Nota Técnica

Landscape Management for Sustainable Supplies of Bioenergy Feedstock and Enhanced Soil Quality

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Summary

Agriculture can simultaneously address global food, feed, fiber, and energy challenges provided our soil, water, and air resources are not compromised in doing so. Our objective is to present a landscape management concept as an approach for integrating multiple bioenergy feedstock sources into current crop production systems. This is done to show how multiple, increasing global challenges can be met in a sustainable manner. We discuss how collaborative research among USDA-Agricultural Research Service (ARS), US Department of Energy (DOE) Idaho National Laboratory (INL), several university extension and research partners, and industry representatives [known as the Renewable Energy Assessment Project (REAP) team] has led to the development of computer-based decision aids for guiding sustainable bioenergy feedstock production. The decision aids, known initially as the «Corn Stover Tool» and more recently as the «Landscape Environmental Assessment Framework» (LEAF) are tools designed to recognize the importance of nature's diversity and can therefore be used to guide sustainable feedstock production without having negative impacts on critical ecosystem services. Using a 57 ha farm site in central Iowa, USA, we show how producer decisions regarding corn (*Zea mays* L.) stover harvest within the US Corn Belt can be made in a more sustainable manner. This example also supports REAP team conclusions that stover should not be harvested if average grain yields are less than 11 Mg ha^{-1} unless more balanced landscape management practices are implemented. The tools also illustrate the importance of sub-field management and site-specific stover harvest strategies.

Keywords: soil management, soil quality, soil conservation, bioenergy, sustainable agriculture

Resumen

Gestión del paisaje para la producción sustentable de materia prima para bioenergía y mejora de la calidad del suelo

La agricultura puede abordar simultáneamente los desafíos de producción global de alimentos, forrajes, fibra y energía, siempre que los recursos suelo, agua y aire no se comprometan al hacerlo. Nuestro objetivo es presentar un concepto de gestión del paisaje como un enfoque para integrar múltiples fuentes de materia prima para bioenergía a los sistemas actuales de producción de cultivos. Esto se hace para mostrar cómo múltiples demandas globales pueden ser atendidas y resueltas de manera sostenible. Discutimos cómo la investigación colaborativa entre el servicio de investigación agrícola del USDA (ARS), el Laboratorio Nacional de Idaho del Departamento de Energía (DOE) de Estados Unidos (INL) (DOE), y varios socios de investigación y extensión de la Universidad, junto con representantes de la industria [conocidos como el equipo de proyecto de evaluación de energía renovable (REAP)] condujo al desarrollo de lineamientos informáticos para guiar la toma de decisiones en la producción sostenible de materia prima para generación de bioenergía. El producto conocido inicialmente como «herramienta de rastrojo de maíz» y más recientemente como «Landscape Environmental Assessment Framework (LEAF) está diseñado para reconocer la importancia de la diversidad de la naturaleza y por lo tanto, puede utilizarse para guiar la producción sostenible de materia prima, sin impactos negativos en los servicios de los ecosistemas críticos. Usando un predio agrícola de 57 hectáreas en Iowa central, USA, mostramos cómo las decisiones del productor sobre la cosecha

de rastrojo de maíz (*Zea mays* L.), en el cinturón maicero de Estados Unidos, pueden hacerse en forma más sostenible. Este ejemplo también respalda las conclusiones del equipo REAP en cuanto a que no debe ser cosechado el rastrojo si los rendimientos medios de grano son menores de 11 Mg ha^{-1} a menos que se implementen prácticas más equilibradas de manejo del paisaje. La herramienta también ilustra la importancia de la gestión del subsuelo y de estrategias de cosecha del rastrojo específicas para cada lugar.

Palabras clave: manejo de suelos, calidad de suelos, conservación de suelos, bioenergía, agricultura sostenible

Introduction

A recent report by the Chicago Council on Global Affairs concluded that «a landscape-based framework is needed to resolve agricultural, energy, and environmental trade-offs inherent in bioenergy production systems (Brick, 2011). But, what is landscape management and why is it important for sustainable biofuel feedstock production and enhanced soil quality? We define landscape management as land-use that recognizes the importance and impact of nature's diversity and acknowledges both, immediate and long-term as well as on- and off-site impacts associated with every soil and crop management decision.

When focusing on complex agricultural production systems that are being challenged to meet global food, feed, fiber, and renewable fuel needs, it is extremely important to capitalize on nature's diversity to simultaneously achieve these goals. Why? Simply stated, a diverse landscape provides multiple ecosystem services including: (1) feedstock for bioenergy, (2) enhanced nutrient cycling, (3) multiple pathways for sequestering carbon, (4) food, feed, and fiber resources, (5) filtering and buffering processes, (6) wildlife food and habitat, (7) soil protection and enhancement of soil quality, and (8) economic opportunities for humankind.

If landscape management is so important, why is it a difficult concept for some to grasp and what barriers need to be overcome to implement it for sustainable bioenergy feedstock supplies and enhanced soil quality? This too is a very complex question, so perhaps illustrating it as a «wicked» problem (Figure 1) is an appropriate way to show why land use decisions of today are so much more challenging than during past decades (Batie, 2010). Wicked problems are those difficult-to-describe issues that are subject to considerable political debate. They tend to arise from civil society, not from experts, and they are often thrust upon policymakers and scientists. Wicked problems tend to have neither a clear definition nor an optimal solution, and attempts to solve them can easily cause the problem to change. Addressing wicked problems does not tend to lead to definitive «solutions.» Instead, the action often results in outcomes that are simply «better or worse.» In other words, wicked problems are not «solved» but rather they are «managed.»

Unfortunately, soil scientists and other agricultural specialists no longer have the luxury of focusing solely on simple, single issues problems such as the perils of wind, water or tillage erosion. Instead, they are faced with complex challenges such as balancing environmental and economic tradeoffs associated with using crop residues or changing

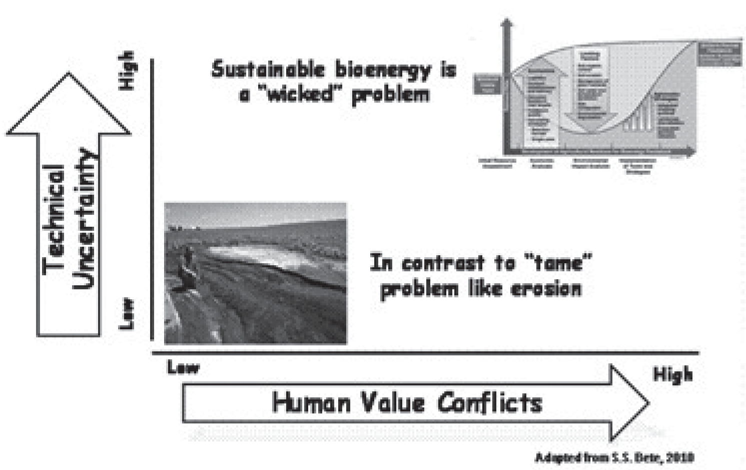

Figure 1. An illustration of the complexity and «wickedness» of landscape management.

land use to provide lignocellulosic feedstock for ethanol or advanced biofuel production. Not only are these specialists confronted by many technical uncertainties, but also their socially acceptable solutions are further restrained by value-laden issues associated with different human perceptions of sustainability and the seemingly endless list of complex tradeoffs that could be considered. Furthermore, these complex challenges are often presented negatively in the press as «food versus fuel» debates (Rosillo-Calle and Johnson, 2010) rather than optimistically as land use opportunities to provide society with abundant food, feed, fiber and fuel supplies. This is therefore, an example of a «wicked» problem for which new technologies as well as research and education programs for society as a whole are needed. Unfortunately and more frequently than ever before, alternative land uses and conservation goals have become subordinate to policy goals including protection of income and wealth for a few at the environmental expense of many. We suggest that one reason for this is the lack of tools that can integrate vast amounts of knowledge into decision aids that can help all of the people involved in making these complex decisions and land use changes visualize their options and the tradeoffs associated with achieving a mutually agreeable, manageable solution.

Our goal is to illustrate the concept of landscape management by examining alternative opportunities for sustainable bioenergy feedstock production on a Central Iowa USA farm. The over-arching requirement for the different scenarios is to strive for balance among economic drivers favoring the use of soil and water resources to produce feedstock materials (Figure 2) and ecologically limiting factors that would minimize feedstock (*i.e*., crop residue) harvest to ensure that ecosystem services including soil quality are not compromised (Wilhelm *et al.*, 2010). Through this example, we show that with regard to sustainable biofuel feedstock production, landscape management plans recognize there are many different potential feedstock materials and that every one of them has both advantages and disadvantages depending upon location and many other factors.

Potential bioenergy feedstock materials can be grouped into four broad categories: (1) corn residue (Johnson *et al.*, 2011) and sweet sorghum (*Sorghum bicolor*) (Shoemaker and Bransby, 2011); (2) perennial herbaceous crops such as switchgrass (*Panicum virgatum*), *Miscanthus*, sugarcane (*Saccharum* spp.), and alfalfa (*Medicago sativum*) (Mitchell *et al.*, 2011); (3) woody species belonging to the genus *Salix* (willow) or *Populus* (cottonwood, poplar) in the Salicaceae family, eucalyptus (*Eucalyptus* spp.), sycamore (*Platanus occidentalis* L.), sweetgum (*Liquidambar styraciflua* L.), loblolly pine (*Pinus taeda* L), black locust (*Robinia pseudoacacia* L.), silver maple (*Acer saccharinum* L.), and shrub willow (Volk *et al.*, 2011), and (4) biomass residuals which include materials left over from other processes – some of it currently used and useful as well as some of it considered a waste material that must be managed carefully to prevent unintended ecological damage (Brick, 2011).

There are many challenges associated with implementing a landscape management plan to ensure sustainable biofuel feedstock production. We have chosen just three to highlight within this paper. They are: (1) multiple interactions (e.g. air, water, soil, biota) – many that cannot be equivalently described or quantified; (2) balancing difficult-to-monetize factors (e.g. soil quality) with those that can more easily be monetized (e.g. yield); and (3) tradeoffs between long-term ecosystem

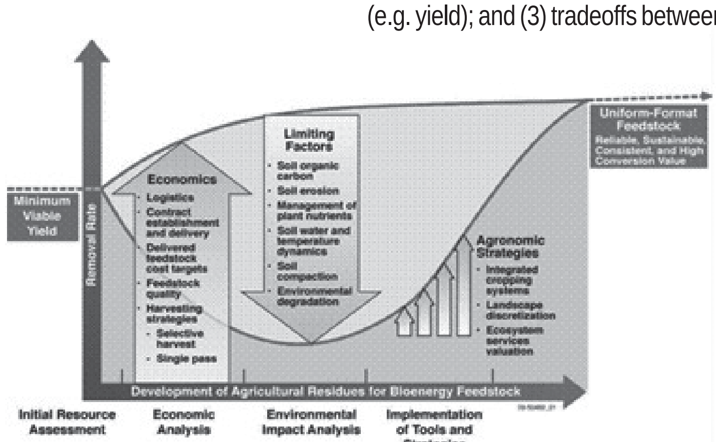

Figure 2. An illustration of competing economic drivers and environmental sustainability forces that must be balanced to achieve sustainable cellulosic feedstock supplies to support the transition from fossil to renewable fuels.

protection and/or improvement versus short-term profit or return on investment.

Why is landscape management important in a world dominated by short-term economic concerns that focus primarily on easily monetized factors for decision making? From a societal perspective, a diverse landscape provides many more ecosystems services than simple land use systems focused on a limited number of crops. But what about financial costs or potential profit losses associated with implementing diverse landscape management strategies?

If a decision is made to only use current energy assessments, fossil fuels will have a significant competitive edge that is not likely to disappear in the foreseeable future (Brick, 2011). Currently, most bioenergy technologies are smaller in scale and less efficient than their fossil fuel counterparts. Also, in addition to process efficiencies and economies of scale, fossil fuels currently have many other important advantages. Substantial existing energy infrastructure is already depreciated making its cost basis a fraction of that required for new technologies. Also, many energy markets are either monopolies or oligopolies which make market access very difficult for new entrants. Supportive policies and subsidies are therefore needed to encourage adoption of practices whose ecosystem service benefits are clear but currently unrecognized by markets. At the same time, markets for those ecological attributes must be created as soon as possible to ensure that appropriate long-term economic signals are in place for socially beneficial behavior (Brick, 2011). In other words, landscape management for biofuel development is difficult because it is a «wicked» problem (Figure 1) rather than a «tame» one such as soil erosion for which there is little uncertainty and virtually no human value conflicts involved when addressing it.

Our objective for this paper is to introduce some emerging decision aids that we anticipate being very useful for helping producers implement landscape management plans, not only for bioenergy feedstock production, but for many other land uses as well as the soil and crop management decisions that support them.

Methods and Matherials

Having introduced the need and rationale for landscape management, we will now focus on introducing a decision aid that was developed to help guide producers through the transitions required to move from conventional agricultural practices that focus solely on row crop production to a landscape approach designed to balance food, feed, fiber, and bioenergy feedstock production. The decision aid, initially known as the «Corn Stover Tool» and more recently as the Landscape Environmental Assessment Framework (LEAF) was developed through collaborative, inter-agency research. Engineers from the Department of Energy (DOE) Idaho National Laboratory (INL) provided advanced computer engineering knowledge and skills to link multiple simulation models while USDA-Agricultural Research Service (ARS) scientists, associated with the Renewable Energy Assessment Project (REAP) team, provided plot- and field-scale data to calibrate and validate simulation model output information from the decision aid. Several USDA Natural Resources Conservation Service (NRCS) personnel also contributed to the project by providing soil survey and other data sources as well as the experiential knowledge required to calibrate and validate soil erosion and soil conditioning index values. Through an advanced, sophisticated linkage of several simulation models, each optimized according to their individual guidelines, the tools use the various data sources to achieve an optimum balance as described by the limiting factor model (Wilhelm *et al.*, 2010) and to thus assess sustainability of bioenergy feedstock production based on multiple factors.

Built using science-based, long-term field and laboratory research data and appropriately calibrated simulation models, the decision aids can be used to predict optimum solutions and new management strategies for balancing food, feed, fiber, and ethanol or advanced biofuel production. The Corn Residue Tool and LEAF (http://www.inl.gov/LEAF) both use NRCS SURGO soil database input for factors including soil organic matter and sand fraction. To understand the intricacies of the decision aids, readers are referred to Muth (2012) who used a precursor to the Corn Residue Tool to evaluate responses for all agriculturally relevant soils throughout the USA. County average crop residue and slope estimates for each soil type were used to estimate available crop residue for the Revised Billion Ton Report (BT2) report (Department of Energy, 2011). Those estimates were much more spatially precise than values used for the initial 2005 Billion Ton Study estimates (Perlack *et al.*, 2005). Subsequently, further improvements to the decision aids were made by using field-specific lidar elevation data and actual crop yield information provided by yield-monitor records from farm combine operators. This resulted in even better site-specific resolution and provided information needed to create field-scale stover harvest maps for a several farms. These advances ultimately led to the release of the LEAF version of the decision aid.

Results and Discussion

To develop and predict multiple outcomes associated with different landscape management plans using the decision aids, the user (usually a producer and NRCS or commercial crop management consultant) assess all impacts of current land use decisions and management practices using the NRCS Soil Water Air Plant and Animal (SWAPA) framework outlined in Table 1. Next, they identify the most promising options for changing current landscape management practices (Table 2). The decision aids can be used to identify areas in fields that are not suitable for harvesting crop residues because of one or more limiting factors (Wilhelm *et al.*, 2010). Then, by considering another feedstock material (e.g. switchgrass), a landscape management concept plan can be developed to provide the producer with options that could have both a greater economic return and fewer potential negative environmental consequences, such as further degradation of soil quality.

A Corn Stover Tool Case Study

A case study using an advanced version of the Corn Stover tool was conducted to investigate the conceptual impacts of implementing a bioenergy feedstock based landscape management plan on a central Iowa USA farm. An integrated, sub-field version of the tool was used to investigate the effects of two landscape management strategies, cover crops and switchgrass, on an environmentally vulnerable 57 ha field located in Cerro Gordo County Iowa (Figure 3). This is a very typical Midwestern USA agricultural field, currently used primarily for corn and soybean crop production. The field has significant diversity in soil properties, surface slope, and historical crop yield levels (Figures 3a-d). Tillage practices for this field are modeled as reduced tillage consistent with the definitions provided by the Conservation Technology Information Center (CTIC) (Conservation Technology Information Center, 2002).

Table 1. Assessment questions based on the NRCS Soil-Water-Air-Plant-Animal (SWAPA) model for evaluating current practices before designing a landscape management plan.

Resource	Critical Question
Soil	Is long-term soil quality improving or degrading?
Water	What are the surface and subsurface water quality impacts of current practices?
Air	What are the air quality (e.g. PM10, odors, GHG) impacts of current practices?
Plant	What cropping system is best for this landscape? Do I have the best spatial and temporal arrangement of plants?
Animal	Are livestock production systems affecting environmental quality?

Table 2. Potential landscape management practices that could facilitate conservation, provide bioenergy feedstock, and enhance soil quality.

Conservation Practice		
Riparian buffers	Re-saturated riparian buffers	Riparian forest buffers
Two-stage ditches	Nutrient interception wetlands	Riparian herbaceous buffer
Contour buffer strips	Vegetative barriers	Filter strips
Grassed waterways	Windbreaks	Field borders

Figure 3e shows the predicted results projected for harvesting corn stover using a standard, commercially available rake and bale operation. The model projections, which are consistent with NRCS assumptions regarding water erosion, wind erosion, and soil organic carbon constraints, show that only 21% of the field can sustainably support a rake and bale corn stover harvest operation (Muth, 2012).

Diversity in slope, soil properties, and grain yield result in conditions that would make sustainable residue removal very challenging in this field, but those same characteristics also make the field an interesting case study for exploring landscape management strategies. Two alternative crop management scenarios, (1) use of cover crops and (2) identifying areas of the field where traditional row cropping may simply not be sustainable were modeled to illustrate how adoption of a landscape management plan could both increase biomass feedstock availability and protect soil quality. The «at-risk» areas within this field are designated by

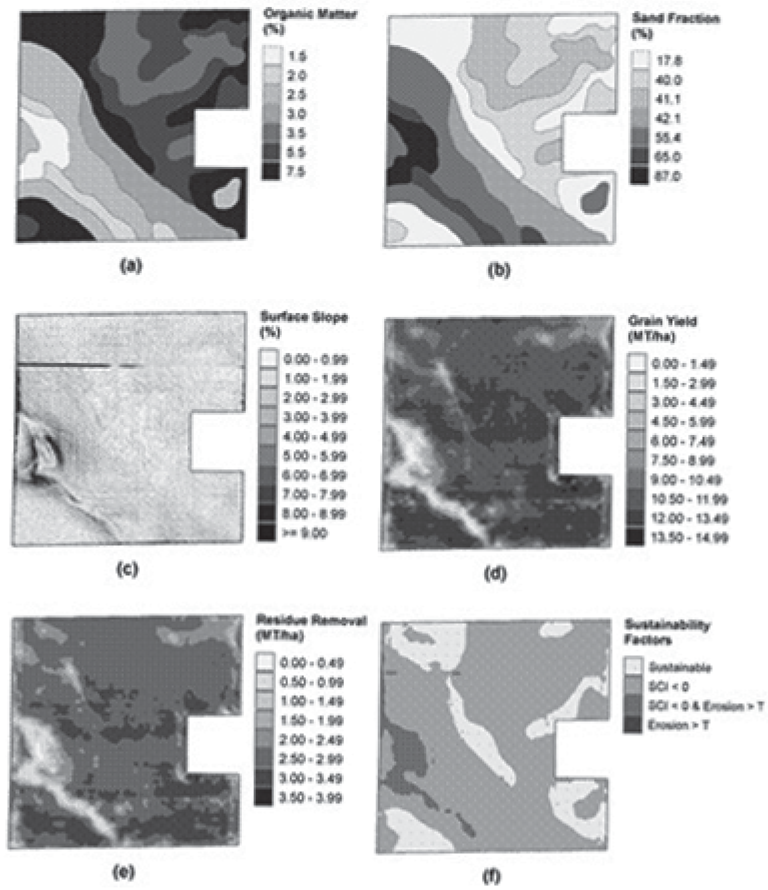

Figure 3. Soil properties (a and b), surface topography (c), grain yields (d), and residue removal tool results (e and f) for the 57 ha case study field in north central Iowa (from 6).

the purple outline in Figure 4a. To reduce economic and environmental vulnerability of the two areas, two alternate land management treatments were investigated using the Corn Stover tool. The treatments were: (1) use of a rye (*Secale cereale*) cover crop, and (2) planting switchgrass in the most vulnerable parts of the field. For Treatment 1, the model simulated planting winter rye following corn harvest to provide soil protection and additional carbon inputs during the winter and early spring months. As shown in Table 4, the rye is assumed to be planted with a drill following the corn grain, residue harvest, and tillage in the fall. It is also assumed that the winter rye will be killed in the spring with an herbicide application. For Treatment 2, the selection factors used to determine where switchgrass would be planted were low grain yield and areas where continuous removal of crop residue, even with a cover crop, were determined to be unsustainable. These factors were chosen for two reasons. First, areas in the field where grain yields are low are more likely to see an economic benefit associated with the transition to an alternative crop. Second, continuous areas where residue removal is unsustainable even with a cover crop treatment would represent the most at-risk and marginal areas of the field. For economic analysis, the switchgrass production system was assumed to have a two-year establishment period and six years of stand productivity before reestablishment was required.

The projected results from these treatments are used to determine the total quantity of biomass removed in a sustainable manner from this field and the annual average soil loss associated with the seven different landscape management scenarios listed in Table 2. The first scenario is the baseline for row crop production with a rake and bale residue removal operation. The second scenario is the same as Treatment 1 except that a rye winter cover crop is used between the row crops. The third scenario incorporates switchgrass as described in Treatment 2, but does not include

Table 3. The three management scenarios used in this study with operation timings in month/day format.

Corn/Soybean	Corn/Soybean w/Rye	Perennial Switchgrass			
4/20 Year 1	Fertilizer Application	4/20 Year 1	Fertilizer Application	11/1 Year 1	Chisel Plow
5/1 Year 1	Field Cultivation	5/1 Year 1	Field Cultivation	4/15 Year 2	Field Cultivation
5/1 Year 1	Plant Corn	5/1 Year 1	Plant Corn	4/15 Year 2	Plant Switchgrass
10/15 Year 1	Harvest Corn	10/15 Year 1	Harvest Corn	12/15 Year 3	Harvest Switchgrass
10/15 Year 1	Rake Residue	10/15 Year 1	Rake Residue	12/15 Year 4	Harvest Switchgrass
10/18 Year 1	Bale Residue	10/18 Year 1	Bale Residue	12/15 Year 5	Harvest Switchgrass
11/1 Year 1	Chisel Plow	10/25 Year 1	Chisel Plow	12/15 Year 6	Harvest Switchgrass
5/15 Year 2	Plant Soybeans	10/26 Year 1	Plant Rye Cover	12/15 Year 7	Harvest Switchgrass
10/10 Year 2	Harvest Soybean	5/25 Year 2	Kill Rye	12/15 Year 8	Harvest Switchgrass
		6/1 Year 2	Plant Soybean		
		10/10 Year 2	Harvest Soybean		

a winter rye cover on the remaining corn-soybean area of the field. The fourth scenario combines Treatments 1 and 2 by growing switchgrass on vulnerable areas and including a rye cover on the remaining corn and soybean areas of the field. Scenarios five, six and seven present results representing only the areas of the field which are identified for switchgrass production. These areas are given focus because they are the most at-risk areas and present the best opportunity for significant environmental benefits, including soil quality improvement, when compared to baseline row crop management practices. Scenario five shows the characteristics of the at-risk areas of the field when used for corn and soybean production. Scenario six represents what happens in those areas when a cover crop is planted, and scenario seven shows the impact of converting this portion of the field to switchgrass.

Planting switchgrass on the at-risk areas of the field identified in Figure 4 would mitigate negative ecological impacts from row crop production while producing 86 metric tons of biomass feedstock each year. As shown in Table 4, this would be an annual increase of 53 metric tons of biomass compared to only collecting corn stover with a rye cover crop. As shown in Figure 4b, managing 100% of the switchgrass in a sustainable manner and incorporating a rye cover crop on the remaining portions of the field would result in a total of 193 metric tons of residue per year could be sustainably removed from the field, with only 4% of the area being classified as having unsustainable management practices. With regard to bioenergy processing platforms, landscape management also means that multiple pathways are possible. Simply stated, the critical message is that diversity means there is no single solution! This includes using multiple feedstock materials, including various residuals or traditional waste streams (Brick, 2011; Holtman *et al.*, 2011) processed using biochemical (fermentation),

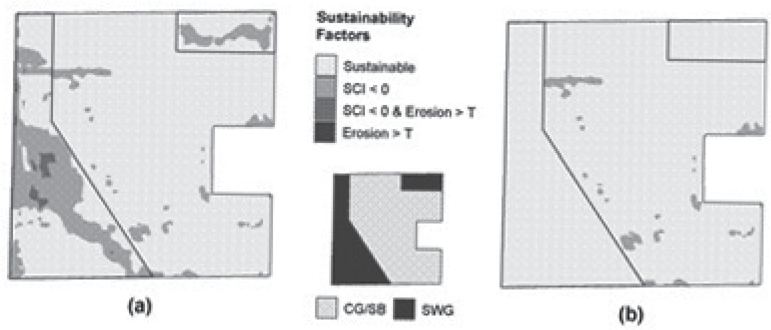

Figure 4. a) Sustainability analysis for rye cropping scenario; approximately 20 ha of the field are identified for potential switchgrass production within the purple outline. b) All switchgrass acreage is found to be sustainable.

Table 4. Annual residue removal, fraction of field managed sustainably, and annual soil loss for seven different management plans.

Rake and Bale Removal	**Reduced Tillage**		
	Annual Sustainable Residue (metric tons)	**Percentage of Field Managed Sustainably**	**Annual Soil Loss (metric tons)**
Scenario 1 (Corn/Soy)	36	21%	316
Scenario 2 (Corn/Rye/Soy)	140	83%	182
Scenario 3 (Corn/Soy & Switch)	113	48%	155
Scenario 4 (Corn/Rye/Soy & Switch)	193	96%	114
Scenario 5 (Switch)	86	100%	11
Scenario 6 (Corn/Soy in Switch area)	10	18%	172
Scenario 7 (Corn/Rye/Soy in Switch area)	33	61%	79

thermochemical (pyrolysis), and/or various direct catalyst reactions.

As illustrated by this case study, development of sustainable bioenergy feedstock production systems may also be an effective approach for restoring or improving soil quality. Again, the process begins by assessing and reevaluating new management practices (Table 2) using questions such as those outlined in Table 1. The Soil Management Assessment Framework (SMAF), which was previously used to evaluate long-term effects of harvesting crop residue for bioenergy production (Karlen, 2011; Karlen *et al.*, 2011a, 2011b) can be used to monitor the soil quality effects. As previously shown after five years of continuous corn production near Ames, IA, USA, soil bulk density (BD) increased slightly and therefore the SMAF BD score decreased (Karlen *et al.*, 2011b). There was also a slight decrease in the total organic carbon (TOC) score, perhaps because stover harvest resulted in less annual carbon input into the soil, but measured TOC levels were not statistically different. Overall, the soil quality index (SQI) for that research site indicated the soil was functioning at 90 to 97% of its inherent potential after five years of stover harvest. In a near-by rotated corn and soybean study, TOC and soil-test K scores were much lower and the soil-test P score was slightly lower following the 2009 harvest. The net result, according to the SQI for the rotated site, was that the soil was functioning at 81 to 85% of its potential following three stover harvests. In both cases the SMAF assessments were consistent with those reported for other corn stover harvest sites (Karlen *et al.*, 2011a).

Based on these studies, and other, on-going collaborative REAP research, we are now suggesting that to sustain soil resources within the US Corn Belt, corn stover harvest with current crop management practices should not exceed 1 to 1.5 Mg ha^{-1} unless average grain yields are greater than 11 Mg ha^{-1}. However, if more intensive landscape management practices, as illustrated by the case study, are implemented, the quantity of biomass per hectare that can be harvested in a sustainable manner increases substantially. Furthermore for areas east and west of the primary Corn Belt, where non-irrigated corn grain yields are frequently lower, corn can still be part of an overall landscape approach for sustainable feedstock production, simply not the sole source of biomass. Finally, based on soil quality assessments, the REAP team also suggests that producers with consistently high yields (> 12.6 Mg ha^{-1}) may be able to sustainably harvest even more stover by simply decreasing their tillage intensity. This would also decrease fuel use, preserve rhizosphere carbon, and/or maintain soil structure, thus ensuring that soil quality benefits often attributed to no-till production systems are indeed realized.

What then is the most limiting factor restricting further development of landscape management strategies? We suggest it is a continued focus on individual problems or goals. Every economic, environmental, and social issue has important aspects that must be rigorously investigated, understood, and advocated for. However, for complex and wicked problems such as sustainable bioenergy feedstock development, air quality, water quality, soil quality, wildlife, carbon sequestration, rural development, and use of residual or waste streams are critical factors that simply cannot be evaluated singularly. Rather, they must be addressed as an integrated system. Fortunately, this is not an impossible task or a nirvana state of mind as the USDA NRCS has already developed SWAPA + energy (E) + human (H) factor guidelines for their Field Office Guide. In fact, the (SWAPA + E + H) approach for land use assessment has been available for comprehensive farm planning since 1993. The key in our opinion is simply recognizing and capitalizing on nature's diversity using advanced computer-based technologies rather than trying to impose a «one-size fits all» model on living, dynamic systems.

Conclusions

The concept of landscape management is introduced as a strategy to help solve complex problems such as providing biofuel feedstock without impacting long-term productivity of our soil resources. The challenge to implementing landscape management is often the multitude of options that must be considered. To facilitate this challenge first and second generation decision aids known as the Corn Stover Tool and LEAF were developed using advanced computer engineering techniques and validated with plot- and field scale data. The use of these tools is demonstrated with a case study for a 57 ha agricultural field in central Iowa, USA. The results show that by replacing conventional row crop practices with a landscape management plan, the quantity of bioenergy feedstock can be increased six-fold while reducing soil erosion three-fold from this site. Development of decision aids such as these provide a key for more sustainable land use, not only in the USA but around the world.

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