1 Collaborative Geodesign to Advance Multifunctional Landscapes

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1. Introduction

Geodesign is emerging as an important evolution of earlier innovations in planning support systems (PSS) and public participation geographic information systems (PPGIS). These earlier approaches placed significant emphasis on the technology, analytical capabilities, and decision support, while highlighting the prospects for their use in public engagement processes (Geertman& Stillwell, 1993; Klosterman, 1997; Obermeyer, 1998). As we move into the era of geodesign, we have the potential to more fully integrate technology and decision-making processes, producing better projects and outcomes for the environment and communities. As Dangermond(2010, p. 506) suggests, “The quality of the results improves because the project is designed around, in concert with, and/or to fully leverage certain geographic, environmental, and social features while simultaneously minimizing undesirable impacts to those same features.” This point is fundamental to the conception of geodesign as an evolution of a general design or planning process. It is the geovisualization and integration of multiple information types coupled with rapid and iterative quantitative modeling that makes geodesign unique and offers so much promise for public engagement.

Building on this prospect, this paper focuses on the application of geodesign, drawing deep insights from practical use and offering evidence as to its effects in decision making processes that involve varied landscape conditions, diverse community perspectives, and myriad environmental, economic, and social concerns. The paper specifically examines the application of geodesign in enhancing decision making to advance multifunctional landscapes, acknowledging that these kinds of landscapes are not accidental, but are rather the outcomes of landowner and government decisions that have the potential to produce public and private goods. Thus, this research explicitly examines geodesign application within the context of collaborative

processes and decision making, where it has the potential to contribute to the social learning, consensus-building, and improved outcomes predicted in the literature (e.g. Daniels & Walker, 1996; Innes, 1992; Margerum, 2002b; Mandarano, 2008).

2. Framing Geodesign for Application

While the geodesign term is widely used, research on the concept and its application is quite limited (Batty 2013). As noted earlier, geodesign can easily be considered an outflow or evolution of earlier decision support and participatory geographic information system (GIS) applications. Looking back even further, it can be characterized as an evolution of McHarg's (1969) *Design with Nature* approach characterized concisely as the "stack of layers" predecessor to current GIS (Dangermond, 2010; Goodchild, 2010, p. 8). Regardless of the particular genesis of the term, geodesign can be characterized by three facets. First, geography within geodesign is illustrated in its relationship to processes and forms on or near the Earth's surface, accomplishing what Steinitz (2012) calls "geography by design." Second, design in geodesign is about "sketch" and "simulation," accomplished through the "technology of design" (Goodchild, 2010, p. 8). Third, geodesign is characterized by social and process dimensions, as it incorporates scientific knowledge, integrates with human decision-making, and allows decision makers to enact the pattern-process-design relationship (Dangermond, 2010; Goodchild, 2010; Nassauer & Opdam, 2008). This last facet reveals a key prospect for application and further development. In particular, geodesign is acknowledged as a means of simulating impacts within geographic contexts (Flaxman, 2010) and decreasing the cycle time of participatory design processes (Dangermond, 2010), by facilitating an efficient process of proposition-disposition for design ideas (ESRI Press, 2013; Lyle, 1985).

As planning and design move to more participatory and collaborative approaches that bring together diverse interests in working toward consensus (e.g. Bryson et al., 2013; Healey, 1996; Margerum, 2002a), geodesign offers a critical support mechanism. Collaborative approaches are well-recognized for their ability to produce improved outcomes (e.g. changes in social and environmental conditions) and outputs (e.g. plans, models, data) (Koontz & Thomas, 2006; Mardarano, 2008). As summarized in Margerum (2002b), collaborative processes are intended to engage participants in a joint search for information. Geodesign in collaborative processes can accomplish this kind of engagement by supporting group processes that utilize and integrate multiple geo-data sources to inform planning and design. Interaction among diverse people in collaborative processes facilitates communication, allowing participants to learn from each other, and ultimately accomplishes “collaborative science” (Bentrup, 2001; Mandarano, 2008, 460). Integrating expert and “local knowledge” occurs as participants communicate their own perspectives and respond to those of others (Balram et al., 2004; Innes & Booher, 2010; Van Herzele, 2004). Geodesign tools in collaborative processes can support participants as they communicate information and discuss multiple data sources, including their own perceptions, informing potential scenarios that can be instantaneously visualized. Finally, collaboration produces a process by which participants can interact with each other, producing social learning outcomes characterized by changes, including convergence in perceptions (Schively, 2007; Deyle & Slotterback, 2008). Participants in collaborative processes are often able to achieve consensus, even around contentious issues (Innes & Booher, 1999; Margerum, 2002a; Schively, 2007). Geodesign supports social learning and fosters consensus through iterative group-based exploration of alternative scenarios and outcomes.

Another emerging trend in planning and design is a focus on multifunctionality, acknowledging that the best performing landscapes, communities, and organizations are more resilient (Fisher, 2013; Walker & Salt, 2006), more competitive (Mettenpenning et al., 2011), and more equitable (Werrij, 2000). For example, in agricultural landscapes, multifunctionality can be defined as the co-production of food, fuel, and fiber as well as ecosystem services such as water quality, plant and animal habitat, carbon sequestration, aesthetic value, and more (Boody et al., 2005; Jordan et al., 2011; Naveh, 2001). Even though multifunctional landscapes produce ecosystem services (i.e. nonmarket goods), under current market scenarios certain multifunctional landscape configurations may not be economically viable for landowners even if they are desirable for society. As a result, in order to implement multifunctionality, society needs to either pay for nonmarket landscape services through ecosystem service payments (Daily et al., 2009), or create new bioeconomies that utilize a product of multifunctional landscapes (Jordan & Warner, 2010; Termorshuizen & Opdam, 2009). The specific economic investments required depend on the specific context in which multifunctionality is implemented (Fisher et al., 2009).

3. Prospects for Integrating Geodesign and Collaboration for Multifunctionality

In order to consider the tradeoffs and synergies within multifunctionality, decision makers must have informed, interconnected, and legitimate insights into the various ecological, social, and economic functions of landscapes. In short, multifunctionality requires a systemic understanding of the coupled human-environmental system in question (Jordan et al., 2011; Jordan et al., 2013). Engaging and enacting systemic understanding in multifunctional landscapes involves both anticipating and prescription science (Naveh, 2001). Anticipating science requires decision makers to collectively search for information and communicate about

their perceptions of potential implications of that information. The process of searching for and communicating about information overtime results in social learning, and the social learning process enables decision makers to come to a consensus for action. This action requires prescription science (Naveh, 2001). Taken together, these notions of science, learning, and action are fundamental to adaptive management, an essential strategy for the creation and maintenance of multifunctional landscapes (Wostl, 2006). Geodesign embodied within a collaborative process, as described above, is uniquely suited to facilitate the emergence of such multifunctional landscapes because it offers the capacity to reveal information about key landscape functions, and merges these information via mapping for systemic understanding (Soini, 2001).

By allowing users to integrate multiple sets of geographic information in the generation of alternative scenarios for landscape change, generate realistic visualizations of change scenarios, and estimate impacts of alternative scenarios on multiple ecosystem services (Flaxman, 2010), geodesign holds the promise of facilitating adaptive design of multifunctional landscapes. This process allows designers – whether expert or lay, acting independently or in a collaborative mode – to engage in an iterative process of pursuing scenario proposition and disposition (Lyle, 1985) toward realization of alternative multifunctional landscapes. As is often noted with reference to Steinitz (2012), such a process is the hallmark of the design process. Geodesign technology holds the prospect of enabling a process of multifunctional landscape design in which evaluative feedback loops occur in real-time. This process allows the continual proposition and disposition of alternative scenarios. As a result, participants can iteratively explore the tradeoffs and synergies inherent in different design scenarios, and test the groups' assumptions about the effect of different land management approaches.

4. Collaborative Geodesign in Practice

This article explores the application and intentional integration of geodesign and collaboration for multifunctionality. The findings of this study come from the Seven Mile Creek Fuelshed Project located in southern Minnesota. The project is an effort to explore the prospects for the balanced production of biomass, food, water quality, and habitat values in a 23,551-acre (~9,531-hectare) watershed on the Minnesota River. The project engaged roughly 40 community members, including representatives of local, state, and federal agencies, extension and educational institutions, agricultural producer organizations, and environmental advocacy organizations. The group met over 10 months in eight half-day meetings focused on landscape-scale planning and design for the watershed. The landscape planning and design effort was intended to identify opportunities for expanded biomass production from multiple sources (e.g. corn stover, native prairie perennials, switchgrass) on a landscape currently dominated by highly productive corn and soybean row crop agriculture. The biomass was assumed to be a source for a future processing depot to be constructed in a prospective “fuelshed” that would produce pellets for use in renewable energy production or as feed for ruminants (Jordan et al., 2013). Consideration of biomass production opportunities was coupled with the exploration of environmental and economic priorities, as participants jointly planned for improvements to water quality, habitat protection and restoration, as well as biomass and food production.

The meetings were convened and facilitated by the authors and included presentations by the conveners and other experts, including those from the participant group. Small and large group discussions were integrated into each meeting, with substantial opportunities for interaction among participants. Table 1 summarizes the meeting schedule, goals, and activities. Four meetings focused on small-group landscape-scale planning and design exercises, supported

by a geodesign system. The geodesign system allowed participants to interact with information on a 55-inch all-in-one, multi-touch display equipped with Microsoft Windows 8 technology. Participants could view orientation layers as well as data layers pertaining to the watershed, controlling the presence and transparency of each layer. Orientation layers included information pertaining to the location of transportation and hydrographic features, Public Land Survey System section boundaries, land cover, hillshade topographic relief, and watershed boundaries. Data layers included information on restorable wetland soils, habitat quality, soil erosion and water quality contamination potential, and crop productivity. Figure 1 shows the geodesign display and participants interacting with the technology and each other.

INSERT TABLE 1

INSERT FIGURE 1

On the displays, participants could draw (with their fingers or a stylus) designs containing polygons relating to areas within the watershed to be converted from existing agricultural practices to best management practices for conservation tillage and low phosphorous management as well as biomass production practices related to removal of 60% of corn stover or planting of native prairie mixes or switchgrass. The geodesign system gave participants nearly instantaneous (i.e. 15 seconds) feedback on the performance of their designs based on information generated from the Soil Water Assessment Tool (SWAT) (Arnold et al., 1998) and InVest (Nelson, 2009). Performance data on the participant-generated designs included delivery of total suspended solids, total phosphorus, and total runoff to the mouth of Seven Mile Creek. The data also characterized the implications of a design for habitat quality, carbon

sequestration, and financial profitability. The geodesign tool also presented images portraying the visual appearance of the practices (e.g. corn stover removal, switchgrass buffers along waterways) included in each design. By providing real-time feedback of performance parameters, groups were able to create and evaluate multiple designs (at least one group had 16 iterations) within a relatively short period of time. The geodesign tool included capacity to compare across up to four designs simultaneously, allowing participants to examine tradeoffs as they worked toward an optimal design.

The development of the geodesign tool required hundreds of hours from multiple teams of researchers working on the front end user interface design, the backend servers, and the biophysical and economic modeling. Additionally, the research team invested considerable time to make the previously mentioned components function smoothly together utilizing “off-the-shelf” technologies. For more details on the most up-to-date iteration see <http://communityGeodesign.umn.edu>. Setting up the geodesign tool required transporting the five touchscreens and a central server to each workshop site where they communicated over a wireless local area network (LAN).

Table 2 offers further insight into the intentional design and facilitation of the workshop process and the critical interplay between the collaborative process and geodesign. The interplay was structured around three points of intersection between these two approaches (see Figure 2) outlined in the earlier literature review: 1) *information*, 2) *communication*, and 3) *process*, with the intention of setting the stage for the exploring the prospects for multifunctionality and producing multifunctional landscape plans and designs. The table reveals how collaboration and geodesign came together to allow participants to:

- identify and verify multiple data sources (*information*),

- communicate diverse perspectives and integrate multiple data sources, including their own expertise or local knowledge (*communication*); and
- interact in a manner that fosters learning, iterative exploration, and consensus (*process*).

The method and analysis presented in the next two sections explores the intersection of collaboration and geodesign and its implications for multifunctionality.

INSERT FIGURE 2

INSERT TABLE 2

5. Methods

To explore the intersection of collaboration and geodesign and its ability to produce multifunctional outcomes, a mixed quasi-experimental design was utilized. The analysis was designed to account for outcomes at the participant and community scale, as well as to assess the planning and design outcomes of the process. The primary means of data collection was a participant survey administered at the end of each meeting. The surveys consisted of 12 to 24 questions, with many of the questions consistently asked across each survey. The survey was intended to generate data consistent with a simple interrupted time series experimental design (Cook & Campbell, 1979). Other questions were asked only once at the end, following a post-test only quasi-experimental design (Cook & Campbell, 1979). The questions consisted of a mixture of Likert scale questions (i.e. strongly disagree, moderately disagree, unsure, moderately agree, strongly agree) and a limited number of open-ended responses. The surveys were designed to assess the *Information-Communication-Process* framework as it played out in the context of

the integrated collaboration and geodesign effort. The surveys also explored the perceived prospects for multifunctionality. Only responses from those participants who attended 4 or more meetings were included in the quantitative analysis ($n = 17$). Summary statistics for the quantitative data were calculated in the R Statistical Package (R Core Team, 2013). The surveys also included a limited number of open-ended responses, which were analyzed through coding in MaxQDA software (MAXQDA, 2014), utilizing a qualitative content analysis approach. Phrases and small sections of text were coded for primary content. Then, the codes were placed into categories of information, communication, process, and multifunctionality.

6. Findings

Following from the mixed method data analysis approach outlined above, the findings include outcomes relative to the *Information-Communication-Process* framework, and its intersection with perceptions of multifunctionality. Findings from the quantitative survey data are presented, along with the results of content analysis of narrative responses to open-ended questions to provide for deeper interpretation of collaborative geodesign outcomes.

6.1 Information

As indicated in Table 3, the results indicate that participants on average moderately to strongly agreed that they learned something or gained new information during the workshopmapping activities (mean of 4.11 out of 5), and largely trusted the information provided by the researchers/experts at the meetings (mean of 4.52 out of 5). One participant stated that a specific researcher “did a good job explaining” information and that “his questions helped to bring out views and observations.” This quote illustrates both the participants’

perceptions of the experts, which involved a high level of trust for the information they provided, and that the process engaged multiple sources and perspectives in the search for information. Participants also maintained a high level of trust in the information provided by other participants, represented by a mean of 4.32 out of 5. In tandem with the information shared among participants, geodesign provided a technological platform for groups to explore and utilize multiple data sources at multiple scales. Participants, in open-ended responses, agreed that geodesign informed planning and design through the “information and immediate feedback provided by the mapping tool.” Specifically, it “allowed [them] to make decisions based on data rather than more theoretical knowledge.” One point of contrast was meeting 8, where participants were unsure or moderately disagreed that they learned something or gained new information (mean of 2.38 out of 5). It is difficult to interpret whether this result is associated with technical difficulties associated with the geodesign tool at this meeting, whether it is associated with meeting 8 being the last in the process, or another reason.

INSERT TABLE 3

Open-ended responses offer further insight into the joint search for information and the scales of that information. Participants suggested that they wanted a stronger connection to the farm-field scale, allowing them to explore implications at the smaller scale at which planning and design decisions are more commonly made. Participants expressed an interest in designing at that scale and expressed the desire for more farmers to be included in the meetings. One participant stated that the process included a “good mix” of people, but “still need[ed] to have a production farmer at each table.” This quote implies that by including more production farmers

at each table, the farmer perspective would be heard in every small group. Taken in combination with the desire to design at a finer spatial resolution, it appears that participants wanted to engage with the possibilities of biomass production at the scale of decision-making with the people who are engaged in making management decisions.

6.2 Communication

In regard to communication within the process, participants moderately to strongly agreed that they learned or gained new information during the small group discussions (mean of 4.42 out of 5), indicating that collaboration fostered communication among participants, which facilitated that sharing of information and learning (Table 3). The qualitative data further illuminate this point. Participants felt that “the sharing of information between participants was valuable.” High levels of trust may be one reason for the effective communication. Participants moderately to strongly agreed that they trusted the information provided by other participants (mean of 4.32 out of 5) (Table 3). One participant stated that one of things he/she learned by sharing information was that “most participants have similar goals.” In contrast though, participants had some uncertainty as to whether or not their perceptions of the prospects for biomass development in the Seven Mile Creek watershed were similar to other participants (mean of 3.54 out of 5) (Table 3). Qualitatively, participants felt that “some people [didn’t] shift their views much at all.” Even with a level of uncertainty or continuity relative to other participants’ perspectives, the relatively high level of trust in information provided by other participants supported learning and the collaborative science outcomes predicted in the literature. Participants believed the geodesign technology effectively supported groups as they worked to communicate and integrate information from multiple sources. One participant said the

technology “definitely engaged group members and fostered conversation that helped build understanding....” As a result of communication within the process, one point of learning that participants stated they would apply in their work after the meetings was “whole systems thinking.”

6.3 Process

Overall, the process proved “very effective in educating and putting new info[rmation] to use,” with the participants moderately to strongly agreeing that the workshop process was an effective forum for exchanging information and perspectives about biomass development (mean of 4.53 out of 5) (Table 3). When taken together with the above findings on information and communication, this result indicates that the process as a whole was perceived as effective, and that the joint search for information through communication aided by geodesign technology enabled the group to experience the predicted outcome of social learning. This outcome occurred not only because of the ability to integrate multiple data sources, but also because of the diversity of the participants, which is illustrated by the quotes above. As reflected in participants’ desire to include more production farmers in the small group discussion, participants felt early on in the workshops that there “need(s) to be better integration between agencies, NGOs, academia, community members and farmers.” This statement reflects a general pursuit of diverse types of knowledge, and at the same time, participants felt a major strength of the process was the group diversity.

Additionally, while the process and collaborative geodesign as a whole were effective, due to technical issues with the geodesign tool, participants felt that the technology “had its problems.” In meetings 7 and 8, the geodesign technology encountered errors that held up the

design process in those meetings. These technical issues likely impacted participants' ability to engage in a joint search for information from the multiple data layers of the geodesign technology. Even so, when the technology was working, it accomplished the goal of providing "immediate feedback" and enhanced social learning. A review of the mean scores for meetings 5 and 6 provides an indication of the overall positive outcomes that were achieved in association with the geodesign tool. During these two meetings, the geodesign tool was used by participants and worked flawlessly, and the mean scores for nearly all of the questions are among the highest from across the eight meetings. Finally, as indicated in the trends in decreasing standard deviations surrounding participants' perceptions of the prospects of biomass production discussed below, it appears that the process enhanced consensus. Though without a rigorous statistical analysis that could be conducted if the number of participants was larger, this result needs to be interpreted carefully.

As participants worked through the collaborative geodesign process and meeting activities, they stated that they were unsure or moderately agreed on average that their perceptions of the prospects for biomass development were similar to those of other participants (mean of 3.54 out of 5). This uncertainty may explain why participants felt that the group diversity provided a point of learning as indicated in the above quotes. In their work, participants stated they intend to apply "collaborative decision making," in a manner that ensures "people of diverse perspectives are present in the decisions that will impact them." In summary, there is evidence that geodesign and collaboration supported social learning and consensus building.

6.4 Multifunctionality

The results provide some indication that the participants came to new realizations about the potential for landscape multifunctionality through biomass production. Participants were unsure or moderately agreed on average that their perceptions of the prospects for biomass development changed as a result of meeting activities (mean of 3.49 out of 5) (Table 3). While the results should be cautiously interpreted due to small sample sizes, it is worth noting that the highest mean responses of 3.79 and 3.92 and the smallest standard deviations of 0.70 and 0.64 occurred at the meetings 5 and 6, where the geodesign tool was first used. Additionally, for this question, the data show a trend from meeting 1 through meeting 6. The average response increased toward moderately agree in regard to the prospects for biomass development, and the standard deviation decreased, which indicates greater consensus among participants over time. We cannot determine the full significance of these results due to limitations in statistical analysis capability due to small sample sizes and somewhat inconsistent participation, but the results are worth noting. As an additional point of caution, the trend does not continue or plateau through meetings 7 and 8, but reverses direction. Technology, small sample sizes, and changing participants may be possible explanations. The qualitative data revealed that participants had the significant realization that “it’s possible to increase profit, habitat, and water quality simultaneously,” which is consistent with an upward trend in participants changing their perceptions of the prospects for biomass development. Therefore, the results provide an indication that participants learned, and changed in their perceptions surrounding the potential for landscape multifunctionality through biomass production.

7. Discussion

The findings presented above offer important preliminary evidence of the outcomes of collaborative geodesign. These findings are presented in the context of the *Information-Communication-Process* framework, which represents the very intentional structure for integrating collaboration and geodesign in the Seven Mile Creek Fuelshed Project. Organizing the analysis under this framework allows for parsing out the particular contributions of the various collaborative and geodesign activities integrated into the overall workshop process. At the same time, the integrated whole of the collaborative geodesign approach can be assessed relative to impacts on participants' perceptions of multifunctionality.

As noted above, the prospects for statistical analysis of the data available from this application of collaborative geodesign are limited. The number of participants was relatively small and the participation of individuals varied somewhat across meetings, thus pre-post statistical tests and other quantitative assessments of changes in perceptions across meetings cannot be easily applied. That said, the methodological and data collection structures of this study could be informative and potentially replicated in future studies of processes that involve larger community groups or perhaps multiple community groups working in different contexts. Key in conducting a more sophisticated statistical analysis is the availability of survey data from a larger number of participants, preferably with consistent participation over time. It is important to couple such analyses with data that can be qualitatively assessed, such as open-ended responses from surveys, meeting transcriptions, and notes from small and large group discussions.

Beyond these limitations and recommendations for future study, it is important to note the significance of this research. As geodesign continues to evolve and become more visible, it

is essential to generate empirical studies that document its impacts. Studies such as this, which place geodesign within the context of existing theory and practice are especially useful in positioning the potential contributions and prospects of the approach. Geodesign can be easily integrated with decision-making processes to produce better outcomes, which benefit the environment and communities. Geodesign is particularly well-suited to make important contributions to collaborative and participatory planning and design. It provides a platform for interaction and has the potential to enhance the well-recognized outcomes of deeper, more deliberative engagement. Such deeper, deliberative engagement appears to create trust through communication, and that trust extended between participants, experts, and the information from the geodesign technology. The results correspond to Harvey's (2003) points that "a user's trust is perhaps most closely related to their knowledge and understanding of the technology" (p. 30), and that trust is built in a complex web of social and technological interaction. By engaging participants deeply in a collaborative process that considered the underlying assumptions of the technology, participants not only trusted the information from the technology more, but also the information coming from other participants and experts. In addition, geodesign offers significant prospects for enhancing consideration of multifunctionality. The technical capabilities of geodesign systems allow for simultaneous exploration and integration of multiple information sources, as well as the examination of tradeoffs through planning and design scenarios. In addition, the interactive nature of geodesign systems further allows for adaptive design among lay and expert participants, that can produce landscape diversity and ecosystem services.

Finally, we hypothesize that an additional value of collaborative geodesign is a capacity to facilitate such adaptive design among multi-perspective groups as they address wicked problems (Bouma et al. 2011; Rittel and Webber, 1973) related to multifunctional landscapes.

Such problems involve highly-valuable resources, and different community groups often have strongly divergent perspectives on the nature of the problem situation and feasible options for addressing it. Consequently, progress toward collaborative and participatory planning and design is notoriously difficult. In the case of interested individuals and groups concerned with multifunctional landscapes, a crucial question is whether such landscapes have potential to produce a set of goods and services that is broadly beneficial, such that the group is willing to cooperate to realize this potential (Jordan et al., 2011). Evidence shows that answering this crucial question is time consuming and contentious, particularly when participants differ in their worldviews, values, and ethics, and the situation is marked by complexity, contingency, and the need to balance multiple interests (Bouma et al., 2011).

In these situations, we propose that collaborative geodesign has potential to significantly help interest groups as they explore the possibilities for mutual gain from multifunctional land use, increasing the likelihood that such a possibility will be recognized and decreasing the duration and cost of such explorations. We suggest that this effect results from the interplay of information, communication, and process dimensions of collaborative geodesign, including the opportunity to rapidly visualize and apprehend the complex effects of landscape change, including trade-offs among various ecosystem goods and services. Further critical is the ability to engage in these activities in a group, wherein repeated dialogue about their shared and separate interests in a landscape intersect and tradeoff. Our evaluation data are insufficient to fully test these conjectures, but our data provides valuable supportive evidence. Specifically, we observed that our participants increased their belief in the potential value of creating multifunctional “biomass landscapes,” and we found indications of trust and mutual learning in small-group dialogue sessions, stimulated by design activities. In this case, we were able to

measure the value of collaborative geodesign in developing multifunctional landscapes that support the sustainability intensification of agriculture – i.e., production of more food, feed, bioproducts and bioenergy, while also improving conservation of critical resources of soil, water and biodiversity (Garnett et al., 2013). If we are correct and these outcomes can be similarly revealed via collaborative geodesign in other contexts, the prospects for achieving broader multifunctionality are significantly enhanced.

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Table 1. Summary of Workshop Process Meeting Goals and Activities

Table 2. Designing and Facilitating the Integration of Collaboration and Geodesign

Table 3. Participant Responses to Survey and Interview Questions

Table 1. Summary of Workshop Process Meeting Goals and Activities

	Meeting 1	Meeting 2	Meeting 3	Meeting 4	Geodesign			
					Meeting 5	Meeting 6	Meeting 7	Meeting 8
<u>Meeting Goals</u>	Introduce participants to the research team, each, the SMC watershed & surrounding region, & the concept of multifunctionality	Provide deeper consideration of biomass production, multifunctionality, & technology feasibility	Consider win-win possibilities for biomass production & ecological service delivery	Identify landscape priorities and develop "rules of thumb" to guide Geodesign sessions that may accomplish win-win scenarios	Introduce participants to Geodesign technology & empower participants to integrate thoughts on biomass and crop production placement	Provide small groups the opportunity to collaboratively & iteratively design with landscape performance feedback	Design using "rules of thumb" at the watershed scale and reflect on the overall meeting process	Design using "rules of thumb" at the watershed scale and reflect as a group on the overall prospects for biomass production and conservation
<u>Major Activities</u>	Overview expert presentation of process	Overview expert presentations on food, fiber, fuel production; biomass processing technology	Expert presentation on assessing ecological quality & environmental stress; habitat & biomass prod.	Discussion of participant priorities for production and ecological services	Technology overview and design practice with Draw Tool	Small group implementation of "rules of thumb"; what practice where?	Group reflection on ecological services and production values	Small group watershed design using Design Tool (technology difficulties)
	Introductions	Discussion of biomass crop options	Discussion of participant priorities for ecological services & production	Discussion developing "rules of thumb" for food, biomass, water quality, and habitat	Small group regional landscape design with Draw Tool	sub-watershed scale designs with "rules of thumb" & Design Tool	Small group watershed design using Design Tool (technology difficulties)	Group reflection on design process
	Watershed Tour							
	Small group discussion on landscape characteristics & biomass prod.		Discussion of potential win-win scenarios	Breakout group discussion of consensus "rules of thumb"	Group reflection on design process	Small group presentations of designs	Large group reflection on the meeting process	Discussion of future supply-chain design meetings

Table 2: Designing and facilitating the integration of collaboration and geodesign

Points of intersection between collaboration and geodesign	Collaboration approach	Geodesign approach
<i>Information</i>	Collaboration engages participants in the joint search for information from multiple sources	Geodesign provides a platform for groups to explore, utilize, and visualize multiple data sources to inform planning and design
<i>Communication</i>	Collaboration fosters communication among participants, producing shared information and collaborative science	Geodesign supports participants as they communicate, integrate, and visualize information, from multiple data sources including their own local knowledge
<i>Process</i>	Collaboration supports interaction among participants to produce social learning	Geodesign enhances social learning and consensus through multi-user interactive and iterative visual exploration

Table 3. Participant Responses to Survey and Interview Questions

Question	Theme	Geodesign									Quotes
		Mtg 1	Mtg 2	Mtg 3	Mtg 4	Mtg 5	Mtg 6	Mtg 7	Mtg 8	All Mtg	
		mean	mean	mean	mean	mean	mean	mean	mean	mean	
		sd	sd	sd	sd	sd	sd	sd	sd	sd	
I learned something or gained new information during today's mapping activity.	Communication	-	-	-	-	4.93	4.69	3.67	2.38	4.11	"The touch screens definitely engaged group members and fostered conversation that helped build understanding..."
		-	-	-	-	0.27	0.48	1.15	1.19	1.22	"Technology is wonderful but has its problems."
I learned something or gained new information during today's small group discussions.	Information	-	-	-	-	4.64	4.54	4.08	4.33	4.42	"I think the sharing of information between participants was very valuable."
		-	-	-	-	0.50	0.52	0.67	0.87	1.22	"Need better integration in discussions between agencies, NGOs, academia, community members and farmers."
I trust the information provided by researchers/experts at today's meeting.	Information	4.36	4.42	4.58	4.60	4.50	4.58	4.33	4.89	4.52	"The presentations about the AFEX process. [Researcher] did a good job explaining and his questions helped to bring out views and observations."
		0.93	0.67	0.51	0.52	0.76	0.81	0.98	0.33	0.73	
I trust the information provided by other stakeholders/participants at today's meeting.	Communication	4.14	4.00	4.42	4.50	4.36	4.58	4.25	4.33	4.32	"The information and immediate feedback provided by the mapping tool allowed us to make decisions based on data rather than more theoretical knowledge."
		0.66	0.95	1.00	0.71	0.84	0.57	1.06	1.12	0.86	
My perceptions of the prospects for biomass development in the Seven Mile Creek watershed area changed as a result of something I heard at today's meeting.	Multifunctionality	3.36	3.42	3.45	3.50	3.79	3.92	3.17	3.22	3.49	"Some people don't shift their views much at all."
		1.01	0.90	0.82	0.85	0.70	0.64	0.83	0.83	0.84	"It's possible to increase profit, habitat, and water quality simultaneously."
My perceptions of the prospects for biomass development in the Seven Mile Creek watershed area are similar to those of other participants.	Process	3.07	3.42	3.67	3.60	3.57	3.92	3.42	3.78	3.54	Process's impact on participant work: "Collaborative decision making and ensuring people of diverse perspectives are present in the decisions that will impact them."
		0.73	1.00	0.49	1.07	1.09	0.64	0.79	0.83	0.86	
Thus far, the stakeholder process has been an effective forum for exchanging information and perspectives about biomass development in the Seven Mile Creek watershed area.	Process	4.25	4.25	4.83	4.65	4.64	4.85	4.33	4.44	4.53	"Good mix [of people] at each table - still need to have a production farmer at each table."
		1.05	0.62	0.39	0.58	0.63	0.38	0.65	0.53	0.67	"The overall process was very effective in educating and putting new info to use."

Note: Responses to questions were organized on a 5-point Likert scale, with 5 = strongly agree, 4 = agree, 3= uncertain, 2 = disagree, 1 = strongly disagree

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Figure 1. Workshop Process Participants interacting with Geodesign Technology

Figure 2. Linking Information, Communication, and Process to Advance Multifunctional Landscapes

Multifunctionality

Information

Communication

Process