).
54 Lamond, R.E., Whitney, D.A., Bonczkowski, L.C., and Hickman, J.S. 1988. Using legumes in crop rotations. Cooperative Extension Service Bulletin L778. Kansas State University, Manhattan, KS.
55 Kanwar, R.S., Cruse, R.M., Ghaffarzadeh, M., Bakhsh, A., Karlen, D.L., and Bailey, T.B. 2005. Corn–soybean and alternative cropping systems effects on NO_3-N leaching losses in subsurface drainage water. Applied Engineering in Agriculture 21:181–188.

56 Randall, G.W., Huggins, D.R., Russelle, M.P., Fuchs, D.J., Nelson, W.W., and Anderson, J.L. 1997. Nitrate losses through subsurface tile drainage in Conservation Reserve Program, alfalfa and row crop systems. Journal of Environmental Quality 26:1240–1247.
57 Perfect, E., Kay, B.D., van Loon, W.K.P., Sheard, R.W., and Pojasok, T. 1990. Rates of change in soil structural ability under forages and corn. Soil Science Society of America Journal 54:179–186.
58 Reid, J.B. and Goss, M.J. 1981. Effects of living roots of different plant species on aggregate stability of two arable soils. Journal of Soil Science 32:521–541.
59 Su, Y.Z. 2007. Soil carbon and nitrogen sequestration following the conversion of cropland to alfalfa forage land in northwest China. Soil and Tillage Research 92:181–189.
60 Drury, C.F., Yang, X.M., Reynolds, W.D., and Tan, C.S. 2004. Influence of crop rotation and aggregate size on carbon dioxide production and denitrification. Soil and Tillage Research 79:87–100.
61 Senwo, Z.N. and Tabatabai, M.A. 2005. Aspartase activity of soils under different management systems. Communications in Soil Science and Plant Analysis 36:2575–2585.
62 Dodor, D.E. and Tabatabai, M.A. 2005. Glycosidases in soils as affected by cropping systems. Journal of Plant Nutrition and Soil Science 168:749–758.
63 Ekenler, M. and Tabatabai, M.A. 2002. β-Glucosaminidase activity of soils: effect of cropping systems and its relationship to nitrogen mineralization. Biology and Fertility of Soils 36:367–376.
64 Moore, J.M., Klose, S., and Tabatabai, M.A. 2000. Soil microbial biomass carbon and nitrogen as affected by cropping systems. Biology and Fertility of Soils 31:200–210.
65 Karlen, D.L., Hurley, E.G., Andrews, S.S., Cambardella, C.A., Meeka, D.W., Duffy, M.D., and Mallarino, A.P. 2006. Crop rotation effects on soil quality at three northern corn/soybean belt locations. Agronomy Journal 98:484–495.
66 Russell, A.E., Laird, D.A., and Mallarino, A.P. 2006. Nitrogen fertilization and cropping system impacts on soil quality in midwestern mollisols. Soil Science Society of America Journal 70:249–255.
67 Putnam, D. 1998. Contributions of alfalfa to wildlife and the environment. Proceedings of the 28th National Alfalfa Symposium, Bowling Green, KY.
68 Angers, D.A. 1992. Changes in soil aggregation and organic carbon under corn and alfalfa. Soil Science Society of America Journal 56:1244–1249.
69 Clark, E.H.I., Haverkamp, J.A., and Chapman, W. 1985. Eroding Soils: The Off-farm Impacts. The Conservation Foundation, Washington, DC.
70 United States Environmental Protection Agency. 2006. Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2004. United States Environmental Protection Agency, Washington, DC.
71 Deng, S.P. and Tabatabai, M.A. 2000. Effects of cropping systems on nitrogen mineralization in soils. Biology and Fertility of Soils 31:211–218.
72 Gebhardt, D.L., Johnson, H.B., Mayeux, H.S., and Polley, H.W. 1994. The CRP increases soil organic carbon. Journal of Soil and Water Conservation 49:488–492.
73 Russell, A.E., Laird, D.A., Parkin, T.B., and Mallarino, A.P. 2005. Impact of nitrogen fertilization and cropping system on carbon sequestration in midwestern mollisols. Soil Science Society of America Journal 69:413–422.
74 Gregorich, E.G., Drury, C.F., and Baldock, J.A. 2001. Changes in soil carbon under long-term maize in monoculture and legume-based rotation. Canadian Journal of Soil Science 81:21–31.
75 Dodor, D.E. and Tabatabai, M.A. 2003. Effect of cropping systems on phosphatases in soils. Journal of Plant Nutrition and Soil Science 166:7–13.
76 Robinson, C.A., Cruse, R.M., and Ghaffarzadeh, M. 1996. Cropping system and nitrogen effects on mollisol organic carbon. Soil Science Society of America Journal 60:264–269.
77 Meyer-Aurich, A., Weersink, A., Janovicek, K., and Deen, B. 2006. Cost efficient rotation and tillage options to sequester carbon and mitigate GHG emissions from agriculture in Eastern Canada. Agriculture, Ecosystems and Environment 117:119–127.
78 Thompson, R.L. and Thompson, S.M. 2004. Alternatives in Agriculture. Thompson On-farm Research, Boone, IA.
79 Diebel, P.L., Williams, J.R., and Llewelyn, R.V. 1995. An economic comparison of conventional and alternative cropping systems for a representative northeast Kansas farm. Review of Agricultural Economics 17:323–335.
80 Sheaffer, C.C., Barnes, D.K., and Heichel, G.H. 1989. 'Annual' alfalfa in crop rotations. Minnesota Agricultural Experiment Station Bulletin 588. University of Minnesota, St. Paul, MN.
81 Delate, K., Duffy, M., Chase, C., Holste, A., Friedrich, H., and Wantate, N. 2003. An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa. American Journal of Alternative Agriculture 18:59–69.
82 Mitchell, R., Vogel, K., Varvel, G., Klopfenstein, T., Clark, D., and Anderson, B. 2005. Big bluestem pasture in the Great Plains: an alternative for dryland corn. Rangelands 27:31–35.
83 Nimrick, K., Oswald, D., and Staff, R. 2005. Economics of grazing stocker cattle as a sustainable alternative to row crops. Proceedings of the American Forage and Grasslands Council, Bloomington, IL.
84 Rotz, A.C., Roth, G.W., Soder, K.J., and Schnabel, R.R. 2001. Economic and environmental implications of soybean production and use on Pennsylvania dairy farms. Agronomy Journal 93:418–428.
85 Duffy, M. and Smith, D. 2004. Farmland ownership and tenure in Iowa 1982–2002: a twenty-year perspective. Iowa State University Extension Publication PM 1983. Iowa State University, Ames, IA.
86 Duffy, M. and Smith, D. 2005. Estimated crop production costs in Iowa. Extension Bulletin FM1712. Iowa State University, Ames, IA.
87 Hay and Forage Grower. 2003. Prices are Largely Unchanged. Available at Web site: http://hayandforage.com/mag/farming_prices_largely_unchanged/index.html (verified 15 April 2006).
88 Wisner, B. 2003. Counter-cyclical payments for corn and soybeans. Ag Decision Maker Newletter 9(1). Iowa State University Extension, Iowa State University, Ames, IA. Available at Web site: http://www.extension.iastate.edu/AgDM/articles/wisner/WisFeb03.html (verified 3 January 2006).
89 Lozier, J., Rayburn, E., and Shaw, J. 2005. Growing and selling pasture-finished beef: results of a nationwide survey. Journal of Sustainable Agriculture 25:93–112.

90 Naylor, R., Steinfeld, H., Falcon, E., Galloway, J., Smil, V., Bradford, E., Alder, J., and Mooney, H. 2005. Losing the links between livestock and land. Science 310:1621–1622.
91 Dougherty, E. and Geuder, J. 2007. Corn Acres Expected to Soar in 2007, USDA Says. USDA National Agricultural Statistics Service Newsroom. Available at Web site: http://www.nass.usda.gov/Newsroom/2007/03_30_2007.asp (verified 9 April 2007).
92 Environmental Working Group. 2006. Farm Subsidy Database. Available at Web site: http://www.ewg.org/farm/ (verified 18 May 2006).
93 Hanson, M., Miller, R., and Padgitt, S. 2002. Incorporating Grassland Agriculture into Row Crop Systems. Iowa State University Extension, Iowa State University, Ames, IA.
94 Shoemaker, R., McGranahan, D., and McBride, W. 2006. Agriculture and rural communities are resilient to high energy costs. Amber Waves 4(2):16–21.
95 Marshall, L. and Greenhalgh, S. 2006. Beyond the RFS: The Environmental and Economic Impacts of Increased Grain Ethanol Production in the U.S. World Resources Institute, Washington, DC.
96 Boody, G., Vondracek, B., Andow, D.A., Krinke, M., Westra, J., Zimmerman, J., and Welle, P. 2005. Multifunctional agriculture in the United States. Bioscience 55: 27–38.
97 Trout, S.K., Francis, C.A., and Barbuto, J.E. 2005. Evaluation and perceived impacts of the North-Central Region SARE grants, 1998–2002. Journal of Sustainable Agriculture 27(2):117–137.
98 Keeney, D. and Kemp, L. 2004. How to Make it Work: Required Policy Transformations for Agroecosystem Restoration. Institute for Agriculture and Trade Policy, Minneapolis, MN. Available at Web site: http://www.mcknight.org/hotissues/news/makeitwork_kemp-keeney.pdf (verified 8 January 2007).
99 Traxler, G., Acquaye, A.K.A., Frey, K., and Thro, A.M. 2005. Public Sector Plant Breeding Resources in the US: Study Results for the Year 2001. Cooperative State Research, Education, and Extension Service, United States Department of Agriculture. Available at Web site: http://www.csrees.usda.gov/nea/plants/part/pbgg_part_study.html (verified 18 April 2007).