Enhancing the Multifunctionality of US Agriculture

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Multifunctional agriculture (MFA) enhances the quality and quantity of benefits provided by agriculture to society, by joint production of both agricultural commodities and a range of ecological services. In developed countries, new agroecosystem designs for MFA are appearing rapidly, but adoptions are limited. We present a heuristic strategy for increasing the adoption of MFA through development of new enterprises that enable farmers to profit from production of both agricultural commodities and ecological services. We propose that such enterprises can arise through feedback between social and biophysical systems operating across a range of scales. Such feedback depends on coordinated innovation among economic actors in a range of interdependent social sectors, supported by new "subsystems" that produce site-specific agroecological knowledge, and by change in the encompassing "supersystem" of public opinion and policy. This strategy can help guide efforts to increase the adoption of MFA.

Keywords: multifunctional agriculture, agroecology, sustainable development, land-change science, biofuels

Rising interest in biofuels is but one indication of a rapid increase in the social importance of agriculture. First, society is demanding increased production of traditional agricultural commodities as well as other goods, services, and amenities (Robertson and Swinton 2005, Meyer et al. 2008). These goods and services include biofuels, various bioindustrial products (Eaglesham 2006), and marketable environmental services produced by agriculture, such as carbon storage and aquifer recharge inputs (Boody et al. 2005, Jordan et al. 2007). Second, current agricultural land-use patterns may interact with climate change; for example, to increase water discharge from agricultural landscapes (Reilly et al. 2003), thereby increasing exposure to hazards such as the catastrophic urban flooding in the US Midwest in 2008. Consequently, redesign of agricultural landscapes may be essential to provide expanded goods and services while managing risks to the security of food supplies and infrastructure (Hanson et al. 2007).

In response, scientists, policymakers, and community groups have advanced multifunctional agriculture (MFA); that is, joint production of both agricultural commodities and a range of ecological services, including beneficial effects on pest and nutrient management, water quality and quantity, biodiversity, and amenity values (Wilson 2007). In essence, MFA is a project of "sustainable land architecture": MFA develops a complex land-use and land-cover strategy that can meet multiple human needs from diverse ecosystems, while sustaining these systems over multiple generations (Turner et al. 2007). Despite its potential value to society, adoption of MFA in the United States is not yet extensive; in our view, adoption has been impeded by sociopolitical, economic, and ecologic factors that are interrelated and mutually reinforcing. A comprehensive approach to surmounting such barriers is therefore essential. To that end, we propose an integrative and heuristic strategy—a "theory of change"—that aims to enhance the multifunctionality of US agriculture by pursuing change at three distinct levels of integration. The strategy capitalizes on certain distinctive attributes of multifunctional agroecosystems.

Multifunctional agroecosystems

Increasing plant diversity and perenniality in agroecosystems—informed by ecology, economics, and policy—can increase their multifunctionality relative to more simplified designs that are based on annual field crops (Boody et al. 2005, Wilson 2007). More multifunctional systems make use of multiple perennial crops grown on environmentally sensitive sites such as riparian areas; on sites well suited to annual commercial grain crops, noncommodity cover crops are grown during periods when soils would otherwise be bare. Multifunctionality arises from the spatial and temporal pattern of perennial, annual, and cover crops across landscapes and the resultant ecological processes. For illustrative purposes, we focus on MFA systems for the upper Midwest region of the

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United States, a globally important area comprising about 135 million acres of cropland.

Perennial-based agroecosystems well suited for this region include woody and herbaceous perennial polycultures (Tilman et al. 2006), agroforestry systems (Jorgensen et al. 2005), and managed wetlands (Hey et al. 2005). There is mounting evidence that such agroecosystems, integrated in a well-designed landscape, can produce agricultural commodities abundantly and profitably while producing nonmarket public goods and services more effectively than annual systems such as corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.). For example, (a) soil and nitrogen loss rates from perennial crops are less than 5 percent of those in annual crops (Gantzer et al. 1990); (b) perennial cropping systems have a greater capacity to sequester greenhouse gases than annual-based systems (Robertson et al. 2000); (c) in certain scenarios, some perennial crops appear more resilient to climate change than annuals—for example, increases of 3 to 8 degrees Celsius (°C) are predicted to increase North American yields of the perennial crop switchgrass (*Panicum virgatum* L.), whereas declines are expected for annual crops (Brown et al. 2000); and (d) among species of concern for conservation, 48 percent increased in abundance when on-farm perennial land cover was increased in European Union "agro-environmental" incentive programs (Kleijn et al. 2006).

Thus, these new landscape designs address problems created by current Midwest agricultural land use, where corn-soybean farming alone occupies about 90 million acres—two-thirds of total cropland and more than 85 percent of total land area in certain areas. In these areas, fish and game populations and other contributors to biodiversity have been much affected by habitat loss, pesticide pollution, and facilitation of the invasion of harmful exotic species (Gibbs et al. 2009). Crop growth is limited to a four- to six-month period, and these landscapes are otherwise largely unvegetated. Consequently, soil protection and the uptake of water and nutrients are also limited. These effects interact with regional-scale changes in the hydrology of agricultural landscapes, caused by agricultural drainage, to exacerbate drought and flood risks and compromise water quality by discharges of nutrients, sediment, and flood waters to surface waters (Goolsby et al. 1999, Oquist et al. 2007, Donner and Kucharik 2008).

In addition to creating environmental hazards (e.g., flooding), current farming systems appear to be creating major challenges to their own economic viability through increased input costs, newly introduced pests and diseases, soil degradation, groundwater depletion, and increasing risk from climate extremes (Hanson et al. 2007, Zhang et al. 2007). More complex and multifunctional landscape designs have the potential to provide cost-effective solutions to these profitability problems (Wilson 2008). Multifunctional landscapes are also favored by a number of other trends in food and energy. The rapid development of bioenergy production could provide a market force strong enough to establish perennial "energy crops" across the Midwest landscape. Demand for grass-fed meat and dairy has increased dramatically, and markets are emerging for high-value products from new perennial and woody crops, such as perennial flax (*Linum perenne* L.) and hybrid hazelnuts (*Corylus*). Multifunctional agricultural systems may enable relatively small farm units to respond to these new economic opportunities, which may in turn provide the capital and population base necessary for healthy, productive, and dynamic rural communities (Flora 2001, Argent et al. 2007). An integrative assessment of the potential economic, social, and environmental performance of MFA designs in the upper Midwest is provided by a modeling study (Boody et al. 2005). Model simulations project that major environmental and socioeconomic benefits could be attained from MFA designs without an increase in public subsidy costs.

To capitalize on these opportunities and address current problems, we suggest that coordinated change is needed in certain social and biophysical dimensions of Midwest agriculture. In particular, economic incentives must be reconfigured to achieve multiple social goals; for example, through payment for ecological services (Swinton et al. 2007). As well, we need new modes of perception, knowledge production, and decisionmaking (Warner 2008). These innovations are necessary to develop the policies and markets required to stimulate a diversified flow of goods and services from MFA landscapes. Below we outline a systemic strategy for increasing multifunctionality in Midwest agriculture. This strategy has emerged from the work of Green Lands, Blue Waters (GLBW 2009; box 1), a consortium of Midwest land-grant universities and nongovernmental organizations (NGOs) from agricultural and environmental sectors.

Theory of change: A social-ecological system model for enhancing multifunctionality in US agriculture

Our model encompasses three distinct dynamic processes that operate at different space and time scales. We first describe the central "system" level, which addresses "enterprise development"; that is, the development of new economic opportunities, and related systems of management and policy, for farmers of multifunctional agroecosystems. Next, we portray a pivotal subsystem of the enterprise development model: "agroecological partnerships" that produce knowledge needed for multifunctionality in working agroecosystems. Finally, we describe how social values shape the "supersystem" of public opinion and policy, and how this can be configured to reward increased MFA. Our approach reflects recent theoretical advances in the integration of natural and social science with sustainable development processes and social and biophysical change processes at various scales (Turner et al. 2007, Holtz et al. 2008).

Focal level: Enterprise development through "virtuous circles." We draw upon an emerging theory of endogenous (i.e., "bottom-up") rural development, termed "virtuous circles" (Selman and Knight 2006). Virtuous circles of rural development are positive feedback loops that integrate and enhance rural resources, including assets that are natural, human, social,

Box 1. The Green Lands, Blue Waters Initiative.

The Green Lands, Blue Waters Initiative (GLBW; *www.greenlandsbluewaters.org/*) is a consortium of scientists, policy experts, farmers, and community organizers from more than a dozen nonprofit organizations, six land-grant universities, and multiple government agencies in states from the upper Midwest to the Gulf of Mexico; both authors have been GLBW participants, and the theory of change articulated in this forum emerged from deliberation within the GLBW. Organized in 2004 with foundation and university support, the consortium is focused on the upper Mississippi basin, but is expanding geographical scope to the Great Lakes region. Group members aim to pool and "co-leverage" resources to more effectively promote multifunctional agriculture. To do so, the GLBW has a primary strategic focus: to develop, promote, and implement new economic enterprises for Midwest landscapes on the basis of MFA strategies. This goal is pursued through the following means:

- Expand knowledge regarding multifunctional agroecosystems, perennial crops, and other forms of continuous living cover, with emphasis on environmental, economic, and health impacts.
- Coordinate and enhance ongoing existing research, education, and implementation activities that advance multifunctional agriculture in the Mississippi River basin.
- Increase capacity of stakeholders to participate in multistakeholder networks addressing multifunctional systems, including scientists and farmers, farm advisers, extension educators, input suppliers, bankers, processors, NGO personnel, civic leaders, faith leaders, and others.
- Identify and promote market and policy changes needed to encourage and support adoption of perennial crops and other forms of continuous living cover.

The GLBW is functionally organized around two tiers of complementary and interconnected activities: (1) the consortium, consisting of all partners, focuses upon integrative work that crosscuts all participating organizations and working groups, such as overall strategy plan development, communications, outreach and education, evaluation, and fundraising; and (2) five working groups serve as hubs for research and development around the most viable and promising perennials and other continuous living cover systems (i.e., agroforestry, biomass, cover crops, grazing systems, and perennial grain).

cultural, political, and financial in nature. In principle, the virtuous circle process generates synergy between natural resources situated in MFA systems and other resources, resulting in their joint increase.

The operation of a virtuous circle process (figure 1) is based on effective joint production of traditional agricultural commodities and other valuable goods, services, and amenities. To the extent that joint production occurs efficiently, there will be the opportunity to capture value from both of these streams of production (Selman and Knight 2006), and a variety of sectors will have incentive to do so. For example, in Minnesota, recent analyses indicate that restoration of about 2 million acres of high-quality duck habitat will be needed to restore duck populations and address widespread concern with recent population declines. Current approaches cannot achieve this goal, so state and NGO conservation agencies are increasingly focused on MFA designs that improve the quality and quantity of duck habitat in agricultural landscapes. This approach appears to offer substantial cost savings to conservation agencies; some of these could be used to support incentive payments to landowners.

Such opportunities are becoming widely recognized (Swinton et al. 2007), and we posit that where transaction costs are low, multiple interest groups (e.g., wildlife groups, farmer organizations, and renewable energy interests) will be willing to cooperate in support of multifunctional agroecosystems that can provide amenities, goods, and services on terms that are attractive to these groups (Selman and

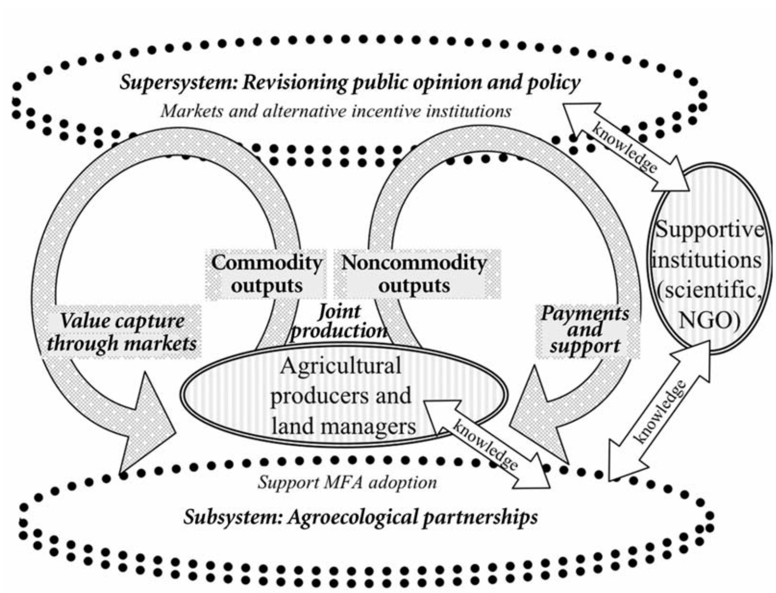

Figure 1. Multifunctional agriculture (MFA) enterprise development through the virtuous circle model. The model features central feedback loops connecting agricultural producers to markets and incentive institutions (e.g., brokers for ecological services produced by MFA) through joint production of agricultural commodities and noncommodities outputs such as ecological services. Stakeholders, markets, and institutions provide a range of forms of payment and support for MFA. Enterprise development interacts with a "supersystem" of public opinion and policy, as stakeholders attempt to change this supersystem to increase support for MFA. Agroecological partnerships form a subsystem that supports enterprise development by increasing multifunctionality.

Knight 2006). When cooperation is effective, new forms of support for MFA appear. Such support may result in new markets for commodities, amenities, goods, and services from multifunctional agroecosystems, or in supportive, non-market mechanisms such as "farmland protection programs" and other policy measures at local or regional levels. Cooperation may also increase support for these agroecosystems provided by a wide range of sectors (e.g, banking, regulatory, technical, commercial, and educational; Steyaert and Jiggins 2007). In principle, these flows of revenue and resources to landowners and managers of multifunctional agroecosystems serve to close the positive feedback loops that drive the virtuous circle process, thereby increasing the adoption and extent of multifunctional agroecosystems.

The virtuous circle model highlights several aspects of development of MFA that are underappreciated, in our experience. First, since substantial costs and risks are of course associated with any major change in farming practice, landowners and farmers require substantial support if they are to make this transition successfully. Therefore, revenue streams from both agricultural commodities and non-commodity goods, amenities, and services are likely to be generally necessary to support transition. For example, some form of payment for environmental services or other similar revenue appears crucial to give incentive to produce perennial biomass feedstocks for bioenergy in the upper Midwest, as a recent analysis (John and Watson 2007) suggests that current prices offered for biomass per se are too low to attract landowners.

Second, new MFA enterprises must overcome the inertia—both social and biophysical—that tends to reinforce established production and management systems. Factors militating against MFA include the opposition of dominant political actors and long lag times before perennial-based MFA begins to produce commodities and ecological services. The virtuous circle model provides a tool that can organize and direct strategic collective action to address such barriers (e.g., "broken" links in the feedback loops of the virtuous circle). The sheer complexity of these situations makes tools for critical and systemic thinking vitally important to multi-stakeholder groups attempting to establish MFA. Indeed, the virtuous circle model—or any systemic modeling framework—is principally useful for its heuristic value.

Third, the model underscores the need for development of new "management regimes" (Holtz et al. 2008) for MFA that will support an ongoing process of intercoordinated "knowledge innovation" across social, technical, market, and policy sectors. For example, such innovation is urgently needed to organize systems that pay farmers for production of environmental services. Such management regimes will rarely emerge spontaneously; rather, new levels of multistakeholder cooperation, communication, learning, deliberation, and negotiation of conflicting interests are needed, which require new coordinating mechanisms and agents (Pahl-Wostl 2007). In our professional experience, we find very little appreciation of the need for new management regimes, coordinating mechanisms, and agents among relevant stakeholder groups and agencies.

Despite these barriers, a considerable number of cases demonstrate the operation of virtuous circles (e.g., Selman and Knight 2006, Steyaert and Jiggins 2007). Most are in the socioeconomic, cultural, and biophysical context of Western Europe, but some exist in North America, where state and local policy innovations in the northeastern region preserve traditional agricultural landscapes in areas of rapid land-use change (Batie 2003), and support development of a regional food system development around Toronto (Friedmann 2007). Current examples are relatively limited in scope and scale but suggest considerable potential for wider deployment of these strategies. Of course, because the virtuous circle process is driven by positive feedback, it is subject to various forms of self-limitation (e.g, depletion of suitable land area, saturation of demand for certain goods or services).

Subsystem level: Collaborative social learning for multifunctional agriculture. Multifunctional agriculture requires new forms of knowledge production. Typical agricultural research and extension systems emphasize technology transfer to increase commodity production. These systems are poorly designed for generating site-specific, agroecological knowledge for multifunctionality, or helping diverse stakeholders reconcile multiple goals for managing working landscapes. Sustainable MFA enterprise development requires a more integral agricultural resource management strategy to yield multiple benefit streams. This demands balancing and synthesizing multiple socioeconomic goals—held by diverse individuals and institutions—within the biophysical constraints of specific agroecosystems. Research and extension institutions are poorly designed for the negotiated and multidisciplinary activities necessary to address multiple agroecological goals (Warner 2008). Different types of biological and practical knowledge must be coordinated and integrated to generate a multifunctional benefit stream. Advancing multifunctionality depends upon social learning, which we define as participatory research by diverse stakeholders to manage specific agroecosystems.

Agroecological partnerships have emerged around the United States to facilitate social learning about multifunctionality; partnerships have focused on horticultural crops, small grains, and integrated pasture dairy farming (Warner 2007a). New knowledge emerges from partnerships through coordination of social learning among agricultural producers, scientists in a range of disciplines, professional consultants, public agency officials, and other parties possessing relevant knowledge (Warner 2008). Partnerships incubate innovative practices and integrated approaches for diversifying commodity production and enhancing ecosystem services such as biodiversity conservation, watershed protection, amenity values, or carbon storage (Steyaert and Jiggins 2007).

Recent land-use conflicts in California provide a compelling example of the power of partnerships to increase multifunctionality. In these situations, partnerships evolved to cope with environmental regulatory pressure in farming. These pressures arose as high-value wine-grape (*Vitis vinifera* L.) production and high-value residential development have come into intimate contact in California, and a heated public debate has erupted about pesticide and water use (Warner 2007b). In response, growers, scientists, and public officials have created new social networks to produce knowledge needed to reduce pesticide and water use by increasing the multifunctionality of wine-grape production systems. These developments have significantly reduced land-use conflict in a number of cases.

Agroecological partnerships also address knowledge gaps about multifunctional systems that can hinder enterprise development. For example, divergent views among stakeholders recently resulted in the blockage of a proposed program to publicly subsidize perennial biofuel production systems in Minnesota. Conservation interests preferred species-rich perennial biomass production systems, while farmers and biomass processors preferred less-diverse systems. By appropriate design (e.g., intermingling of species-rich conservation areas and low-diversity production areas), a biofuel production system likely could address key concerns of both parties. Such a system will require a careful and locally specific approach to design and management. Our experience suggests that a close coupling of research activity to multistakeholder processes of learning and deliberation can help resolve such stakeholder disputes (Warner 2008). Partnerships can achieve this coupling, but only if certain key resources are available, so that individuals and institutions can facilitate shared research agendas, access resources, and extend partnership networks along a "vertical" dimension to influence research institutions and relevant public policy.

Supersystem level: Revisioning the relationship between American agriculture and society. Agriculture is the fundamental metabolic relationship between nature and society because it organizes nutrients and energy to sustain human life (FitzSimmons and Goodman 1998). As a metaphor, "social metabolism" highlights the mutual influence and exchange of nutrients and energy that integrates agriculture into human society. Ultimately, enhancing MFA requires broad public support for the focal and subsystem levels, grounded in a new vision for diverse nutrient and energy flows from agriculture to society. The popularity of recent bestsellers such as *The Omnivore's Dilemma* (Pollan 2007) indicates broad public discontent with our current agrifood system, which could be transformed into economic and policy support for an alternative system. Indeed, early critics of agricultural industrialization addressed its environmental and human health consequences and laid the foundation for subsequent political and ethical critiques (Nestle 2002). However, public deliberation regarding the US agrifood system has been relatively narrow (Morgan et al. 2006), limiting consideration of alternative approaches to its configuration. To generate fresh ways of conceptualizing the relationship between agriculture and society, we must simultaneously revision relationships both within the agrifood system and between this system and broader society, guided by the integration of multiple social goals.

Toward this end, we suggest that the contemporary agrifood system discloses collective societal assumptions about the environment, human health, social equity, and the relationship between rural and urban life. The current agrifood system assumes these to be essentially discrete, if not completely separated (FitzSimmons and Goodman 1998). Articulating an integrated social vision supportive of MFA is needed, because in our experience many key stakeholders do not yet recognize the potential of such agriculture to address their interests. For example, there are many concerns about animal agriculture for meat production in the United States, and there is some awareness that new grazing systems can address many of these concerns. However, from interviews with stakeholders in southeastern Minnesota, we believe that relatively few advocates for change in animal agriculture and in associated agrifood systems are aware of the full range of the beneficial environmental effects of well-managed grazing systems (Boody et al. 2005). Consequently, these stakeholders are not able to appreciate the potential size and strength of a coalition of support for grazing. In our view, a widely shared integrated vision is crucial to organize MFA; in its absence, MFA will continue to face skepticism and institutional inertia at the level of public judgment and policy formation (e.g., economic incentives offered to farmers).

Consequently, enhancing the multifunctionality of US agriculture depends on marshaling public opinion and creating a much broader base of socioeconomic support for alternative agricultural development trajectories (Morgan et al. 2006, Warner 2007b). Such an integrated vision would reflect a multidimensional worldview, a shared societal ethical narrative incorporating cultural, social, economic, and political dimensions. In our theory of change, "communities of ethical concern" play a crucial role in translating this vision into manifestations of specific support for multifunctional farming and policy. They do this by publicly critiquing the aspects of industrial agriculture to which they object, and by encouraging public support for MFA with sustainable rural enterprise development and policies that reward MFA. Communities of ethical concern have greatly increased in number and activity during the past decade, manifested by myriad citizen-led efforts to develop agrifood systems that balance economic development, social equity, and environmental protection (Allen et al. 2003, Morgan et al. 2006). Many projects work to promote a more "civic agriculture" (Lyson 2004); that is, an agrifood system that is integrated into the social and economic development of a local community and that fosters participation in civil society. Through changes in institutional and organizational behavior and formation of cross-sector coalitions, significant political power can be mustered in support of policy changes necessary to support multifunctional agriculture and the operation of virtuous circles (Steyaert and Jiggins 2007).

Box 2. Applying the theory of change: The Koda Energy Fuelshed Project.

A pilot project on sustainable bioenergy production is unfolding in the lower Minnesota River valley at the edge of the Minneapolis-St. Paul metro region. Koda Energy LLC has invested $60 million to create a biomass-based cogeneration system. The aim is to source 30 percent of fuel for the generation facility from local perennial energy crops, creating demand for circa 50,000 tons per year of biomass, drawing from a 20-mile radius "fuelshed" (i.e., the region supplying biofuel feedstocks to the generation facility). If this demand is met by multicultural agricultural (MFA) production of diverse perennial energy crops targeted to 10,000 acres of environmentally sensitive sites, major regional benefits could be realized on a very cost-effective basis; these include improved water quality, conservation of wildlife and other biodiversity, reduced flooding risks, and greatly enhanced recreational and amenity value. The Koda Energy project will pilot a "multifunctional bioenergy fuelshed" to jointly produce regional economic and environmental benefits and renewable energy. Various stakeholder organizations are deploying resources for the Koda project, which is guided by an informal steering group (including author N. J.).

Agroecological partnership. University of Minnesota researchers have received substantial external grant support for research on the agroecology of multifunctional fuelshed landscapes in the Koda region. With these grants researchers are collaborating with other actors to enable the cocreation of localized knowledge. Coresearchers include local soil and water conservation district personnel, and other stakeholders such as the Minnesota Department of Natural Resources (DNR) and The Nature Conservancy. The Minnesota DNR has recently catalyzed the formation of a partnership by recognizing the value of perennial biomass agriculture to its conservation goals. The DNR is providing various financial incentives and helping to convene coresearchers around a common interest in the multifunctionality of the conservation area, and is an actively collaborating in research. A set of local research and demonstration sites is being developed, and high-priority sites are being identified for conversion to biomass crops.

Enterprise development. There is a willing buyer for perennial biomass from the fuelshed region; therefore, present work focuses on creation of a pilot system of payment for environmental services (PES), which appears crucial to profitable biomass production. We are working to create a brokering entity that can aggregate multiple "environmental commodities" and other goods and services, market these, and pay landowners. This effort is leveraging the University of Minnesota and NGO research on local and regional demand for environmental commodities and other goods and services, which has found that a number of local and regional stakeholders are interested in providing PES in the fuelshed. State and federal policy measures now offer subsidy payments to "biomass production areas" that have an existing market for biomass and in which sufficient biomass production will occur to support these markets. We are working to prepare a competitive application for these subsidies. To support these enterprise development efforts, we have organized a multistakeholder confederation of state agencies, NGOs, local partners, local and regional government officials, and University of Minnesota research and extension personnel. This group supports the learning, innovation, and collective action that are essential to the operation of the virtuous circle model of enterprise development.

Reshaping public opinion and policy. We are working to build support for policy changes that will support a multifunctional fuelshed, at local to regional levels. Local efforts concentrate on dialogue with local land-use and development planning agencies; state-level efforts emphasize environmental, agricultural, and economic stakeholder groups, aiming to form a coalition that can win new state policy support on a number of levels. Finally, we are using strategic communications methods to reframe public awareness and understanding of bioenergy among key influencers of public opinion and policy.

Conclusions

Dramatic pressures are driving transformative changes in American agriculture. Rapid biophysical and social changes are under way, challenging conventional farming practices and related systems of agriculture. Scientific, economic, and social analyses indicate that MFA can reconcile the concerns and interests of environmental, economic, and agricultural sectors of society. Realizing the potential of MFA poses multiple challenges, as it will depend upon coordinated scientific and social action integrated across multiple scales, sectors, and systems (e.g., the Koda Energy Project; box 2). The theory of change outlined above offers an ecologically informed heuristic for negotiating these challenges. Such heuristics are crucial to cross-sector initiatives for sustainable development such as Green Lands, Blue Waters (box 1), which are now developing and refining strategies for increasing multifunctionality in agriculture and in land use generally. Scientists and scientific institutions have a history of standing largely above or apart from such cross-sector initiatives and projects. We urge scientists and scientific institutions to shift to a different stance, in which they deeply engage their scientific work in such initiatives, and address their best critical faculties to the grand challenge of doing so in the face of complexity, controversy, and contingency. New research funding for MFA will of course be required, such as the new emphasis on multifunctionality in the US Department of Agriculture competitive grant program, the Agriculture and Food Research Initiative, and the new Long-Term Agricultural Project funding program (USDA 2009).

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