Development of a Healthy Farm Index to assess ecological, economic, and social function on organic and sustainable farms in Nebraska's four agroecoregions

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A need shared by current and future generations is a reliable food supply. Components of agroecosystems include food and fiber production, domestic and wild biodiversity, surrounding environments, local and global markets, and human communities (Francis et al. 2003). Thus, understanding and maintaining agroecosystems will require a multidisciplinary approach and decision-making tools that integrate ecological, economic, and social parameters (Gliessman 1998; Francis et al. 2003; Boody and DeVore 2006; Perrings et al. 2006). However, the role of ecological processes in agricultural systems remains poorly understood. A better understanding of ecological processes offers promise toward maintaining food production, biodiversity, and ecosystem services that support and regulate key functions.

Demands on agroecosystems are mounting because of a growing and increasingly affluent global population, greater interest in maximizing local production, and an emerging call to conserve biodiversity and protect the global environment (MEA 2005). These competing demands influence decisions by farmers, consumers, and policy makers. Ideally, these demands will lead to a shift to more sustainable farming systems (United Nations 2008).

While we cannot predict what the future of agriculture will entail (Ikerd 2001), the challenge of sustainable farming continues to evolve as agroecosystems change in response to climate shifts, market demands, new technology, and other ecological and socioeconomic factors. In the Great Plains of North America, as elsewhere, field size, yields, costs, input use, and urbanization have increased (Matson et al. 1997; Tilman

1998). Meanwhile, domestic and wild biodiversity, landscape heterogeneity, and our connection to food systems have declined (Matson et al. 1997; Tilman 1998; Peterjohn 2003; Pollan 2006). As a consequence, a broad spectrum of ecosystem services are being ignored or lost, robbing agricultural land and food systems of their natural capital, inherent health, and resiliency (Matson et al. 1997; Perrings et al. 2006). This oversight is being paid for by society as a whole at an annual cost to human and ecosystem health estimated to be between \$5.7 and \$16.9 billion in the United States (Tegtmeier and Duffy 2004).

Awareness of the negative impacts of an intensified, industrialized, and expanding agricultural system has resulted in numerous calls for a paradigm shift toward new approaches for assessing farm success that address ecosystem services and biodiversity (Jackson and Jackson 2002; Tilman et al. 2002; Perrings et al. 2006). Conventional means of assessing and valuing agricultural landscapes use cost-benefit analysis with a narrow focus on short-term economic growth and payout, do not respond to changes in biodiversity or the functioning of ecosystem services (Tilman et al. 2002), and ignore the costs of externalities that result from agricultural production (Tegtmeier and Duffy 2004). Assessments are often limited to yield and cost per land area with a focus on maximizing current production of a limited number of subsidy-supported commodities. Consequently, analysis of current systems and future alternatives is limited (Francis et al. 2003).

Diversified and sustainable agroecosystems provide ecosystem services to both the agroecosystem and areas beyond (Swinton et al. 2007). The Millennium Ecosystem Assessment (MEA 2005) defined four categories of ecosystem services related to agroecosystems – cultural, provisioning, supporting, and regulating. Services that provide benefits beyond agroecosystems include provisioning services of food production and biodiversity conservation and regulating services of water purification and climate change mitigation. Regulating and supporting services benefiting agroecosystems include pest suppression, pollination, microclimate regulation, soil and water control, and soil formation (Swinton et al. 2007; Zhang et al. 2007). The level of services provided and received by agroecosystems varies depending on how farms are situated and managed (Santelmann et al. 2004). New monitoring and assessment tools are needed to recognize and reward sustainable farm systems for the provisioning, supporting, and regulating services they provide and to guide the restoration or enhancement of ecosystem function in food systems (Daily and Matson 2008). New tools must assign appropriate value to biodiversity and functioning ecosystem services within agricultural landscapes.

We wanted to develop a practical and integrated assessment tool to facilitate the enhancement and restoration of biodiversity and ecosystem services within working farms and to communicate the value of these services to decision makers. A single integrated and balanced tool that provides the means to assess and measure each category of ecosystem service provided by mixed farm systems would be valuable to farmers, consumers, and policy makers. To better ensure sustainable food production, the Healthy Farm Index will demonstrate optimization of ecosystem services by modeling tradeoffs in ecosystem function that result from different land-use and land-cover patterns. Understanding these tradeoffs will allow concerned farmers to better optimize production of quality food for local and global markets, enhance ecosystem function, conserve biodiversity, and support local communities. Policy makers will have a clearly quantified metric to inform policy decisions. Communicating these benefits may facilitate adoption of appropriate sustainable or organic practices by conventional producers, enhancing the sustainability of all farm systems (Beecher et al. 2002; Pimentel 2005). In this chapter, we present an overview of the Healthy Farm Index structure and development and a preliminary assessment based on four model farms. Data collection to strengthen initial components is ongoing on Nebraska farms, and specific studies to assess remaining components are being developed.

Methods

Building a Healthy Farm Index. Developing an applicable index requires relevant and measurable indicators that can be quantified and communicated. Many farm assessment tools focus on a single component (Coppedge et al. 2006; Zobeck et al. 2008). Few attempts have been made to address the multidisciplinary nature of agroecosystems. We followed a content-based framework to communicate specific objectives and establish quantitative indicators (Van Cauwenbergh et al. 2007). The difficulty in placing an economic value on many parameters of a healthy farm (e.g., biodiversity, ecosystem services, farmer satisfaction) necessitates a form of nonmarket valuation or multiple criteria analysis (Hajkowicz 2008). A multiple criteria analysis has the advantage of allowing cost to be included as a criterion without limiting assessment to economic measures alone (Hajkowicz 2008). Following the direction of the Millennium Ecosystem Assessment (MEA 2005, 21), we used valuation "as a tool that enhances the ability of decision makers to evaluate the tradeoffs between alternate ecosystem management regimes."

A broadly applicable index of farm health needs to be flexible enough to fit the location of the farm and the resources and labor that are available (Karr and Chu 1997; Dale and Haeuber 2001). Being able to detect change in the endpoint is essential so that any management change is reflected in the index (Karr and Chu 1997). To ensure a holistic view of the farm not typically provided by other content-based frameworks (Van Cauwenbergh et al. 2007), we selected indicators from multiple categories of ecosystem services to and from agroecosystems. Indicators of these ecosystem services that provide flexibility among ecoregions include stability and resiliency of food production; richness, diversity, and abundance of domestic and wild biodiversity; farmer satisfaction; and land use and land cover patterns. These indicators fall under four categories of ecosystem services—food and fiber production, biodiversity enhancement, quality of life enhancement, and environmental quality enhancement (figure 1). Further discussion of each category and indicator follows.

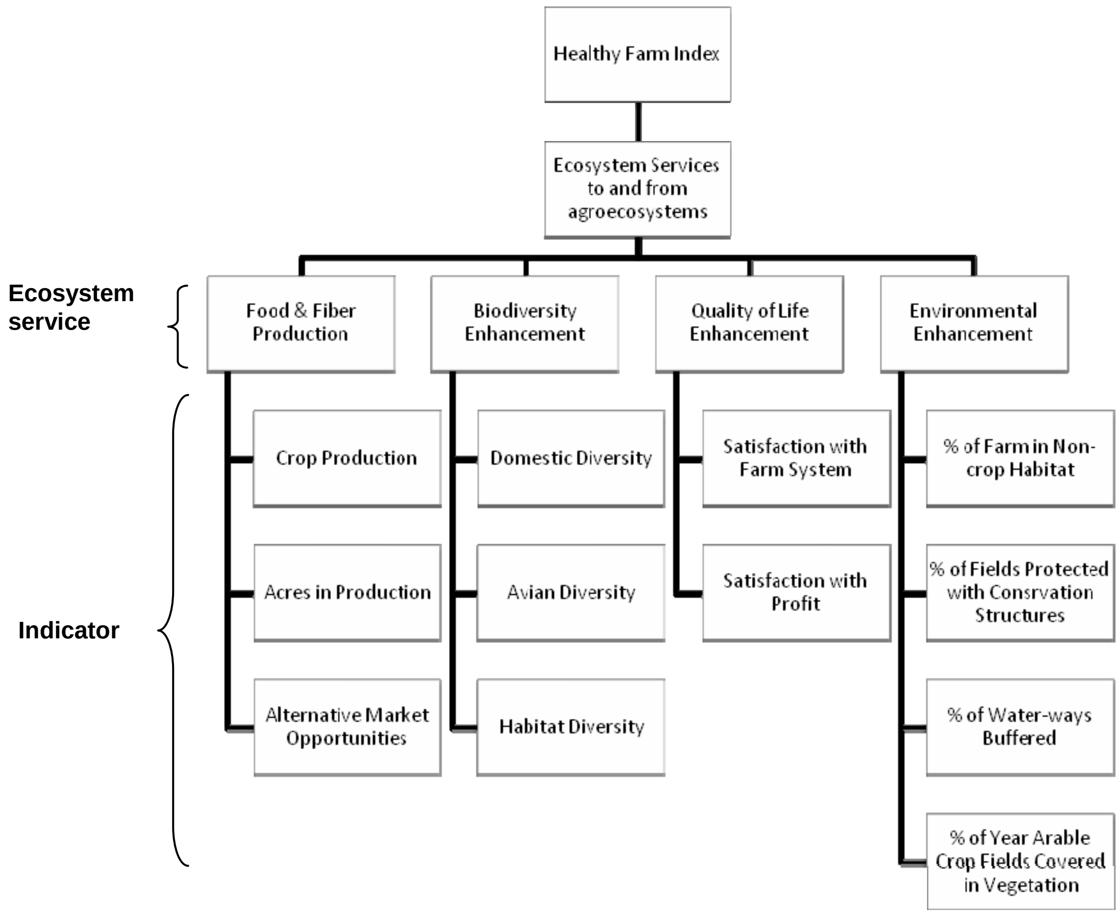

Figure 1. Indicators of ecosystem services in healthy agroecosystems.

Food and Fiber Production. The primary management goal of agricultural systems is typically the provision of food, fiber, and fuel (Zhang et al. 2007), outputs that provide farm income and products to society. Crop diversity can improve profits and provide resiliency in volatile markets, a concept particularly applicable on diversified or small farms where value per land unit is frequently higher (Rosset 1999). Inclusion of noncommodity and niche products, including vegetables or fruits for local markets, popcorn, woody florals, direct to consumer grass-fed cattle and bison, cheese, and other value-added products creates economic resilience for the farm.

Food production will be assessed by (1) yield of local crops adjusted by the average yield of crops in the region for a farm type (organic or conventional, irrigated or dryland), (2) land area in production, and (3) number of noncommodity products produced. Farmers will be asked to provide their production data.

Biodiversity Enhancement. Wild and agricultural biodiversity are threatened locally and globally (Perrings et al. 2006), yet remain an essential part of agroecosystems (MEA 2005). Increased diversity of species on a farm makes the farm ecosystem more resistant and resilient to environmental fluctuations, stochastic disturbances (weather, insect outbreak), and changes in climate or precipitation patterns (Tilman et al. 2006). Pasture and forage crops on farms with livestock add diversity in land-cover patterns and benefits to some grassland birds (Wiens 1969; Hanson 2007). A regionally appropriate and diverse crop rotation creates a dynamic farm system that benefits from crops compatible with local ecology and synergisms that exist between crops in a rotation (Tanaka et al. 2005). Important genetic diversity is retained through the conservation of declining breeds of crops and livestock (Seedsavers 2008; Taberlet et al. 2008).

Both crop and noncrop areas serve as important habitat for associated wild biodiversity (Vandermeer et al. 1998; Beecher et al. 2002). Many wild farmland species fulfill essential ecological roles as pollinators and pest suppressors, specific roles that do not have a natural replacement (Sekercioglu et al. 2004). Because wild biodiversity is sensitive to land-use and land-cover change, it can be an effective indicator of the ecological health of the environment at multiple scales.

As a complete inventory of all species is not practical, an accurate and suitable indicator species or group is necessary (Dale and Polasky 2007). Ideal ecological indicators provide information about structure, function, and composition of the ecological system (Dale and Beyeler 2001). Birds stand as an ideal ecological indicator because of their ease of detection, sensitivity to environmental change, broad presence in the environment, varied tolerance among species to disruption, and well-understood ecology (Jarvinen and Vaisanen 1979; Browder et al. 2002). Because species assemblages are a more powerful indicator then a single species, including the use of diversity, richness, and evenness indicators is valuable (Buchs 2003). Presence of a diverse bird community may also indicate a healthy community of beneficial insects (Beecher et al. 2002) and the functioning of ecosystem services (Altieri 1999).

Biodiversity will be assessed by (1) richness (number) of domestic crop and livestock species, (2) Simpson's Index of avian species diversity (includes both richness and evenness), (3) richness and abundance of avian indicator species, and (4) Simpson's Index of land cover diversity. Six bird species were identified for this chapter as indicators of two noncrop habitat types, i.e., grassland and edge/shrub. Assessment of avian diversity and richness includes moderating effects of land use and land cover at field, farm, and landscape scales. Other landscape metrics will be considered for future assessment. Farmers will be asked to supply their current crop and livestock diversity. Avian diversity will be sampled by research-based point counts, remote acoustic sensors, volunteers, or the farmers themselves. Land-use and land-cover patterns can also be used to predict expected species richness and diversity.

Quality of Life Enhancement. Integrating human dimensions into agroecology can facilitate the development of a more healthy food system. Farmers are the decision makers at field and farm scales. They have been the backbone of rural communities and are essential to future conservation (Pretty and Smith 2004). Ultimately, a healthy farm must sustain both the land and its people (Doran 2000; Pretty and Smith 2004). Quality of life for farm families is influenced by satisfaction with their farm system. Satisfaction could be influenced by a variety of factors, including yield, farm appearance, connectedness to the community and environment, biodiversity, pest and weed control, and family well-being. Although many farmers are motivated by more than income alone (Quinn and Burbach 2008), a reasonable income is necessary, suggesting satisfaction with profit is also a quality of life indicator. To assess the quality of life, organic and sustainable farmers in Nebraska will be surveyed about satisfaction with their farm system, yields, and profits.

Environmental Enhancement. Land-use and land-cover patterns have a strong impact on ecosystem services (Matson et al. 1997; With et al. 2002; Santelmann et al. 2004) and biodiversity composition (Perkins et al. 2003; Ricketts et al. 2008). Beneficial features in agricultural landscapes enhance ecosystem services (Santelmann et al. 2004; Mize et al. 2008). Windbreaks limit evapotranspiration from crop fields, thereby increasing yields (Brandle et al. 2004; Mize et al. 2008), and host natural enemies of insect pests (Dix et al. 1995; Matson et al. 1997). Cover crops contribute to soil fertility and field's nutrient balance (Clark 2007), suppress many harmful insects and weeds (Bender 1994), and increase yields (Lauer et al. 1997). Cover crops, terraces, grass strips, windbreaks, shelterbelts, and other vegetated buffers limit the impacts of erosion and soil loss. Vegetated riparian areas can filter runoff, limit water contamination, and improve the quality of wetland habitat (Dosskey et al. 2008). By regulating the flow of soil and contaminants, these beneficial landscape features limit water and wind erosion and reduce impacts on the surrounding region. They also constrain the impacts of detrimental land-use practices on future generations.

Wild noncrop habitat, including vegetated streams, wetlands, prairie, wooded areas, and other infrequent landscape elements in agricultural systems, are habitat refuges that benefit wild biodiversity, create wildlife corridors between critical habitats (Johnson and Beck 1988), and contribute to minimum amounts of noncrop habitat needed to support some species (Perkins et al. 2003). The importance of such areas is recognized in some organic certification requirements, such as those of Bio Suisse that specify at least 7% of the farm must be dedicated to promotion of biodiversity (Bio Suisse 2008).

Environmental quality will be assessed by (1) percent of farm in noncrop habitat, (2) months of the year arable land is covered with crops or cover crops, (3) percent of waterways buffered, and (4) percent of farm fields buffered/sheltered with soil conservation structures. Land-cover images (Farm Service Agency and Landsat) and farmer surveys of land use will be used to assess the land use and land cover on a farm.

Scale of Assessment. Spatial scale of other assessment tools varies from a landscape perspective (Piorr et al. 2003) to a field (Zobeck et al. 2008). Others include multiple spatial scales (Van Cauwenbergh et al. 2007). The Healthy Farm Index deals with ecological, economic, and social components at the field and farm scales. These scales are the management units where agroecological changes are most frequently made (Pacini et al. 2003; Van Cauwebbergh et al. 2007). It is at these scales where decisions about crops, inputs, and farm practices are enacted and where the interface with community occurs. Understanding the driving forces and relationships at field and farm scales will aid in understanding the impacts of those decisions at higher scales (Francis 2004). The Healthy Farm Index is structured to address the challenge of assessing multiple spatial and temporal scales for monitoring the variety of system components and processes in agroecosystems. Many of the processes and structures assessed in the index impact not only the single farm system, but also local watersheds and the global ecosystem. Inversely, a farm is embedded in its surrounding ecosystems (Zhang et al. 2007) and is impacted by systems beyond its boundaries (Matson et al. 1997; Kirschenmann and Gould 2006).

Target Values. Target values must be set for each indicator based on local variables in a given ecoregion. Data collection to determine target values for Nebraska's four agroecoregions is ongoing on 27 organic farms. Two years of ecological data have been collected and will be coupled with past data from research in Nebraska. Land-use and land-cover data are being gathered from Farm Service Agency and Landsat images. Economic, production, and social data are being collected as part of a continuing effort in support of organic and sustainable agricultural systems through the University of Nebraska. Here we present preliminary target values for eastern Nebraska (table 1) based on our data. Further research will provide more sensitive target values for this region and others.

Table 1. Target values and weights of the Healthy Farm Index.

Category	Indicator	Target value	Weight within category	Weight within index	Final score
Food production	Alternative market opportunities	3	0.1	0.25	HFI score
	Crop production	100	0.9		
Biodiversity	Domestic biodiversity	6 species	0.3	0.25	
	Wild biodiversity I (indicator bird species)	3 species/habitat	0.25		
	Wild biodiversity II (avian diversity)	1	0.2		
	Habitat diversity	1	0.25		
Environmental enhancement	% in noncrop habitat	15	0.25	0.25	
	% of year arable land covered in crops or cover crops	100	0.25		
	% of waterways buffered	100	0.25		
	% of farm fields protected with soil conservation structures	100	0.25		
Quality of life	Satisfaction with profit	100	0.5	0.25	
	Satisfaction with farm system	100	0.5		

Designing Model Landscapes. To demonstrate the preliminary framework of the Healthy Farm Index, we created four farm scenarios (figure 2). These farm scenarios were developed on an 80-by-80-pixel grid with each pixel equal to 10 m. Each pixel was assigned one land-cover type. Three scenarios emphasized a specific ecosystem service or management goal: (1) maximum farm production, (2) wild biodiversity enhancement, and (3) enhancement of environmental quality. A fourth scenario was developed using the average land use and land cover of central and eastern Nebraska. Basic land-use (organic) and land-cover features (topography, waterways, unit of land area = 64.7 hectares) were retained throughout.

These farms were designed to incorporate varying amounts of mixed farming methods, including pasture, crop rotations, cover crops, grass strips, windbreaks, riparian buffers, prairie, woodlands, and wetlands. Hypothetical corn, soybean, hay, alfalfa, and wheat production levels were compared on each farm to the regional average for organic farms. Land-use and land-cover components of farm scenarios were based on working organic farms in central and eastern Nebraska. For each scenario, the primary land use and land cover were ranked (table 2) and described below.

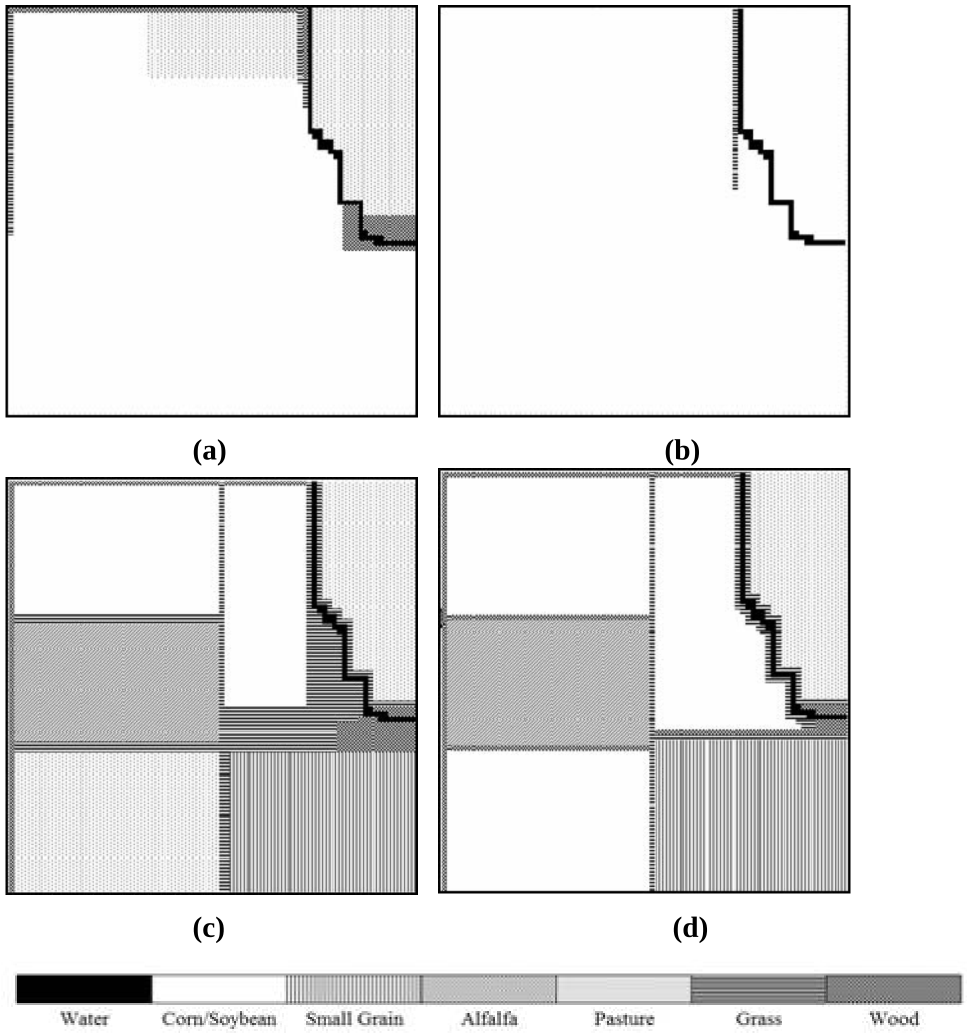

Figure 2. Farm models.

Table 2. Rank and percentage of land-use and land-cover types in each farm scenario.

Rank	Average		Maximum production		Environmental quality		Wild biodiversity	
1	Row crop	78.1%	Row crop	98.3%	Row crop	47.7%	Pasture	27.6%
2	Pasture	17.3%	Water	1.1%	Small grain	17.2%	Row crop	26.4%
3	Wood	2.5%	Grass	0.6%	Alfalfa	15.0%	Small grain	15.6%
4	Water	1.1%	Small grain	0.0%	Pasture	10.7%	Alfalfa	14.4%
5	Grass	1.0%	Alfalfa	0.0%	Wood	4.4%	Grass	11.0%
6	Small grain	0.0%	Pasture	0.0%	Grass	3.9%	Wood	3.9%
7	Alfalfa	0.0%	Wood	0.0%	Water	1.1%	Water	1.1%

The first scenario (figure 2a) approximated the current average land use and land cover of farm land in Saunders and Hamilton Counties, Nebraska (Henebry et al. 2005). This scenario, labeled “average,” was used as a starting point for other scenarios. Crops produced on this farm were limited to corn and soybean. A small portion of the farm was dedicated to pasture. A limited portion of the farm remained in noncrop habitat along the waterway. A windbreak was included on the north and partial west sides of the field, providing some protection from wind.

The "maximum production" scenario (figure 2b) maximized production of two commodity crops, corn and soybeans. This farm system did not include pasture and had minimal noncrop habitat. To maximize current production, crop fields abutted the local waterway, and the landscape contained no beneficial, nonproduction features. This scenario represented the current intensive farming paradigm of the Great Plains.

The "wild biodiversity" scenario (figure 2c) emphasized the amount and arrangement of suitable breeding and foraging habitat for wild birds within the matrix of working arable farmland and pasture. This working landscape was managed at a lower intensity with a higher weed and insect tolerance providing foraging opportunities throughout working fields. Native grasses and forbs were maintained in margins and in set-aside land, providing a source of food and nest sites. Field size was limited and pasture and woodland provided habitat for wildlife.

The "environmental quality" scenario (figure 2d) emphasized biophysical properties. The waterway was buffered in its entirety. Windbreaks throughout the farm moderated the microclimate at each field, reduced evapotranspiration, and limited soil loss from wind (Mize et al. 2008).Vegetation features provided sufficient resources to increase the richness and abundance of beneficial insects and birds. Cover crops were used throughout the farm as part of a diverse crop rotation to enhance insect and weed suppression and crop production benefits associated with rotations.

Results

At best, a farm could score 100 through the Healthy Farm Index. The four model farms were scored (table 3) using previous research data (Beecher et al. 2002; Perkins et al. 2003; Hanson 2007) and preliminary data from farms participating in the current project. Of the four farm scenarios, environmental quality scored the highest (77), followed by wild biodiversity (72), average (60), and maximum production (50). Overall, mean index score was 64 with a difference between highest and lowest of 27. Average and maximum production scenarios, both of which personify the current farming paradigm, were below the mean.

Table 3. Healthy Farm Index results for each farm scenario.

	Average farm	Maximum production	Wild biodiversity	Environmental quality
Food production score	86	88	69	86
Enhance biodiversity score	63	38	92	87
Enhance environmental quality score	41	22	76	84
Enhance quality of life score	50	50	50	50
Final HFI score	**60**	**50**	**72**	**77**

The food production score demonstrated the lowest variation among scenario results, with 20 points separating the highest and lowest. Maximum production scenario scored highest in production, but environmental quality and average scenarios were less than three points lower. Wild biodiversity scenario had the lowest food production score, due to the low intensity of farming practices and greater percentage of noncrop habitat on the farm. Environmental quality scenario scored high in food production, despite less land under production, reflecting benefits provided by the extensive windbreak system.

Biodiversity scores in the environmental quality and wild biodiversity scenarios were similar. However, biodiversity scores in these scenarios were two times higher than in the maximum production scenario. Environmental quality scores were three times higher in wild biodiversity and environmental quality scenarios than in the maximum production scenario. The expansive scale of current farming systems did not facilitate the inclusion of beneficial landscape features. Environmental quality scores were similar between wild biodiversity and environmental quality scenarios. Human dimension score was set as a constant. Data from farmers are needed to complete this portion of the index. We expect this score to vary because of different philosophies and motivations.

Discussion

One of our greatest challenges is to find ways to produce sufficient food and, at the same time, develop rural communities, protect the environment, and conserve global biodiversity for future generations (Matson et al. 1997; Krebs et al. 1999). Within this challenge is the underlying need for sustaining ecosystem services essential for sustainable agroecosystems (Pretty and Smith 2004). Our preliminary assessment, using designed model farms, provided logical outcomes from four scenarios, maximum production, wild biodiversity, environmental quality, and average. The positive outcome from the environmental quality scenario for each of the ecosystem services assessed (food production, biodiversity enhancement, and environment protection) was encouraging.

The underlying land-use and land-cover patterns on farms are key variables influencing function of ecosystem services and associated biodiversity (Santelmann et al. 2004; Polasky et al. 2008). The Healthy Farm Index provides a means to assess these variables and associated impacts using multiple criteria and a straightforward output to communicate findings to multiple stakeholders. Management for multiple ecosystem services involves tradeoffs among services, particularly between production and other land-use and land-cover practices that sustain the system for the long term. Polasky et al. (2008) suggest that landscapes are not currently used optimality to achieve any one management goal. The challenge of optimizing multiple ecosystem services is great and requires knowledge of inherent tradeoffs among various management options (Zhang et al. 2007). Ultimately decisions about land use and land cover must be well planned (Zhang et al. 2007).

The four scenarios presented demonstrate the ability of the Healthy Farm Index to assess potential outcomes on farms from various land-use and land-cover scenarios and to provide information about tradeoffs among different categories of ecosystem services. Designed with the goal of optimizing their target ecosystem services, model farmscapes scored highest in their respective management goal. Maximum production scenario scored highest in the production category. However, the value to society of focusing only on increasing yield faster than human population growth (Matson et al. 1997), without considering issues related to food distribution and farming intensity, should be considered with caution. Maximizing output can be accomplished in the short term, but it costs society and the local environment, as shown by current challenges such as hypoxia in the Gulf of Mexico (Boody and DeVore 2006) and other externalities (Pretty et al. 2000;

Tegtmeier and Duffy 2004). The Healthy Farm Index does not quantify these costs, but demonstrates associated reductions in biodiversity and ecosystem services that, when lost, no longer carry benefits to agricultural systems (Bianchi et al. 2006; Dale and Polasky 2007) and to society (Santelmann et al. 2004).

Enhancing biodiversity scenario scored the highest for biodiversity, reflecting an interest and necessity in conserving biodiversity in working agroecosystems (Jackson and Jackson 2002; United Nations 2008). This scenario had 15% of the farm set aside as noncrop habitat. Such a high percentage of set-aside land is not typical. However, individuals may be motivated to set aside land for reasons such as alternate income sources from noncrop land and recreational and aesthetic value of wild habitat. A decline in production resulted from low-intensity, wildlife-friendly farming practices. Balance in agroecosystems between farming and biodiversity is a topic of great interest (Krebs et al. 1999), with questions of whether wildlife-friendly farming, land sparing, or a combination can best provide food for a growing global population and, at the same time, conserve biodiversity (Green et al. 2005; Fischer et al. 2008).

Although we currently lack human dimension data, we do expect these scores to vary among farms and to affect scores of the overall Healthy Farm Index. For example, the maximum production scenario may provide satisfaction through high yields, clean fields and margins, and from fewer management concerns. Using just two commodity crops in rotation requires less time and labor compared to the greater complexity of managing multiple crops or rotations. Human dimension scores in the environmental quality or wild biodiversity scenarios might reflect satisfaction from greater control over their farm and future because of fewer debts or loans associated with large-scale equipment, from aesthetic or recreational benefits of biodiversity, from greater family involvement and community interactions associated with smaller-scale farm practices, and from sustaining land and resource opportunities for future generations.

The overall highest scoring scenario was environmental quality, achieved by optimizing multiple indicators that were inherent in the goal. Small or modest adjustments in farm management can increase farmland health. Protecting the environment through appropriate land use and land cover also provides habitat with enhanced biodiversity and pest suppression and assists with pollination of fruit and similar crops. Moreover, the protective land cover and vegetation in this scenario provides microclimate modification that benefits crop production.

Conclusion

The Healthy Farm Index is currently a work in progress. In this chapter, our goal was to illustrate the structure of the index, reflecting its development. Results from four model farm landscapes provided an initial assessment of both the index and the eastern Nebraska farm systems. The Healthy Farm Index structure provides a framework in which to add empirical data that have and are being collected. Further data and analyses are needed to assess soil health, profit, energy use, and farm families. Proposals to evaluate and integrate these indicators are being developed. Our current analysis was built around the production of commodity crops, which justified the individual indicators selected. Applying the index in other farm systems would require adjustment of indicators. We welcome your comments and suggestions and encourage you to join us and others in meeting this challenge. Rural landscapes and their opportunities in the future depend on our collective wisdom to make reasonable assessments of sustainability. We believe that the Healthy Farm Index offers a framework to help address this challenge.

The value of assessment tools, such as the Healthy Farm Index, needs to be communicated to decision makers both on and off the farm (Karr and Chu 1997). A key outcome in using the Healthy Farm Index will be to provide farmers and policy makers a simplified measure of farm health, reflecting productivity as well as other valuable ecosystem services dependent on management choices. Moreover, the Healthy Farm Index may also provide a means of assessing the contribution of ecosystem services from farms to the greater landscape. Aggregated Healthy Farm Index scores from farms across watersheds could provide a mechanism to assess the status and trends in ecosystem services at larger scales.

There is increased interest in targeting government programs to provide support for farm management decisions that benefit society through ecosystem services. Research suggests that if ecosystem service payments are not well designed or do not include multiple services, they may cause more harm than good (Daily and Matson 2008). The Healthy Farm Index provides a mechanism to quantify and recognize a range of services provided by farms using sustainable land management. Taking the Healthy Farm Index to policy makers could provide a means to assess and distribute offset payments or other incentives to encourage ecosystem services. Future policy could perhaps link Farm Bill or similar subsidies for ecosystem services provided by a farm, in part, to a farm's Healthy Farm Index score.

Maintaining ecosystem services on a farm system and all its working components will also optimize key ecosystem services provided from agroecosystems to other areas. Farms that focus on maintaining ecosystem services to the farm will in turn ensure food production and biodiversity. The benefit of managing for ecosystem services has been demonstrated at larger scales. Santelmann et al. (2004) suggested that management for water quality and biodiversity at a watershed scale maintained a satisfactory level of food production. This preliminary demonstration of the Healthy Farm Index suggests that at the field and farm scale, a focus on ecosystem services that enhance environmental quality may create the healthiest or most balanced farm in optimizing output of farm products while reducing costs of externalities.

The Healthy Farm Index expands assessment from simply production volume to an integrated approach toward maintaining both production and the services that sustain the system. The basis of conservation ecology is restoring and protecting ecosystems by maintaining all the working parts. A premise of agroecology is to integrate ecology and agriculture for mutual benefit (Francis et al. 2003). The Healthy Farm Index provides a mechanism for integrating and communicating interdisciplinary data toward farm practices and policy that optimize food production, biodiversity, and ecosystem services.

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