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Landlabs: An Integrated Approach to Creating Agricultural Enterprises That Meet the Triple Bottom Line

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Abstract

Global demand is increasing for food, feed, and fiber; for additional agricultural outputs, such as biofuels; and for ecosystem services, such as clean water and outdoor recreation. In response, new agricultural enterprises are needed that produce more outputs from existing lands while meeting the "triple bottom line" of high performance in economic, environmental, and social terms. Establishing such enterprises requires coordination and development within three critical domains: landscape configurations (i.e., types and arrangements of land uses), supply/value chains (i.e., processing and utilization), and policy and governance. In this essay, we describe our efforts, as land-grant university scientists, to support coordinated innovation and enterprise development in integrated place-based institutions, which we term landlabs. We describe our experiences in three prototyping efforts and outline key features of landlabs that are emerging from these efforts. Land-grant universities have a central and crucial role to play in organizing and operating landlabs.

Introduction

U.S. agriculture has tremendous assets and capacities. It also faces major challenges, including rising demand for commodities and other ecosystem services in the face of increasing climate variation, energy and resource scarcity, diet-related public health issues, and food distribution problems. Meeting these challenges will require substantial innovation and development *(Jordan et al., 2007; Reganold et al., 2011)*, creating, in turn, new economic opportunities for farmers, landowners, rural communities, and commercial enterprises on many scales *(Defries et al., 2012)*.

Here we outline a vision for addressing major agricultural challenges by pursuing these opportunities. The U.S. agricultural research and development (R&D) system is addressing these challenges and opportunities on many fronts, but the need remains for certain crucial capacities and integration among them. This is particularly true for those capacities related to systemic change in agricultural production and postproduction systems *(Reganold et al., 2011)*. To provide these capacities and thereby accelerate the emergence of new agricultural enterprises that meet new challenges by seizing new economic opportunities, we argue that new integrative institutions are needed, which we term landlabs. In this essay, we discuss the nature of landlabs, which serve as active incubators for coordinating technological, economic, and policy innovations in enterprise development, and thereby reduce the economic and environmental risks and uncertainties faced by farmers, entrepreneurs, and public and private investors. We argue that land-grant universities must play a central role in organizing the multisector public engagement that is essential to landlabs.

Our work on landlabs is inspired by a major paradigm shift that we perceive among private, governmental, NGO, and research sectors concerned with the agriculture-environment nexus. In our view, these sectors are shifting from a problem-focused discourse on biophysical resource conditions per se and their causes (e.g., coastal hypoxia), to a broader opportunity-focused perspective *(Defries et al., 2012)*, emphasizing total agroecosystem productivity and capturing value from undervalued resources, such as water and nutrients that are released from current agroecosystems. This shift in perspective appears to be creating new pathways to land use and management changes that can produce significant progress on complex biophysical challenges such as coastal hypoxia while also producing new commodities and bioproducts. Accordingly, participants in a landlab emphasize opportunity- and solution-based approaches *(DeFries et al., 2012; Kristjanson et al., 2009)* focusing on sustainable enterprise development projects that integrate communication, innovation, and collaborative action by multiple social sectors. Here we present the rationale and modus operandi for landlabs, as these have emerged from our prototyping efforts over the past decade in three U.S. states, and discuss implications for the role of land-grant universities in the development of new agricultural enterprises that can meet societal expectations for performance in economic, environmental, and social terms.

Background and Context

Production of more bioenergy, bioproducts, and marketable ecosystem services—while also increasing the food/feed production that is the backbone of our current agriculture—offers major new growth opportunities in the agricultural bioeconomy. Recent scenario analyses suggest that such broad and substantial increases in total productivity are indeed possible *(Dale, Bals, Kim, & Eranki, 2010; Valentine et al., 2012)* and might strongly contribute to meeting the most profound challenges facing agriculture in the decades to come *(Foley et al., 2011)*. Moreover, society is increasingly aware of and interested in this expanded basket of goods and services from agriculture—and willing to pay for it—as illustrated by the growth of agro-environmental programs in the United States *(Batie, 2009)*. Consequently, new economic opportunities will arise for producers, landowners, processors, agricultural entrepreneurs, and rural communities.

What might this new agricultural bioeconomy be based upon? Conventionally produced commodity products will remain important; however, emerging forms of agriculture and land use are bringing about a wide range of new agricultural enterprises. These enterprises produce food, renewable energy, and biomaterials, as well as other ecosystem services such as pollination, water purification, and opportunities for agrotourism. New production systems for these goods and services involve a wide range of crops and managed plant communities, including herbaceous and woody perennial crops *(Glover et al., 2010)*, winter-annual and cover crops, and certain forms of animal agriculture, such as rotational grazing *(Winsten, Kerchner, Richardson, Lichau, & Hyman 2010)*. Emerging evidence suggests that these new production systems can increase both efficiency of agricultural resource use and total output of food, renewable energy, bioproducts, and ecosystem services from agricultural landscapes *(Dale et al., 2010; Gopalakrishnan et al., 2009)*. Moreover, such systems may also increase the resilience of production in the face of climate variability and market fluctuation *(Jordan & Warner, 2010; Schulte, Liebman, Asbjornsen, & Crow, 2006)*.

This new agricultural bioeconomy appears to offer much to society, but its emergence will require considerable systemic change, and many barriers stand in the way of such change in U.S. agriculture *(President's Council of Advisors on Science and Technology, 2012; Reganold et al., 2011)*. We propose that these barriers can be substantially lowered by focusing on holistic development of new agricultural enterprises that are needed to realize the potential of the new agricultural bioeconomy. Holistic development entails restructuring of production systems on agricultural landscapes, and also encompasses reorganization of infrastructure for harvesting, transport and storage; associated supply, value and marketing chains; and political and institutional support. These elements of new agricultural enterprises must be acceptable to multiple stakeholders, readily adoptable by agricultural producers and other economic actors, and appealing to rural communities and the institutions that support them. We believe that the United States can meet these needs by developing a greater capacity for agricultural innovation that creates viable new agricultural enterprises via coordinated innovation that encompasses the full range of components previously noted. To do so, the United States should complement the strengths of current agricultural R&D systems with new approaches that can more effectively coordinate innovation and change *(President's Council of Advisors on Science and Technology, 2012; Reganold et al., 2011)*. To do so, an intensified focus on processes of innovation is necessary.

Our view of innovation parallels that of Leeuwis and Aarts *(2011)*, who characterized agricultural innovations as effective combinations of three elements: new technologies, new knowledge systems and modes of thinking, and new forms of social and economic organization. More specifically, innovation in agricultural land use/land cover (LULC) configurations is needed to identify broadly supported landscapes that increase total production of food, renewable energy, biomaterials, and other ecosystem services across agricultural landscapes via new economies of landscape configuration *(Dale et al., 2010; Gottfried, Wear, & Lee, 1996; Jordan et al., 2011; Scheffran & BenDor, 2009; Wilson, 2007)*. Innovation is also needed in supply and value chains for new forms of biomass and other biomaterials. Such innovation adds value to new technologies by linking these into supply chains that perform acceptably according to economic, environmental, and social criteria. Innovation is needed in policies as well, including both incentives and regulations; these create a complex environment that bioeconomic development must navigate and effectively mobilize *(Becker, Moseley, & Lee, 2011)*.

To weave these forms of innovation into effective combinations, we argue that contributions are needed from four essential societal sectors: research/knowledge institutions, private enterprise, civil society, and government. Resources and capacities from each must be pooled to create an integrated system of technologies, knowledge and modes of thinking, social and economic organizations, and implementation strategies *(Armitage et al., 2009; Atwell, Schulte, & Westphal, 2010; Bammer, 2008).* Use of collaborative approaches in pilot innovation activities has led to transformational change in other arenas, such as clinical practice and business management in medical and information technology fields, respectively *(e.g., Troy, Carson, Vanderbeek, & Hutton, 2007)*, providing models of collaborative innovation for systemic change.

Landlabs

We have argued that sustainable agricultural innovation depends on linking and leveraging a wide range of public and private resources to design robust agricultural enterprise systems that are well-adapted to the biophysical and social conditions of particular regions. We further contend that enterprise development, as outlined above, requires an implementation-focused approach. At a certain point, a pilot-scale version of new production systems and supply chains must be created in a particular place, new policies applied, and results evaluated. It follows that place-based institutions are needed to create and evaluate the performance of these prototypic enterprises in economic, environmental, and social terms. The essential functions of these institutions, then, are to couple multiple innovation processes across the four key sectors noted, implement the resultant enterprises on pilot scales, evaluate the results, and continue innovation and development as needed to adapt and expand the enterprises to full commercial scale.

We term these place-based institutions landlabs. By linking and leveraging resources from many sectors and stakeholder groups to support and coordinate the innovation processes outlined above, we propose that landlabs can play a pivotal role in transformative change in U.S. agriculture, as called for by Reganold et al. *(2011)*. Landlabs are a form of boundary organization, an institutional form that has emerged in a wide range of arenas in which collective action among multiple social sectors has been important to progress on complex public problems *(Cutts, White, & Kinzig, 2011; Franks, 2010)*. Boundary organizations serve to convene multiple sectors, support mutual learning, and, most important, promote the development and implementation of innovative social and economic organization needed to enable complementary technical innovation *(Franks, 2010)*.

As boundary organizations, landlabs differ substantially in orientation and purpose from certain related institutions, such as long-term ecological research stations *(LTERs; Hobbie, Carpenter, Grimm, Gosz, & Seastedt, 2003)* and long-term agricultural research *(LTAR; Robertson et al., 2008)* sites. These institutions provide long-term "observatories" that expand the spatial and temporal horizons of research programs to address integrative questions about the biophysical and social dynamics of their focal systems. Landlabs, in contrast, have a more focused purpose: coordinated and broadly supported innovation that creates new commercial agricultural enterprises that meet high standards for economic, environmental, and social performance. The creation of new and sustainable economic opportunities for farmers, landowners, and rural communities is the central purpose of landlabs. Consequently, their agenda is much less science-centric than is the case for LTERs and LTARs, traditional agricultural research stations, and much on-farm and farming-systems research. Rather, science is a key resource for action in a landlab-based process of commercialization via development and coordination of new or realigned production systems, supply/value chains, and policies. In this regard, landlabs are inspired by a major paradigm shift about the agriculture-environment nexus that we perceive among private, governmental, NGO, and research sectors: a shift from observation-based approaches toward proactive creation of new opportunities and solutions *(DeFries et al., 2012; Kristjanson et al., 2009).*

Modus Operandi: What Goes On in a Landlab

In essence, landlabs serve to identify technical, economic, environmental, and policy components of new agricultural enterprise systems that can create value for a wide range of stakeholders. These components must be identified to limit uncertainties and risks faced by farmers, landowners, and public and private investors. Consequently, a critical function of landlabs is a "de-risking" process that will enable stakeholders and potential investors to move forward in a coordinated fashion to explore commercialization pathways. Landlabs achieve this by integrating a wide range of knowledge sources to create and share information critical to identifying the goods and services created by new enterprises, the potential values of these for various stakeholders, and prospective returns on investments for development of particular enterprises (Figure 1).

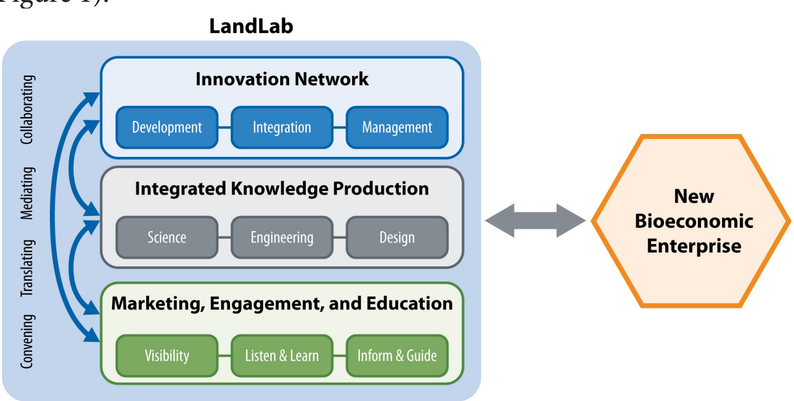

Figure 1. Key features of a landlab, showing interconnections among innovation, knowledge production, and engagement and resulting production of new bioeconomic enterprises.

Such information is critically needed to attract investment from a wide range of public and private sources. For example, a well recognized challenge to biomass-based agricultural bioenergy production is the "chicken and egg" barrier *(USDA, 2010)*, which occurs when investors in conversion technologies and distribution infrastructure are demotivated by lack of biomass supply, and biomass producers are unwilling to invest in new crops and new production systems until there is sufficient demand. By identifying sites for biomass production, cost-effective infrastructure for transport and handling, and potential for production of other valuable goods and services in agricultural landscapes that are producing biomass crops, landlabs can surmount this barrier by reducing uncertainty and enabling risk-sharing across a range of stakeholders. Landlabs thus can play a pivotal role in limiting risk and uncertainty in agricultural development for potential investors, producers, and society at large. We are developing the landlab approach to agricultural innovation in three ongoing prototypes in the upper Midwest.

Three Landlab Case Studies

The Iowa landlab.

This effort revolves around an emerging conservation practice for intensive annual crop production systems called prairie strips. These are bands of native grassland vegetation situated along contours or at the bottom of small watersheds in fields of annual field crops *(Helmers et al., 2012).* Prairie strips have garnered widespread interest from both production-centered and conservation-centered organizations in Iowa because they enable farmers to efficiently meet multiple conservation goals through easy and flexible incorporation into existing farming systems *(Helmers et al., 2012; MacDonald, 2012)*. These attributes of prairie strips appeal to the state's strong agricultural constituency, address the substantial concerns for water quality that the majority of Iowans hold *(Arbuckle & Tyndall, 2013)*, and are valued by groups concerned with biodiversity. Notably, the notion of prairie strips appears to have strongly promoted social learning regarding shared interests and opportunities among a wide range of stakeholder groups *(Grudens-Schuck & Larsen, 2012)*. We believe that two landlab activities have been key to these developments: establishment of a credible prairie strips R&D site, and the formation of a broad network of colearners.

The R&D site is called STRIPS (Strategic Trials of Row crops Integrated with Prairie Strips); it is located at Neal Smith National

Wildlife Refuge (NWR) in Jasper County, Iowa. This site provides data on the dynamic characteristics and functions of prairie strips. STRIPS is run by a group of scientists from Iowa State University, USDA Agricultural Research Service, U.S. Fish and Wildlife Service, and the U.S. Forest Service, based on their shared interest in developing a program to address Iowa's persistent water-quality problems in a cost-effective manner. STRIPS research began in 2006, but team and knowledge building began 4 years earlier in workshops intended to organize an interdisciplinary scientific team.

These workshops engaged participants in systems thinking with a focus toward potential levers for change within the Corn Belt agricultural system. Disciplines engaged spanned agronomy, soil science, ecology, economics, education studies, forestry, hydrology, and philosophy, among others. The STRIPS site emerged from these sessions. It employs a robust long-term experimental design, obtains performance measures of interest to a wide range of stakeholders, and is supported by 10-year commitments from project partners. Its location near the state capital affords easy access by organizations active in the state's agri-environmental policy arena. These features appear to be the basis of STRIPS's credibility and value for shared learning among a wide range of stakeholders.

The landlab approach depends on engagement among private enterprise and NGOs in addition to the research institution and government agencies that established the Iowa Landlab. Accordingly, after establishing the STRIPS site, scientific team members sought to broaden the network of colearners by engaging individuals from production-oriented and environment-oriented NGOs active in Iowa. Participating organizations and individuals formed a project stakeholder committee, initially intended for discussion of scientific matters related to the STRIPS experiment. Findings from this experiment have been extensively interpreted and discussed through the social learning of the project stakeholder committee, which has subsequently communicated these findings and their implications for a wide range of stakeholders *(e.g., Leopold Center for Sustainable Agriculture, 2011)*. The project committee has also been active in seeking support for broader implementation.

Since 2006, the project committee has, however, quickly matured to become a multi-stakeholder arena that enables information sharing and cross-organizational learning among members, including researchers, NGOs, private enterprise, and government agencies. Since the establishment of the STRIPS site in 2006, individuals from 26 organizations—spanning state and federal government and nongovernmental organizations—have participated in landlab meetings. Participants offer many reasons for engagement, such as "being able to get up-to-date research information" and "being involved with helping to expand the efforts." Project committee members have also brought resources beyond knowledge to the project, including funding and connections that have helped scientific members reach their goals of longevity and meaningful impact. Now, 10 years after the initial scientific team discussions, prairie strips are being adopted as a conservation practice by private farmers and institutions across Iowa, and appear to be a powerful leverage point for change.

Recently, the Iowa Landlab has begun to focus on enterprise development related to prairie strips via bioenergy development R&D as an outgrowth of STRIPS. In particular, the landlab's Comparison of Biofuel Systems (COBS) project is comparing fertilized and unfertilized reconstructed prairie to corn systems in terms of its ability to sustainably provide biomass and ecosystems services *(Liebman, Helmers, Schulte, & Chase, 2013)*. Results from the STRIPS experimental site suggest that prairie strips are able to produce an average of 7.2 Mg/ha/year of biomass, a yield comparable to switchgrass monocultures, which are widely being touted as the next bioenergy crop for the region *(McLaughlin & Kszos, 2005)*. The team has also been encouraged to engage in "institutional change" by a major funder. An initial step in this arena has included working with the USDA Natural Resource Conservation Service to revise existing standards to allow participating farmers to receive higher levels of federal cost-share dollars for implementing prairie strips according to the team's design. We have also begun engaging partners to develop a Payment for Ecosystem Services (PES) scheme to link buyers of ecosystem services to farmers using prairie strips to provide services, an effort that will require the development of new financial practices and an organization to manage them in addition to the land management and monitoring practices already in play.

The Minnesota Landlab.

Working in the Middle Minnesota Basin in south central Minnesota, a consortium of University of Minnesota researchers, businesses ranging from farmers to large corporations, NGOs, and government agencies is focusing on the development of a new agricultural enterprise that could be broadly applicable in U.S. agriculture. The enterprise is a production and supply system that will produce a stable and reliable source of lignocellulosic biomass to a pilot biorefinery, and will do so in a manner meeting high performance standards in economic, environmental, and social terms. Although lignocellulosic biomass is a crucial raw material for large-scale production of biofuels, biopower, and bioproducts, it has serious disadvantages as an industrial feedstock, such as bulk, heterogeneity, instability, and variability. Poor development of production capacity and end-use markets creates additional barriers to enterprise development. However, production of lignocellulosic biomass from annual and perennial sources provides a major opportunity to increase total production of both high-value commodities and other ecosystem services from agricultural landscapes *(Dale et al., 2010)*.

To realize the potential of such biomass for enterprise development, we are developing a new commercialization pathway for lignocellulosic biomass, entailing a network of biomass processing depots—termed AFEX™ depots—in which biomass grown nearby is pretreated using the ammonia fiber expansion, or AFEX, process. AFEX produces a stable, inert, dense pellet product from a wide variety of annual and perennial biomass sources, and adds considerable value by increasing the proportion of fermentable and digestible materials in the biomass *(Balan, Bals, Chundawat, Marshall, & Dale, 2010)*. For this reason, AFEX-treated material can be used as high-quality ruminant animal feed *(Bals, Murnen, Allen, & Dale, 2010; Weimer, Mertens, Ponnampalam, Severin, & Dale, 2003)* as well as a biorefinery feedstock (Figure 2). Therefore, existing markets for animal feed can incentivize farmers to produce biomass in advance of strong demand for cellulosic feedstocks for biorefining. Such production will create a reliable source of these feedstocks, thereby substantially reducing risk in developing biorefineries and supply-chain infrastructure. Finally, AFEX depots using local biomass sources could feasibly be owned by producer co-ops, increasing opportunities for farmers, landowners, and rural communities to benefit from a new cellulosic biofuel/biomass industry.

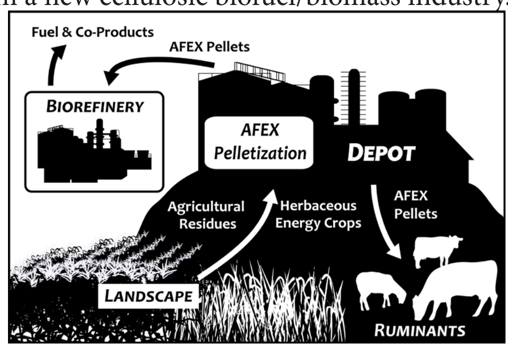

Figure 2. AFEX processing depot in a feed/fuelshed setting, illustrating production of herbaceous biomass feedstocks from a range of sources and production of AFEX biomass pellets for multiple markets and recycling of mineral ash back to production agroecosystems.

AFEX depots provide a novel and promising commercialization pathway for bioenergy systems. This pathway would utilize a feed/fuelshed area of about 500 square kilometers, assuming a collection radius of about 13 kilometers around an AFEX depot. Assuming a conservative biomass yield of 6 Mg/ha/year and a processing capacity of 100 Mg per day, roughly 10% of the fuelshed area would be required to supply biomass to the depot. The depot thus creates a "market pull" for biomass production from about 50 square kilometers within the fuelshed area. Many lines of evidence *(Schulte et al., 2006)* suggest that if such an area of biomass production is strategically located in critical landscape areas of the fuelshed, a wide variety of goods and services can be produced in addition to cellulosic biomass. Such a fuelshed can be justly termed multifunctional, because when strategically located, perennial and certain annual biomass crops can improve soil and water conservation, store carbon, enhance biodiversity, and improve hunting, fishing, recreation, and ecotourism opportunities. Much evidence thus suggests that a wide range of stakeholders could benefit substantially from AFEX depots situated in multifunctional fuelsheds.

To explore the potential of AFEX depots in multifunctional fuelsheds as a bioeconomic enterprise, the Minnesota Landlab is conducting a de-risking process that will enable a wide range of stakeholders and potential investors to move forward in a coordinated fashion to explore commercialization of AFEX depots in multifunctional fuelsheds. Our de-risking process is engaging the full range of landlab participants to identify and reduce uncertainties and risks related to the depots and the fuelshed landscape that will support them. To do so, we are using a spatial decision support tool (DST) that integrates a range of spatial models to design the fuelshed landscape and the supply-chain logistics of the depot *(Jordan et al., 2011).* The DST helps multiple stakeholders make design decisions by estimating economic and environmental performance metrics for various choices of site-specific feedstock production and management systems; harvest, transportation, and storage options; and depot locations and capacities. We will use outputs from this design effort to identify and analyze implementation-relevant policies, thereby addressing additional sources of uncertainty and risk. Our effort is providing the basis for business plans detailing specific value propositions and returns on investment needed to attract investment in depots and fuelsheds from a wide range of public and private sources. Our short-term goal is to gain funding within 3 years for a commercial-scale (100 Mg/day) depot/multifunctional fuelshed.

The Wisconsin Landlab.

This effort, like those previously described, is motivated by widespread interest in perennial herbaceous biomass crops that can produce both renewable energy and resource conservation benefits, and the need to better understand the economic, environmental, and social performance of enterprises based on these crops in particular settings and contexts. Thus, in 2011, the University of Wisconsin–Madison and the U.S. Fish & Wildlife Service Leopold Wetland Management District began a landlab for fostering bioenergy enterprise development in southern Wisconsin. The landlab functions as a "think- and do-tank" that aims to reduce the time, financial resources, and expertise required to gain entry into these enterprises.

In particular, the Wisconsin Landlab was initiated to explore bioenergy enterprise development as a systemic solution to an ongoing wetland management challenge. The Leopold District manages more than 13,000 acres of waterfowl production areas (WPAs) in 17 Wisconsin counties and is continually adding new properties and restoring additional habitat acreage. Currently, controlled burning is used to manage these grassland habitats. However, the district is unable to apply burning at the scale needed to maintain WPA habitats in a healthy condition. Therefore, the landlab partnership is exploring biomass collection as a management method that can maintain habitat value and provide a renewable bioenergy feedstock.

The landlab has established a harvesting experiment to build and test basic components of a model bioenergy enterprise, for which experimental harvests are occurring on six WPAs in five counties. A variety of agricultural, NGO, and commercial/industrial partners are participating in harvest, handling, and use of approximately 1,100 tons of mixed grass biomass annually. A group of UW researchers are evaluating the effects of biomass collection on habitat management goals and other ecosystem service benefits, the economic and technical suitability of the biomass for bioenergy supply and value chains, and potential social and economic effects of this new enterprise system. These experimental harvests will continue, providing long-term educational and research opportunities. Partners in the design and implementation of these experiments and other initial activities include federal agency conservation planners and land managers; agricultural producers; nonprofit organizations; commercial agribusiness; and research and development personnel from academia and industry. These partners have contributed broadly to project design and implementation, and we observe a shared enthusiasm for the harvesting experiment.

The Wisconsin Landlab is also pursuing three concurrent efforts to complement the harvesting experiment: expansion of grass acres; design and installation of a commercial-scale biomass conversion facility; and seeking end-user commitments (i.e., markets). Our agribusiness partner is leading in the search for opportunities to produce dedicated biomass on private lands adjacent to or near WPAs, and organizing grass brokering among various end users to limit competition among new and existing uses of grass materials. A task force has been formed to identify a project area for an anaerobic digestion (AD) facility to utilize abundant nearby livestock wastes (dairy manure) in combination with locally sourced grass biomass. Our industrial partner, an alternative energy subsidiary of a global industrial corporation based in the Midwest, is leading the task force. With our industrial partner we are also identifying potential end users for natural gas produced at the AD facility. We have engaged nonprofit and consultancy partners to identify and leverage additional enabling technologies, policies, and services, including new rules in Wisconsin regarding the discharge of phosphorus. Under the new rules, city and county municipal wastewater treatment facilities are statutorily accountable to reduce phosphorus discharges. These new laws permit the expenditure of funds on land uses upstream, such as grassing of waterways and field margins on private lands, thus potentially serving dual purposes of yield (i.e., biomass harvest) and nutrient uptake/interception.

Over the coming decade, the Wisconsin Landlab aims to produce a market-driven, self-sustaining, commercially viable bioenergy system in southern Wisconsin. This enterprise system will increase total agricultural output and production options for farmers in the study area, with concomitant income improvements (e.g., income security). We expect that a measureable increase in acres in perennial mixed grasses will lead to measureable improvement in surface water quality in the study area, particularly at the scale of secondary and tertiary streams. Future work is likely to address key social and biophysical attributes of such an energy system, including life-cycle analysis and connections with community-based renewable energy initiatives.

Reflections on Case Studies and Implications for Land-Grant Universities

Landlabs are boundary organizations for organizing collective action on complex challenges in agricultural development by identifying and systematically pursuing new opportunities linked to value capture, efficiency in resource use, and coordinated innovation. Landlabs seek to frame these challenges and opportunities in terms that effectively engage with shared stakeholder perceptions about agriculture, water, energy, and economic development. In our experiences, these efforts depend on a set of key processes that includes organization and maintenance of horizontal and vertical networks *(Ison, Roling, & Watson, 2007)*, practice of certain communicative activities *(Leeuwis & Aarts 2011)*, and practice of design and other knowledge production that emphasizes the integration of multiple knowledge sources and the provision of quality control from an extended peer community *(Nassauer & Opdam, 2008)*. In Table 1 and below, we reflect critically on our experiences in the case studies, with focus on these key processes.

Table 1. Key Features of Iowa (IA), Minnesota (MN), and Wisconsin(WI) pilot landlabs

Case	Theme for Enterprise Develpment	Organization	Integrative Knowledge Production	Marketing Engagement & Education
IA	Improving the prosperiity of Iowa farms and agricultural landscapes by improving their functioning and resilience, and enabling payment for ecosystem services.	Project composed of interdisciplinary science team and a stakeholder team broadly representing agri-environmental interests in state.	Researchers from biophysical (agronomy, ecology, entomology, hydrology, and soil science) and social (economics, education, English, sociology) disciplines working together with periodic input from stakeholder team.	Stakeholder team helps science team frame research findings and disseminate them through communication networks.
MN	Establishing a production and supply system to produce a stable and reliable source of value-added lignocellulosic biomass for animal feed and a pilot biorefinery.	Multistakeholder group of place-based private enterprise, researchers, government agencies, NGOs, and farmers; group shares common interest in enterprise development.	Multistakeholder design and planning processes guided by decision support from environmental, techo-economic, economic, and logistical analysis.	Engaging private enterprise, government, NGOs, and researchers in dialogue about enterprise development and the landlab model.
WI	Forcing the conservation-economy nexus via production of dedicated perennial crops and conservation-land management actions in new bioproduct and bioenergy systems.	Transdiciplinary collaboration, including researchers from multiple disciplines, federal agency personnel, local producers, local and regional agribusiness, a global engineering firm, and NGOs.	Researchers from multiple disciplies, conservation managers, engineers, farmers, speciality harvesters, biomass processors, and business executives working together, guided by reflective processes and periodic external review.	Working with groups and organizations to develop and distribute outreach materials and media; engaging researchers and academic administration in dialogue.

Organization of cross-sector networks.

Each of the landlabs has proceeded through an organizing phase of 5–10 years, during which extensive and repeated efforts were made to establish cross-sector connections that variously included researchers, NGOs, government, and private enterprise. In all three cases, these efforts were started and sustained by a small group of land-grant college of agriculture (LGCOA) researchers and key external partners. These small organizing groups had disciplinary knowledge that was the basis of their respective visions for enterprise development, and an inclination to span boundaries between sectors. These organizers engaged with each other and with members of government and private enterprise sectors in a prolonged period of probing for opportunities to work together on shared concerns and interests. These cross-sector connections were costly to establish and maintain. Crucially, in all cases, there were funding streams that supported the activities of this organizing phase, including dialogue, collaborative learning, and conflict resolution. In some cases, funders have appreciated the importance of supporting this organizing work. This funding has provided the organizing groups with continual institutional support (e.g., support has been provided by the Green Lands Blue Waters project, http://www.greenlandsbluewaters.org). Other funding has supported more conventional research programs, but these have emphasized interdisciplinary approaches and reciprocal engagement with other sectors. These small organizing groups have demonstrated a capacity for learning and adaptation; they have thus been able to shift to new framings of the opportunity situation, and have withstood changes in membership.

In each case, we observe that network formation has been strongly facilitated by the emergence of an intermediary object *(Steyaert et al., 2007)*. Intermediary objects (IOs) are defined as conceptual entities (e.g., models, maps, or management strategies) that recognize the interests of—and are therefore significant to—multiple social sectors. For example, the management strategy of capturing value from undervalued resources (e.g., commodity production using water and nutrients that are released from current agroecosystems; *Gopalakrishnan et al., 2009*) is a high-level IO that is strongly appealing to both agricultural and environmental NGOs, in our experience. An effective IO will motivate such sectors to engage in negotiations, collaborative learning, and collective action that address the situation surrounding the IO. We believe that in each case, the emergence of IOs has enabled new cross-sector understandings of opportunities for novel agricultural enterprises that capitalize on perennial-based cropping systems. In the Iowa case, the IO is the concept of prairie strips and the STRIPS experiment. In Minnesota, AFEX depots and their associated fuelsheds are functioning as an IO, and in Wisconsin, the notion of harvestable zones in wildlife management areas provides this function. In the Minnesota Landlab, the emergence of an IO appears to have ended a long latent period that began in about 2003, when a private enterprise announced plans to develop a 20 kW bioenergy facility that would use a range of biomass feedstocks. This move excited wide interest initially, but did not stimulate much enterprise development; in our view, many stakeholders were highly uncertain about economic and environmental opportunities related to the new bioenergy facility. In contrast, the emergence of a new IO in the form of the AFEX depot/fuelshed concept appears to be far more attractive. In particular, this IO appears to offer a more certain "value proposition" to many stakeholders and has attracted much stronger interest across sectors. In the Iowa case, prairie strips function as an IO and have garnered widespread support from both production-centered and conservation-centered organizations within the state, some of which have been fairly entrenched in their approach. Prairie strips fulfill the role because they provide multiple benefits to multiple, diverse stakeholder groups, as shown by the STRIPS research site. Similarly, in Wisconsin, WPAs have served as IOs, providing a tangible challenge around which production-centered and conservation-centered organizations have collaborated to find workable, mutually beneficial solutions via interdependent learning and action.

Communicative activities.

As argued by Leeuwis and Aarts *(2011),* certain forms of communication are basic to coordinated innovation. Within social networks, management of conflict and tensions occurs, as does learning. Such communicative activities are certainly ongoing in each case, in several different forms.

First, we are using new tools from ecological economics, spatial science, collaborative environmental planning, and other disciplines to help multistakeholder groups engage in *systemic learning.* By this term, we mean development of a shared understanding of the economic, environmental, and social performance of an agricultural enterprise, viewed systemically across multiple dimensions of performance and across geographic and time scales *(Collins et al., 2011; Sieber, Zander, Verburg, & Van Ittersum, 2010)*. For example, a set of integrative spatial decision support models is emerging to address biophysical and social uncertainties; these models map and project how production and other ecosystem services of agriculture are distributed across multiple relevant spatial scales and how social and economic systems respond to these biophysical signals *(e.g., Bryan, Raymond, Crossman, & King, 2011).* Such models enable quantification and visualization of trade-offs and synergies that can be expected from a given agricultural system, which in turn enable concrete discussion of scenarios for accommodating multiple stakeholder interests in a redesigned agricultural system *(De Groot, Alkemade, Braat, Hein, & Willemen, 2010)*. Evidence suggests that these models enhance users' understanding of interacting factors such as water, land use, and habitat quality, as well as building awareness of multiple spatial and temporal scales *(Kremer & Lansing, 1995; Prato, Fulcher, Wu, & Ma, 1996; Stave, 2002).*

We are also working to facilitate a different form of multistakeholder learning: *communicative learning*, defined as a social process of reflective deliberation that integrates multiple value perspectives and knowledge sources to construct new understandings among cross-sector and multistakeholder groups *(Kesting, 2010; Mezirow, 1996)*. Communicative learning aims to address barriers that result from diverse and potentially conflicting priorities and goals among sectors and stakeholders. These barriers arise from divergent positions and interests, as well as from unresolved differences in worldviews and mental models. In effective communicative learning processes, stakeholders enable each other to comprehend and appreciate the logical validity, moral basis, and sincerity of their expressed worldviews, mental models, and viewpoints on complex issues. Evidence shows that collaborative and inclusive stakeholder processes that involve significant interaction and information sharing can promote convergence of perspectives in multistakeholder groups *(Deyle & Slotterback, 2009; Forester 1999; Innes & Booher, 1999)* and produce designs and other decisions that are more representative of stakeholder values, have positive environmental impacts, and are more innovative *(Mandarano, 2008; Webler, Kastenholz, & Renn, 1995)*.

In our view, an ongoing and coupled process of systemic and communicative learning is needed to develop the interlinked innovations in land use, supply/value chains, and policies that are needed to establish a new agricultural enterprise. To develop these innovations and thus design a new enterprise, multistakeholder groups must develop and explore alternative scenarios for such enterprises, using visualization and multicriterion decision-support tools *(Jordan et al., 2011)*. These scenarios will differ in terms of land use, supply/value chains, and policies, and will perform differently in economic, environmental, and social terms. To decide on performance standards that can be used to choose among alternative scenarios, ongoing and coupled learning is needed in a multistakeholder group. In particular, interplay is needed between systemic learning—which reveals how a design for a new enterprise is *expected to work*—and communicative learning, in which multiple stakeholders deliberate about how the new enterprise *should* work. In each of the pilot landlabs, this interplay is being used to negotiate and define performance standards that specify key outcomes from new enterprises, and to assign priorities among these outcomes when trade-offs occur.

This model of learning has not been fully realized in any of the pilot landlabs to date. We do believe that substantial communicative learning regarding institutional and organizational goals and motivations has occurred during the organizing phases, and in relation to identification of each landlab's IO. Formal evaluations of such learning processes are under way in the Iowa and Minnesota landlabs. Each landlab also has faced various tensions related to goals and interests, ranging from inability to set firm prices for biomass to mistrust based on publicly critical stances taken by various participants; these tensions and their management have not yet been documented. However, we believe that these learning and conflict-management activities have not yet reached the levels of intensity and effectiveness that will be needed to bring enterprise development to broad implementation. For example, innovation processes related to policy and governance are crucial to enterprise development and will require extensive learning and conflict management; in each landlab, these particular innovation processes are in initial phases.

Knowledge production.

In each case, there are intensive efforts to create new understanding to support the systemic learning that is key to enterprise development. Knowledge production focuses on the IO in each case, so that multiple stakeholder groups can be assured that their key concerns related to the IO are being met. Relevant examples include the creation of databases for decision support for fuelshed landscape design and visualization in the Minnesota case, the evaluation of the biophysical effects of prairie strips in Iowa, and observations on bird, arthropod, and plant community responses to management at landscape spatial scales in the Wisconsin Landlab. All of these efforts are incorporating multiple knowledge forms in the process of knowledge production, and striving for close integration with the enterprise development process. However, the knowledge production to date has been largely confined to natural science research. Each landlab has characterized novel production systems and their effects on related resource systems. Each landlab has plans for landscape and supply-chain design, and for other relevant knowledge production, such as development of supply-chain infrastructure, analysis of willingness to pay for ecosystem services, or analysis of policy factors influencing each enterprise development. However, these investigations are in their initial phases. Each is dependent on recruitment of additional researchers and other contributors of knowledge and analytical capacity. To date, most knowledge production activities have been performed by natural scientists involved in the initial organizing of each landlab. None of the landlabs have yet demonstrated a capacity to bring a wide range of stakeholders and knowledge producers into the sustained and manifold interactions that appear necessary to support the comprehensive and coordinated innovation needed for enterprise development.

Implications for Land-Grant Universities

In our experience, the practical and conceptual foundations of the landlab approach—boundary organizations, networks, communication, and new approaches to knowledge production for agricultural innovation—presently receive little sustained, integrative, and critical attention in land-grant colleges of agriculture (LGCOAs). Certainly, some LGCOA faculty and students are practically and intellectually engaged with these matters, as are faculty and students in other parts of these LGUs. However, in our experience, most of these workers do not participate extensively in the mainstream of LGCOA instruction, research, and outreach.

In our view, this situation is highly problematic; we believe that LGCOAs should play a major if not leading role in the organization and facilitation of landlabs. LGCOAs have many relevant assets, including faculty willing to play key organizing roles, analytical capacities, scientific credibility, and participation by young and creative students in a range of service and community-engaged learning roles. Moreover, LGCOAs, as research institutions, are one of the four sectors whose participation is crucial to the coordinated innovation that is essential to the work of landlabs. Therefore, we believe that some minimal number of LGU personnel should participate in landlabs on a sustained and extensive basis. The previously noted absence of discussion and focused work on the processes that are critical to landlabs is doubtless a barrier to LGCOA involvement.

Conclusion

In this essay, we have argued for the value of integrated place-based institutions, which we term "landlabs," to support the coordinated innovation and enterprise development needed to increase agricultural outputs from existing lands, while meeting the triple bottom line of high performance in economic, environmental, and social terms. In a landlab, a range of innovators are networked to coordinate novel land uses, supply chains, policies, and other domains necessary for the emergence of new agricultural enterprises. Innovation is coupled to knowledge production emerging from science, engineering, and design. Active engagement with a wide range of interested parties occurs via various marketing, learning, and outreach efforts. All three of these core activities in a landlab must be interlinked and coordinated by an emphasis on organization, communication, and two key forms of social learning: systemic and communicative learning. A group of individuals who are willing to provide ongoing organization and integration is key to our landlab model.

Land-grant universities have a central and crucial role to play in organizing and operating landlabs. To enable LGCOAs to play leading roles in landlabs, we propose that LGU researchers will require certain new skills and habits of mind that will enable them to help organize and lead agricultural innovation efforts associated with landlabs. Recently new approaches to agricultural science education have been explored that aim to develop these skills *(Francis et al., 2012; Jordan, Wyse, & Colombo, 2012).* We propose that these skills and habits of mind will complement the deep knowledge of a scientific discipline that is the hallmark of university researchers and enable a critical mass of LGU researchers to be skilled leaders or key participants in landlabs and other efforts to spur broadly based innovation in response to the grand challenges and opportunities of contemporary agriculture.

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