Constructing a Sustainable Agroecological Landscape Through Place-Making: The Preliminary Case Study of the Red Cedar Learning Hub

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Defining the Problem

The Red Cedar Learning Hub was established to address a broad set of challenges related to water quality in lakes, impoundments, rivers, rural communities, social-cultural-economic health, and agricultural systems, which are driving the aforementioned issues. To mitigate these impacts, there have been numerous efforts to conduct outreach and distribute financial incentives for the adoption of practices. These efforts have led to some success, but the scale of agricultural transition needed to meaningfully address the myriad of concerns communities in the Red Cedar face are still forthcoming. At this juncture, our Red Cedar Learning Hub is nascent and still needs to undergo the community-engaged process of Collaborative Landscape Design (CLD). This manuscript has been developed to provide a starting point for people to engage with the Red Cedar Learning Hub and begin the necessary processes of gathering a vision and action plan for the future.

Based on an early and incomplete understanding, we feel that our Red Cedar Community faces six primary socio-ecological-economic challenges related to current agriculture systems. To improve the situation, we feel it vitally important that our solutions seek to address all of these challenges concurrently rather than take a unidimensional approach.

1. *Aging farmer population/changing ag landscape*. Based on the most recent agricultural census of Dunn County, there were 2,192 producers. 189 (roughly 9%) of those producers were under the age of 35. Meanwhile, 687 (roughly 31%) of the producers are over the age of 65 (United States Department of Agriculture, 2017). In the coming decade, there will likely be a sizeable farmland transition. How that transition occurs will have massive social and ecological implications. The configuration of farmland could impact things such as the number of school-aged children and the viability of rural school districts. Fewer individual farmers could mean fewer well-paying jobs that support people visiting the restaurants, bars, and entertainment venues on our main streets (Goldschmidt, 1978; Lobao & Meyer, 2001). There have also been connections between large farms that have concentrated animal feeding with negative environmental impacts on water quality, biodiversity, and climate resilience (Landis, 2017; Raff & Meyer, 2022). Based on current market forces, it seems likely that this transition will lead to increased amounts of farm consolidation and limited entry points for young and beginning farmers. To bring in the next generation of farms will require intentional community involvement to develop vibrant communities and liveable farm income. The tables below summarize the shifting landscape of agriculture in the Red Cedar communities.

Change in farm
characteristics over the years- Dunn County

	Farms	Farmland	Average farm Size	Median Farm Size
1987	1,515	400,589 Acres	264 Acres	N/a
1992	1,383	366,593 Acres	265 Acres	N/a
1997	1,397	368,618 Acres	264 Acres	163 Acres
2002	1,683	398,768 Acres	237 Acres	154 Acres
2007	1,690	382,545 Acres	226 Acres	105 Acres
2012	1,404	372,259 Acres	265 Acres	122 Acres
2017	1,288	348,301 Acres	270 Acres	106 Acres

Dunn County Farm Size Distribution

	1 to 9 Acre Farms	10 to 49 acre farms	50 to 179 Acres	180 to 499 acres	500 to 999 Acres	1,000 or more acres
1987	52	137	449	713	127	37
1992	43	147	435	585	139	34
1997	31	169	525	514	118	40
2002	48	317	680	473	108	57
2007	64	391	673	397	110	55
2012	50	287	579	320	97	71
2017	70	305	458	292	100	63

Dunn County Livestock Distribution

	Beef cows		Milk Cows		Hogs and Pigs	
	farms	number	farms	number	farms	number
1987	241	3,511	868	40,174	158	20,768
1992	280	4,298	669	33,077	134	21,031
1997	314	5,754	478	26,511	69	15,487
2002	357	5,208	323	23,189	48	10,595
2007	397	6,169	252	23,143	49	9,684
2012	356	5,776	199	21,222	28	2,795
2017	349	6,466	129	18,768	38	4,572

Dunn County Cropping Distribution

	Corn		Soybeans		Forage-land used for all hay and all haylage, grass silage, and green chop	
	farms	acres	farms	acres	farms	acres
1987	1165	70,733	193	8,856	1,278	112,710
1992	855	62,644	259	14,632	1,076	91,431
1997	742	73,054	247	19,760	926	79,605
2002	609	71,782	323	37,265	859	39,809
2007	538	82,841	271	39,982	881	58,448
2012	579	104,508	375	54,992	712	46,554
2017	494	83,439	386	66,461	652	42,964

2. *Unfair agricultural markets.* It has been widely documented that farmers are competitively disadvantaged in the marketplace due to oligopolies and weak anti-trust enforcement in the agricultural sector (Ashwood, Canfield, et al., 2022; Ashwood, Pilny, et al., 2022; Hendrickson et al., 2017; Hendrickson & James Jr., 2005). This type of market control can significantly reduce farmers' autonomy to make conservation or community-minded decisions they might otherwise desire to make (Archer et al., 2008; Hendrickson & James Jr., 2005; Stuart & Houser, 2018). In application, farmers likely have the communities' best interests in mind because it often aligns with their personal long-term interests. Still, they might make a decision incongruent with that need since they have their decision-making boxed in by market forces. From a farmer's perspective, taking care of water, biodiversity, soil health, and community well-being are all in their personal interest. These unfair market dynamics due to relaxed anti-trust enforcement could, in part, explain the disconnect between what is in the farmer's and community's best interests and what actually occurs on the ground (Stuart & Houser, 2018)
3. *Social norms are unnecessarily restrictive.* In the popular press, academic literature, and everyday language, we often define certain types of agriculture as conventional (Sumberg & Giller, 2022). This term is often poorly defined and unnecessarily reinforces the status quo. These processes of defining agriculture can create an image of what it means to be a good farmer and shape what is seen to be an acceptable set of agricultural practices (Burton, 2004; Dentzman & Goldberger, 2020; Strauser & Stewart, 2023). To meet community goals, a shift in agricultural practices is likely necessary. Therefore, terminology and actions that create and perpetuate a social climate that unnecessarily restricts the potential solution space are not helpful to the long-term success of the Red Cedar Learning Hub.
4. *Sharply declining biodiversity.* Diversified agricultural operations are vanishing from the Upper Midwest. As there has been a trend toward a simplified agricultural landscape, there has been a dramatic decline in biodiversity. Notably, there has been a dramatic decline in grassland bird species, primarily attributed to simplifying North American agricultural landscapes (Stanton et al., 2018). Additionally, there have been dramatic declines in insect and pollinator populations (Hemberger et al., 2021; Raven & Wagner, 2021). Such a trend is concerning because sustaining biodiversity is essential to ecosystem function. In an applied sense, having a functioning ecosystem is essential to agricultural success and community vitality (Landis, 2017). If we continue to undermine biodiversity, we are, in part, undercutting the long-term success of our agricultural systems.
5. *Soil degradation.* Much like biodiversity, simplifying our agricultural system has had immense negative effects on soil health (Quarrier et al., 2023; Thaler et al., 2021, 2022). The degradation of our soils not only greatly reduces our ability to produce agricultural products but also reduces our ability to mitigate climate change. We need agricultural practices that build up soil carbon, not simply reduce the loss rate of soil carbon (Becker

et al., 2022; Rui et al., 2022; Sanford et al., 2012, 2022). If we are to ensure the long-term viability of agriculture in the Red Cedar Learning Hub, we feel strongly that it is necessary to have agricultural practices that ***build*** soil carbon.

6. *Diminished water quality (both surface and groundwater).* Throughout Wisconsin, a widely documented problem has been regarding the steady decline in surface and groundwater quality. This type of contamination has immense health, economic, and recreational impacts. Nitrogen pollution can contaminate drinking water and lead to adverse health impacts. In 2020, Mathewson and colleagues estimated that in Wisconsin alone, nitrate pollution in drinking wells had a healthcare cost of around $23-$80 million annually (Mathewson et al., 2020). For surface waters, phosphorus pollution can leave economically and recreationally valuable lakes a wash in toxic algae blooms. To meet the water quality goals for Tainter and Menomin Lakes, dramatic adoption of conservation farming practices will be needed. In a 2013 report, it was estimated that 66% of the phosphorus loading came from cropland runoff. The most recent reports put forth by Bill James of UW-Stout suggest that 250,000 pounds of excess phosphorous still reach Tainter Lake annually. It is essential to remember that since Lake Menomin is downstream of Tainter Lake, dramatic reductions in Tainter Lake would translate into improved water quality for Lake Menomin. If we are to meet these phosphorus reductions, dramatic transformations in agricultural land management will need to occur.

It is important to remember that the challenges facing the Red Cedar Learning Hub are not unique to just the Red Cedar community. These six challenges we highlight are an issue for communities throughout Wisconsin and beyond. It is also important to note that these challenges are created at a societal rather than an individual level. Recognizing this is important for two reasons: 1. It means that solving these problems will require a collective effort that is focused on societal rather than individual transformations, and 2) that while some may read this and feel that they are personally being attacked or feel defensive about their current actions, these challenges are created and reinforced by systemic factors and should be viewed as such. In simplistic terms, we feel the primary goal of the Red Cedar Learning Hub is to address these challenges concurrently through coordinated collective action that seeks to envision and work toward a shared future.

Potential solutions and outcomes

A starting point for attaining a shared vision for the future is to weigh out the pros and cons of certain trajectories for change. Rather than focusing on practices, we want to focus on outcomes. All too often, conservation-minded groups jump headlong into implementing practices such as cover crops, no-till, buffer strips, or well-managed rotational grazing without critically analyzing how these individual practices might allow communities to realize a set of shared goals for the future. At this juncture, we want to employ SmartScape™, a web-based decision support tool, to examine a handful of land use scenarios and consider their impact on what we identified as six challenges facing the Red Cedar Learning Hub community (Please note future community dialogue should and will actively explore the challenges and opportunities that community members see for the future). SmartScape™ is a publicly available modeling tool developed at the University of Wisconsin-Madison (training video); we would encourage people to use the tool to develop future scenarios and engage in community conversations. We also emphasize that SmartScape™ is a model, so while it provides us with helpful projections around various land use configurations, it should not be seen as exact results. We propose challenges and potential solutions here not to be prescriptive but to seed a conversation about what the Red Cedar community desires for the future. It is our plan to engage the Red Cedar community to allow them to operationalize the challenges they see facing them and how various solutions might step up to address those needs. In the scenarios proposed, we have focused on the sub-watersheds of Pine and Hay Creek. We focused on these subwatersheds because they currently have an outsized impact on the amount phosphorus in the Red Cedar river system. We again want to emphasize that the scenarios developed in this manuscript are intended to seed a larger community conversation about what is desired for the future and the magnitude of the solutions needed to attain that desired future state.

Scenario 1: Current Trend in Cover Crops and No-Till

In scenario one, we want to consider the impact of the current adoption of cover crops and no-till. In Dunn County, WI, 31% of the crop acres (75,600 acres) are in no-till, and 12% (30,287 acres) are in cover crops. In this modeling scenario, we made an assumption that 31% of the crop acres would adopt both the practices of cover crops and no-till; this scenario is slightly better than what is currently realized.

SmartScape™ Run: 31% of the continuous corn, cash grain, and dairy rotations into cover crops and no-till.

Total Watershed Area: 69,503 acres

Total Area Transformed 7,808 (11.23%)

Variable	Base	Transformation	Relative change	Base-W	Transformation-W	Relative Change-W
Erosion (tons/ac)	2.29	1.72	-25%	0.86	0.66	-23%
Soil Conditioning Index	0.45	0.53	18%	1.74	1.77	2%
Phosphorus loss (lb/ac/yr)	2.67	1.98	-26%	1.09	0.84	-23%

P delivery to water (lb/ac/yr)	2.16	1.6	-26%	0.88	0.68	-23%
Total N loss to water (lb/ac/yr)	25.92	23.91	-8%	10.43	9.71	-7%
Runoff from 3-inch storm (in)	1.28	1.21	-5%	0.88	0.86	-2%
Honey Bee toxicity index	0.28	0.28	0%	0.11	0.11	0%
Bird friendliness index	0.25	0.25	0%	0.2	0.2	0%

1. *Aging farmer population/changing ag landscape*- Implementing cover crops and no-till farming practices are likely to increase the cost of farm operations and do little, if anything, to change the social or economic condition of agriculture or the communities in which they are applied. It seems unlikely that this type of agricultural transition would create an appeal or opportunity for new or beginning farmers. Another likely scenario is that taxpayers shoulder the economic burden of implementing these practices while doing little to fundamentally change the agricultural systems in a way that makes employing these practices self-sufficient, irrespective of government subsidies.
2. *Unfair agricultural markets*- Under this transformation, farmers would likely maintain their current participation in agricultural markets on both the input and output side. There is little reason to expect that such a shift would meaningfully improve the unfair market conditions currently experienced by agricultural producers. It is also unlikely that farmers would be able to command any type of premium pricing for implementing these practices.
3. *Social norms are unnecessarily restrictive*- Over the years, cover crops and no-till have gained acceptance. Across the state of Wisconsin, these practices are increasingly being adopted. In addition to that, there is research occurring at universities such as UW-Madison that seeks to better understand the effectiveness and implementation of cover crops and no-till. Implementing such practices is widely supported by technical service providers in NRCS, UW-Extension, and county conservation staff. While there are historical accounts of farmers being stigmatized for adopting cover crops and no-till as practices, we anticipate that the harshest of these stigmas are a thing of the past.

4. *Sharply declining biodiversity*- One can see the adoption of cover crops, and no-till is expected to have little, if any, positive impact on biodiversity. Honey bee toxicity is increased, and there is no positive impact on the bird friendliness indicator. Such a finding is also supported by studies conducted by VanBeek and colleagues that found implementation of cover crops had little positive effect on nesting habitat for grassland birds (VanBeek et al., 2014).
5. *Soil degradation*- Cover Crops and no-till do reduce soil erosion and improve soil conditioning indexes. These are positive signs that we would expect to see from these types of practices. While these improvements are trending in the right direction, there does seem to be room for further advances across these metrics.
6. *Diminished water quality* - Cover crops and no-till are estimated to reduce phosphorus runoff by roughly 23%. While these results are promising, we anticipate that the improvement regarding nitrogen runoff will be a meager 7%. While these reductions are a trend in the right direction, it would seem unlikely that such shifts would be enough to meaningfully reduce the instances of toxic algae blooms in the reservoirs of the Red Cedar or eliminate worry regarding unsafe levels of nitrogen in drinking water.

Summary: The landscape transition proposed in this model run would undoubtedly have a positive impact, but community members would likely feel that there is still room for improvement before they realize their desired outcomes. It is also notable that while some metrics benefit from this landscape configurations it is also reasonable to expect that other metrics will see little, if any, improvement.

Scenario 2: All Out BMPS

Scenario 1 shows signs of improvement but leaves a desire for more. A logical question becomes, what if we implemented cover crops and no-till on all of the crop acres?

SmartScape™ Run: Adoption of cover crops and no-till was 100% on all the crop acres (continuous corn, cash grain, and dairy rotations).

Total Watershed Area: 69,503 acres

Total Area Transformed 25,187 (36.24)

	Selected Area			Watershed		
Variable	**Base**	**Transformation**	**Relative change**	**Base-W**	**Transformation-W**	**Relative Change-W**
Erosion (tons/ac)	2.29	0.46	-80%	0.86	0.2	-77%
Soil Conditioning Index	0.45	0.71	58%	1.74	1.83	5%

Phosphorus loss (lb/ac/yr)	2.67	0.44	-84%	1.09	0.28	-74%
P delivery to water (lb/ac/yr)	2.16	0.36	-83%	0.88	0.23	-74%
Total N loss to water (lb/ac/yr)	25.92	19.44	-25%	10.43	8.09	-22%
Runoff from 3 inch storm (in)	1.28	1.04	-19%	0.88	0.8	-9%
Honey Bee toxicity index	0.28	0.28	0%	0.11	0.11	0%
Bird friendliness index	0.25	0.25	0%	0.2	0.2	0%

1. *Aging farmer population/changing ag landscape*- Similar to before, implementing cover crops and no-till farming practices are likely to increase the cost of farm operations and do little, if anything, to change the social or economic condition of agriculture or the communities in which they are applied. It seems unlikely that this type of agricultural transition would create an appeal or opportunity for new or beginning farmers. Another likely scenario is that taxpayers shoulder the economic burden of implementing these practices while doing little to fundamentally change the agricultural systems in a way that makes employing these practices self-sufficient, irrespective of government subsidies.
2. *Unfair agricultural markets*- Likewise, under this transformation, farmers would likely maintain their current participation in the agricultural markets. There is little reason to expect that such a shift would meaningfully improve the unfair market conditions currently experienced by producers.
3. *Social norms are unnecessarily restrictive*- The story continues from scenario 1. Societal norms are increasingly accepting of the implementation of cover crops and no-till. With that, farmers who seek to adopt such practices should be able to get the social, technical, and economic support they need to implement such practices.
4. *Sharply declining biodiversity*- Despite increasing the acres committed to cover crops and no-till, there is little reason to believe that the adoption of these practices will significantly improve biodiversity outcomes. Notably, these conservation strategies often depend on the application of herbicides and still perpetuate a monoculture cropping system. Both of these elements are not helpful for improving biodiversity outcomes.
5. *Soil degradation*- Cover crops and no-till do reduce soil erosion and improve soil conditioning indexes. These are positive signs that we would expect to see. When

implemented at a landscape scale, these benefits have a noticeable effect in these dimensions.

6. *Diminished water quality* - If cover crops and no-till are implemented across the landscape, we observe a noticeable improvement in non-point source nutrient runoff from scenario 1. We estimate that phosphorus runoff would be reduced by 74% and nitrogen runoff would be reduced by 22%. Such outcomes would be positive, and it seems likely that society would observe noticeable improvements in water quality.

Summary: Logically, if we ramp up the adoption of cover crops to all of the row crop acres, we see meaningful improvements when it comes to non-point source nutrient pollution and reducing soil erosion. However, it seems unrealistic that cover crops and no-till will ever meaningfully provide a pathway for new and beginning farmers, address the impacts of unfair agricultural markets, or make meaningful progress to staving off sizeable declines in biodiversity. Creating a reasonable question pertaining to what types of landscape configurations would allow us to address these objectives?

Scenario 3: Targeted Conversion of Grassland Acres

In this scenario, we want to move away from the cover crop and no-till path to consider alternative agricultural configurations. The objective is to explore how a fundamental paradigm shift might work to address all six dimensions of interest. In this scenario, the model projects if the continuous corn, cash grain, and dairy rotation acres that are within ½ mile of a stream (2640 feet) were converted to well-managed grazing operations. Please note that Scenario 3 would impact 15,004 fewer acres than what is called for in Scenario 2.

Total work area = 69,503 Acres

Acres transformed = 10,183 Acres (15% work area)

		Selected Area			Watershed	
Variable	**Base**	**Transformation**	**Relative change**	**Base-W**	**Transformation-W**	**Relative Change-W**
Erosion (tons/ac)	1.62	0.1	-94%	0.86	0.63	-27%
Soil Conditioning Index	0.5	1.84	268%	1.74	1.93	11%
Phosphorus loss (lb/ac/yr)	1.97	0.15	92%	1.09	0.82	-25%

P delivery to water (lb/ac/yr)	1.78	0.14	-92%	0.88	0.64	-27%
Total N loss to water (lb/ac/yr)	29.28	7.55	-74%	10.43	7.25	-30%
Runoff from 3 inch storm (in)	1.16	0.43	-63%	0.88	0.78	-11%
Honey Bee toxicity index	0.3	0	-100%	0.11	0.06	-45%
Bird friendliness index	0.23	0.56	143%	0.2	0.28	40%

1. Aging farmer population/changing ag landscape- Well-managed rotational grazing has a low input cost compared to row crop agriculture. This could create greater opportunities for a new and diverse set of farmers to enter the market. However, we need to caution that grass-based agriculture still has numerous hurdles to entry. Beginning farmers would need to learn the technical skills of farming in this manner; compounding that problem, there can be limited technical support for well-managed grazing and the development of grazing plans.
2. Unfair agricultural markets- For well-managed grazing to be successful for individual producers, it will be necessary to develop markets for such products. The good news is that developing new markets presents an opportunity for farmers to participate in a competitive market place that rewards producers for their labor and a superior product. The bad news is that the development of such a market is complex and, at this juncture, extremely nascent. For some, direct marketing products have been seen as a way to gain a premium price for a superior product. While such an approach is logical and encouraged, it is not pragmatic to think 10,000 acres of grass-based agriculture could be supported exclusively through direct marketing outlets. The takeaway is that such an agricultural transition would demand market development, which presents a significant hurdle but also an opportunity.
3. Social norms are unnecessarily restrictive- Well-managed grazing is often dismissed by society as an outdated or unproductive agricultural system. The practice of well-managed grazing is often framed as something you would implement on marginal agricultural land but would not be considered suitable for prime agricultural land. With that, the amount of research, technical, and market support for the practice is limited compared to those for row crop

agriculture. Moreover, it is likely that farmers would face social sanctions from their neighbors if they were to implement these practices in their operations, presenting a barrier to entry.
4. Sharply declining biodiversity- Well-managed grazing creates opportunities to reduce the application of herbicides and pesticides. It also greatly increases the amount of plant diversity in a field, which creates numerous different habitat patches that can be utilized by wildlife. The modeling scenario reflects these benefits by showing tangible benefits in the biodiversity indicators of honey bee toxicity and bird friendliness index comparatively to the cover crop and no-till scenarios.
5. Soil degradation- The results show that the implementation of well-managed rotational grazing can produce meaningful improvements in the soil conditioning index and reduce soil erosion. These positive impacts are likely created by the continuous living cover.

6. Diminished water quality - The water quality improvements created by increasing the amount of well-managed rotational grazing are notable. Much like cover crop and no-till, these practices create improvements when it comes to reducing non-point source nutrient run-off. An area of note is that well-managed rotational grazing is a far superior practice when it comes to reducing the impacts of nitrogen pollution. Mitigating the impacts of nitrogen pollution is critically important because of the threat it presents to human health through our drinking water supply.
Summary: In this scenario well-managed rotational grazing is the vocal point of the land conversion. The exciting finding is that such a conversion provides a full array of benefits. It is a practice that seems to meaningfully address a breadth of outcomes rather than a limited set of elements. The challenge will be that such a transition will require an investment in fundamentally changing our societal relationships with agricultural systems. Such a proposition will be a heavy lift but should not be seen as impossible. We advise that such a transition would need to occur over a time period likely measured in years and would need community buy-in that is supported by grants and philanthropic resources to support/aid conversion.

Conversion Through Collaborative Landscape Design

We hope that the takeaway from the models is that there is not a single correct answer to improving agricultural practices in the Red Cedar Watershed. Rather, there is a set of trade-offs that community members should have awareness of and agency over. It is apparent that if communities desire improvements to the aging farmer population, unfair agricultural markets, social norms, sharply declining biodiversity, soil degradation, and diminished water quality, such changes will only come about through coordinated action that significantly reshapes the ecological and social configuration of agricultural land. With such immense ramifications, it is essential that community members are meaningfully engaged in the process to identify better what is desired for the future of the community. Such a visioning process for the future and plan development is the essence of Collaborative Landscape Design (CLD), which is the central tenant of Grassland 2.0 Learning Hubs. CLD is a set of participatory processes through which regional place-making is being actively pursued and studied.

Developing a social context has an outsized role in enabling transitions to sustainable agricultural systems because it constrains or enables individual changes and frames narratives regarding institutional support for change. The overall goal of CLD is to collectively design places in a way that is consistent with a vision for the future. CLD proposes creating such a shift through an intentional process of place-making grounded at the regional level that encourages communities to connect with each other to identify regionally appropriate goals and to understand how agriculture can be part of solutions to regional challenges. **We are focused on making transformative change by working on the <u>system</u>, rather than exclusively focusing on the <u>individual</u>, by enabling communities to intentionally cultivate change in the social context within which agriculture operates.**

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Appendix I

GRASSLAND 2.0 Scape Model Outputs

What are the various model outputs that are displayed in the Scape Tools? How were they estimated? What do they mean?

Production

- **Yield**: All agricultural land (crop and pasture) is estimated to produce biomass that can then be used to sell off-farm or feed animals on-farm. For corn grain and soybean, we estimate the annual harvested grain biomass using a model previously published by Lark et al. (2020) based on soil properties and county average yields. We then use estimates of corn grain yield to predict corn silage based on a polynomial regression model of the relationship between corn grain yield and corn silage yield (65% moisture) provided by Lauer (2006). We also use corn grain yield to predict oat grain yield and alfalfa yield based on average yield ratios calculated for Dane and Vernon counties from 1995 to 2018. Grain yields are estimated in terms of bushels per acre and converted to tons of dry matter per acre using standard test weights reported by the USDA. For pasture grass, we developed a model to estimate potential yield based on soil and climate properties (predictors) and reported pasture yield from the USDA Soil Survey Geographic (SSURGO, 2023) Database. Separate estimates are given for three different grass species communities (low, medium, and high yielding). These estimates (in tons of dry matter per acre per year) are then modified depending on the pasture occupancy based on USDA-NRCS grazing plan guidance with more frequent rotations leading to higher yields. For rotational cropping systems (e.g., corn-soybean), the average yield across the rotation is reported.
- **Cost per ton-dry matter**: Production costs are estimated based on user-adjusted costs per acre for individual crops and pasture including categories for fertilizer, seed, pesticide, and machinery. Default costs per acre were estimated based on information from Iowa State University and UW-Extension and represent 2022 conditions. Cost per unit yield (ton of dry matter) is then calculated by dividing by the yield from above. While the conversion of all cropping system yields to the common unit of tons of dry matter allows for comparison across systems, users should recognize that crops have different nutritional qualities and values off-farm. For a more holistic economic analysis, we encourage the use of the enterprise-level Compass tools.

Soil

- **Erosion**: Soil loss (erosion) is the expected amount of sediment that leaves a field in an average year in tons per acre per year. It is estimated based on a statistical model of the SnapPlus model that allows us to closely replicate SnapPlus output across a wide range of soil and management properties in a fast and efficient manner. SnapPlus itself uses the RUSLE2 model developed by USDA-ARS to estimate average soil loss based on climate, soil, topography, and land use/management. While maximum soil loss tolerance values for the region are roughly 5 tons/ac/yr, estimated pre-European-settlement soil production rates are 1 to 4 orders of magnitude lower than that (Quarrier et al., 2023). Excessive soil loss has negative impacts on soil productivity/fertility as well as downstream ecosystems.
- **Soil conditioning index**: The soil conditioning index (SCI) is an indicator of soil quality developed by the USDA-NRCS that estimates the impact of a cropping or pasture system on levels of soil organic matter. High levels of soil organic matter improve soil structure, water infiltration and retention, as well as other soil health properties. It is estimated based on a

statistical model of SnapPlus that in turn uses RUSLE2 to predict the SCI. Values typically range from -2 to 2 with higher numbers indicating a potential for building soil organic matter.

Nutrients

- **Phosphorus loss**: Phosphorus (P) is a key nutrient for plant growth but excessive amounts lost through runoff are a primary driver of eutrophication (i.e., harmful algal blooms) in downstream water bodies. P (in both dissolved and particulate form) loss at the edge of a field in pounds per acre per year is estimated based on a statistical model of SnapPlus that also uses the estimated soil loss (see above) as a predictor along with P (fertilizer and manure) application rate and soil phosphorus concentration. Many watershed projects are aiming to reduce P loss below 1-2 lb/ac/year on agricultural land as a long-term goal to meet water quality standards.
- **P Delivery to Water (SmartScape only)**: Once phosphorus (P) is lost from the edge of a field, it can be stored and attenuated before reaching water bodies depending on the path distance and the land slope. Edge-of-field P loss is adjusted to estimate P delivery to perennial water bodies (in lb/ac/year) by multiplying by a P delivery ratio (ranging from 0.45 to 1) calculated based on guidance from the developers of SnapPlus and terrain analysis from a 10-meter digital elevation model.
- **Total Nitrogen Loss to Water**: Nitrogen is a key nutrient for plant growth but excessive amounts applied to agricultural land can be lost to the atmosphere and to water via leaching and runoff. Nitrogen in surface waters can enhance eutrophication (i.e., harmful algal blooms). Nitrogen (as nitrate) in groundwater supplies for drinking water can be a human health threat. Total nitrogen loss to water (via leaching and runoff/erosion) is estimated based on a simple mass balance approach from Meisinger and Randall (1991).

Water

- **Storm Runoff**: Large rainfall events (e.g., 3 inches) generate runoff at the land surface depending on soil properties, slope, and land use/management. Storm runoff (in inches) from different sized rain events (over a 24-hour period) is estimated using the Curve Number method, which is a widely-used empirical model that describes the rainfall-runoff relationship. The Curve Number (CN) - a unitless parameter that ranges from 30 to 100 - is estimated using a statistical model of SnapPlus, which relies on RUSLE2 to determine the CN for different soils and land use/management. In addition, the CN is modified based on slope and whether crops are plowed along the contour or not. higher CN values (e.g., 98 for paved parking lots) lead to more runoff as compared to lower CN values (e.g., 58 grass hay field with sandy loam soil).

Biodiversity:

- **Honey Bee Toxicity**: Pesticides are often applied to croplands to prevent plant damage due to insects and weeds. However, these pesticides also have a detrimental impact on pollinating insects such as honey bees. We used a recently synthesized dataset on average state- and crop-specific pesticide application rates to develop a Honey Bee Toxicity Index for each crop rotation and pasture system. Higher index values represent a higher toxicity risk. Index values range from 0 (pesticide use is assumed to be zero for pasture systems) to 1 (maximum value for Wisconsin, which is for orchards and grapes).
- **Bird Friendliness (SmartScape only)**: Grassland and other perennial/diverse land covers within an agricultural landscape can provide important habitat for animals such as birds. We used a published statistical model to estimate an index of Bird Friendliness ranging from 0 (very poor) to

1 (very good). The model uses statistics of land use/cover within the nearby neighborhood of each grid cell within the SmartScape work area.

Appendix II

Where we want to go as identified by the steering team
• High quality K-12 education system. Quality teachers and students
• People are aware of how they impact the environment and community.
• Have smaller businesses and enterprises that circulate money within a place. While remaining affordable.
• Maintain a strong base of diversified farmers. Important aspects of caring for nature, society, and resilience.
• Inclusive community.
• People act unselfishly
• Have a set of shared goals and collective regional identity
• Grow up and want to stay in the community
• Improved internet and remote work
• Have a fundamental vision of why our watershed is valued
• Housing is accessible (the cost of living aligns with what people are being payed)
• Has amenities, university, athletics, diverse jobs, pool in town, parks and rec department, Ballet, Center for arts, Mable Tainter Theater.
• Develop a localized beef supply chain
• Rural community development

Appendix III

Building Grass-Fed Beef Supply Chains to Support Water Quality

Production Assumptions on Beef Cattle and Stocking Rates

Cow/Calf- Birth to 700#

- .4 head/acre
- Profit $132/acre

Stockers- on pastures at 700# and off at #970

- 1.2 head/acre
- Average 1.5lbs of daily gain
- Profit $298/Acre

Finishing- on pastures at #970 and off at #1300

- .8 head/acre
- Sold for $1,665/hd at open market. Sold for $2,200 in grass fed market (Wisconsin Grassfed Co-op; or 1000 Hills)
- If sold at Co-op, profit $477/acre

	All Values on a Per Head Basis											
	Weight at Beginning	Weight at End	Age in Mo at End	Acres Needed Pasture + Hay *		Purchase Price Beginning ($/Hd)**	Price at End of Phase ($/Hd)**	Cost of feed	Other Cost	Total Cost	Profit per Head	**Profit per Acre**
Cow Calf - Weaned Calf Sold Weaned		550	7	2 3/5	2.60		$1,045	$453	$250	$703	$342	$132
Weaned calf to pre-feeder	550	700	12	1/2	0.52		$1,200	$155	$50	$205		
Total for Feeder (Stocker)								$608	$300	$908	$292	$94
Stocker (Pre-feeder to Transfer to Finishing)	700	970	18	5/6	0.83	$1,200	$1,510	$62		$62	$248	$298
Finishing - Grassfed (Stocker to Finished)	970	1300	24	1 1/4	1.25	$1,510	$2,200	$94		$94	$596	$477

*Dunn Co. Sandy Loam Soils and Assumes

**Prices based on grassfed beef for finishing. USDA AMS Conventional price for feeders and stockers.