WISCONSIN
INITIATIVE ON
CLIMATE
CHANGE
IMPACTS

Soil Conservation Working Group Report

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THE WISCONSIN INITIATIVE ON CLIMATE CHANGE IMPACTS

1st Adaptive Assessment Report

Contribution of the Soil Conservation Working Group

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Contour stripcropping in central Wisconsin
Photo by Ron Nichols, USDA Natural Resources Conservation Service

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SOIL CONSERVATION WORKING GROUP
EXECUTIVE SUMMARY

Conservation of the soil resource in Wisconsin is not a new challenge but one that will become more difficult based on predicted climate changes. Our long-term goal, even in the face of a changing climate and new demands on the land, should be to eliminate sediment and phosphorus impairments of our surface waters and to maintain the potential productivity of Wisconsin's soil resource. We believe that soil conservation and water quality are compatible with current and emerging expectations of Wisconsin's farmlands, **provided that practices we largely know how to do are widely adopted by our farmers.**

Soil particles eroding from agricultural lands both degrade the soil resource, potentially reducing agricultural productivity, and pollute rivers and streams, which impacts Wisconsin aquatic ecosystems. Decades of technical, educational, and financial assistance to land managers have in many places substantially reduced this form of runoff pollution. However, progress is often slowed or stalled by decreases in government attention and oversight and by evolving agricultural practices for both food and fuel. Recently, rising demand for agricultural products and changing precipitation patterns have threatened to eliminate or even reverse progress toward minimizing soil erosion impacts on water quality.

The United States Department of Agriculture-Natural Resources Conservation Service conducts the National Resource Inventory (NRI) to assess land use and soil erosion across the nation. Results indicate that while progress was made in Wisconsin from 1982 through 1997, losses from soil erosion are now increasing (Table 1). The soil erosion phenomenon is enormously complex (Figure 1), but lands being converted from perennial vegetation to row crops and climate change are both likely contributing to this increase.

A relatively small fraction and number of precipitation events each year cause most of the annual soil loss from agricultural fields. There is evidence that highly erosive precipitation events are increasing in frequency, and climate change models predict intensification of the hydrologic cycle in the future. Simulation models that combine future climate conditions with soil erosion calculations indicate that in the absence of appropriate adaptation actions, soil erosion in Wisconsin could more than double by 2050 compared with the 1990s.

At the core of soil conservation in Wisconsin and the United States is voluntary adoption of appropriate practices by farmers. Beginning in the 1930s the federal government became engaged in the problem through research, demonstration, education, and financial and technical assistance to individual farmers. To this day governments at the federal, state, and county level provide technical assistance, such as engineering design and consultations, and financial incentives, known as "cost-sharing." As in the 1930s, individual farmers differ remarkably in their willingness to adopt soil-conserving behaviors. The state of Wisconsin has some limited power to intervene in the face of egregious soil erosion, but this is rarely exercised.

Three levels of government as well as civil society are involved in soil conservation. The government agencies engaged in encouraging soil stewardship in Wisconsin are the United States Department of Agriculture-Natural Resource and Conservation Service (NRCS); Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP); Wisconsin Department of Natural Resources (DNR); and Land Conservation Departments based in county governments (LCDs). Increasingly, civil society organizations, such as the River Alliance of Wisconsin and Trout Unlimited, are playing a role in connecting farmers with government-provided assistance and cost-share funds. The roles and relationships of these actors overlap and slowly evolve with changing laws.

Given the contexts of changing hydroclimate and increased demand for agricultural commodities, reducing soil erosion and the resulting impacts on aquatic ecosystems will likely require greater focus on implementation and maintenance of both structural soil conservation practices, such as terraces or grassed waterways, and non-structural practices like conservation tillage. This work, in turn, depends on government commitment to human resources, data resources, and ongoing monitoring; better tools for cost-benefit analysis, and the political will to both enforce existing regulations and set higher standards for protection of soil and water resources.

Adaptation Strategies

Our adaptation strategies seek to **adjust and strengthen the public-private collaboration that since the 1930s has been central to minimizing soil erosion.** Experience demonstrates that land managers hold a wide range of attitudes about their roles in stewardship of soil and water resources. Today's agricultural economy often forces farmers to make short-term decisions that may be necessary for survival of their business but are not protective of soil and water resources. Additionally, a substantial fraction of Wisconsin croplands (about 30 percent in 2007) is now leased on short-term contracts, so operators lack incentives for investments in soil conservation.

Our adaptation strategies address what we believe are four major components of any soil conservation effort: ***strategy***, ***practices***, ***monitoring***, and ***evaluation***. ***Strategy*** includes planning processes, goal-setting and metrics used to determine success, allocation of human and financial resources, and the roles and relationships ascribed to government and civil society institutions and land managers. ***Practices*** refer to the agronomic and engineering practices prescribed as soil-conserving and the degree to which they are adequate to reach the goals of the conservation program. ***Monitoring*** seeks to determine the extent of the adoption of soil-conserving practices and the degree to which desired outcomes are met. ***Evaluation*** is essential for a rich and informative assessment of programs aimed to increase compliance and seeks to provide insight into the relative importance of strategy, practices, and monitoring to achieving compliance. We found that this framework assisted us in granting appropriate attention to the diverse issues that appear relevant to adapting soil conservation to a changing climate.

1. Strategy

- **Develop new metrics for sustainability of soil and water resources**. The current standard for tolerable soil loss, the soil-specific value of T, has long been debated. It arguably represents a compromise between what will actually sustain the soil resource and what is thought to be achievable practically. Additionally, assigned values of T are generally not adequate to meet current water quality standards. For the time being, however, we must continue to use T as an interim goal while new metrics are explored.

- **Fully utilize and expand cross-compliance provisions and recognize that additional regulatory tools are required.** Cross-compliance refers to legal provisions requiring that landowners who receive government benefits (for example, crop price supports or preferential tax treatment) meet specified soil conservation goals. It is not clear that all of these obligations are met at present. Additionally, new regulatory tools are needed to improve our ability to identify and target poorly managed lands.

- **Provide the human resources necessary to facilitate broad adoption of the practices we know can reduce soil erosion and to ensure compliance with existing rules.** Implementation and compliance assurance of soil conservation programming is labor-intensive. Counties consistently cite lack of staffing as the first impediment to greater success in broadening adoption of soil conservation.

- **Revisit public policy surrounding subsidies for soil conservation practices.** The provision of financial incentives for land managers to follow some practices (and so avoid others) has a long tradition in soil conservation efforts at the federal, state, and county levels. How much other sectors of the economy should pay farmers (or contribute to costs) through cost-share programs is a challenging philosophical question. There is no right or wrong answer, but the debate should be revisited regularly.

- **Expand watershed-based programming efforts, with appropriate targeting of hydrologic units, farms, and fields.** A targeted watershed strategy places highest priority on water bodies that most urgently need improved soil and water conservation, then further focuses resources on lands in the watershed that most affect water quality.

2. Practices

- **Expand adoption of accepted soil-conserving field practices.** Our current toolbox of practices has the potential to handle the increased erosion rates that would accompany predicted hydro-climate changes. However, they are not nearly fully utilized.

- **Research strategies for objectively and efficiently identifying portions of the landscape that should be maintained in healthy, full-cover perennial vegetation, and develop programs to encourage returning these areas to**

this condition. Specific portions of the landscape contribute disproportionately to water quality degradation. Planting perennial vegetation in these areas may be by far the best strategy for eliminating the pollution from them. While the Conservation Reserve Program seeks to eliminate tillage on these highly erodible parts of the landscape, contracts last at most 15 years. There is potential in developing alternative enterprises such as bioenergy feedstocks or managed livestock grazing.

- **Undertake research to enable more inclusive accounting of the costs and benefits of soil management choices.** Research in soil conservation to date has focused on the erosion-productivity relationship and the efficacy of practices at reducing erosion. In the face of climate change we need to broaden our understanding of the costs of soil erosion in terms of greenhouse gas and energy balances.

3. Monitoring

- **Develop systematic, transparent, and accessible monitoring programs for soil conservation and its impacts on water quality**. Soil conservation is a spatially distributed, temporally dynamic endeavor. Understanding what managers are doing across the landscape is a large challenge, but such data are essential both for checking on compliance with legal agreements and for subsequent evaluation of conservation programs. Currently available data are inadequate to for us to know what we are doing well and where our greatest failings are.

4. Evaluation

- **Conduct more evaluation work related to soil conservation.** The substantial public expenditures, institutional complexity, and evolving hydro-climate and policy contexts of soil conservation justify greater effort in understanding what works and why. The tools of evaluation should more frequently be brought to bear on soil conservation challenges.

- **Initiate an ongoing analysis of how bioenergy policies and changing production practices influence efficacy of soil conservation programs.** An important driver of vegetation management on the landscape will continue to be bioenergy markets and policy. Effects of these markets and policies on soil conservation should be given as much attention as changing hydroclimate.

Summary and Conclusions

Soil conservation is a complex biophysical, social, and economic challenge. Recent measurements indicate that soil erosion losses are increasing, probably caused by a combination of cropping system changes, relatively erodible land being returned to cultivation, and, perhaps, changing hydroclimate. The major interactions in play are diverse and interconnected (Figure 10). Climate change, both in temperature and precipitation, has direct negative impacts on soil conservation, but new cropping options

opened by changes in growing-season length and temperature could conceivably contribute in positive ways. Expanded opportunities for bioenergy production from croplands have both potential negative and positive impacts. Greater market value from perennial plantings has the theoretical possibility of encouraging this choice on erodible lands. However, residue removal, expanded cropping onto highly erodible lands, and displacement of hay crops by annual crops can increase erosion.

Conservation research, education, and policy have the potential to improve soil conservation by broadening the range of options available to land managers. New conservation reserve programs in a context of comprehensive enforcement of existing regulations might reduce cultivation of highly erodible lands. Perhaps land grant universities must return to programs of research, demonstration, and education on soil conserving practices.

While climate change and bioenergy endeavors appear on balance to negatively impact soil conservation, many on-the-ground practices and policy decisions can prevent these issues from exacerbating soil erosion. The richness of this complex field promises as much opportunity as reason for concern—we have the ability to adapt soil conservation to a changing climate.

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Soil Conservation and Future Climate Impacts

Soil particles eroding from agricultural lands both degrade the soil resource and pollute rivers and streams, impacting Wisconsin aquatic ecosystems. Decades of technical, educational, and financial assistance to land managers have in many places substantially reduced this form of non-point pollution. However, progress is often slowed or stalled by decreases in government attention and oversight, and by evolving agricultural practices for both food and fuel. Recently, rising demand for agricultural products (food and fuel) occurring simultaneously with changing precipitation patterns threaten to eliminate or even reverse progress toward minimizing soil erosion impacts on water quality.

A relatively small fraction (and number) of precipitation events each year cause most of the annual soil loss from agricultural fields. Annual precipitation is increasing across Wisconsin, as is the number of days with 1 inch or more of rainfall (Kucharik et al. 2010), and the amount of rainfall during the wettest 7-day period of each year also appears to be increasing (Kunkel et al. 1999). These trends increase the opportunities for sequences of precipitation that lead to significant soil erosion. As described in more detail later in this report, computer simulations indicate that Wisconsin's future hydroclimate will cause increased water runoff volumes and soil erosion. Indeed, the issue of soil erosion has now entered the research and documentation efforts of the international Intergovernmental Panel on Climate Change Impacts (IPCC, Kundzewicz et al. 2007). The Soil and Water Conservation Society has explored these issues with respect to the Great Lakes region (SWCS 2007).

Given the contexts of changing hydroclimate and increased demand for agricultural commodities, reducing soil erosion and the resulting impacts on aquatic ecosystems will likely require greater focus on implementation and maintenance of both structural (terraces, grassed waterways) and non-structural (conservation tillage) soil conservation practices. This work, in turn, depends on government commitment to human resources, data resources and on-going monitoring, better tools for cost-benefit analysis, and the political will to both enforce existing regulations and set higher standards for protection of soil and water resources.

Vulnerability Assessment

Our assessment of future soil erosion challenges begins with a review of why this issue is of on-going concern to society. Next we provide a brief overview of soil conservation work in Wisconsin. The available data on soil erosion in Wisconsin are then surveyed. Finally, the Vulnerability Assessment ends with a review of why the future portends increasing environmental damage from soil erosion.

Why Care About Soil Erosion?

Soil erosion has two primary negative impacts: it invariably degrades the intrinsic productivity of the soil resource, and the sediment and associated plant nutrients detached from the land degrade water resources. Each of these impacts is reason-enough to seek to minimize erosion, and together they cause the phenomenon to have a significant impact on environmental quality and agricultural sustainability.

Water quality impacts: The federal Clean Water Act requires that states assess the health of surface water bodies and document those determined to be impaired by various forms of pollution. Of interest here are impairments caused by sediment and phosphorus pollution; these are usually linked because eroded soil particles are the predominant sources of both contaminants. The map below (Fig. 1) shows the water bodies recognized by the Wisconsin Department of Natural Resources (DNR) as so impaired (i.e., on the state's "303d list," named for the section of the Clean Water Act that requires this assessment). For the listed water body to recover and no longer be considered impaired, soil erosion must be significantly reduced. An increase in soil erosion for any reason will make more difficult removing sediment and phosphorus impairments, and could cause more water bodies to be added to the 303d list.

Soil resource impacts: Erosion degrades the soil body by removing material from the surface. The creation of soil from parent materials proceeds in large measure from the top down, as plant carbon inputs are greatest there and soil microbiological activity benefits from good aeration. Anthropogenic nutrient additions, as synthetic fertilizer or livestock manures are greatest there, as are N additions from leguminous plants. Formation of soil structure that facilitates root growth, water infiltration, and desirable water holding capacity is typically most advanced near the surface. In summary, the soil material at the surface is the layer most supportive of plant growth. Stripping away this topmost layer is a loss of natural capital. In extreme cases soil

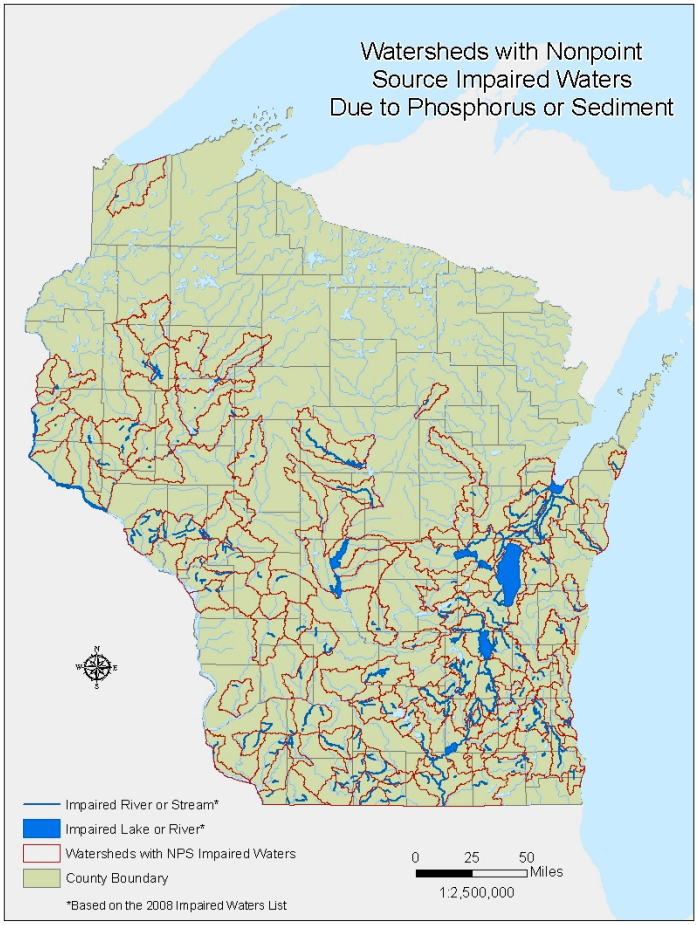

Figure 1. *Rivers, streams, and lakes that are officially recognized as impaired by excessive inputs of sediment or phosphorus.*

erosion creates gullies that interfere with farm machinery operations and early work in soil erosion focused on this conspicuous damage.

The costs of soil erosion in terms of productivity and profitability are strongly site specific, however. There are compensatory phenomena at work, in that much of the eroded soil is deposited downslope, potentially increasing productivity there. At regional scales farmers may reallocate badly eroded lands away from annual crop production, and focus attention on less-eroded areas. Estimates of the relationship between erosion and productivity are highly dependent on experimental methodology and specific soil context. A meta-analysis of erosion-productivity experiments found that yield reductions of about 4% per 10 cm of soil loss were realistic; averaged over Wisconsin this amount of loss occurs over about 200 years at current rates. In a particular setting, however, greater impacts of soil loss can occur if root-restricting conditions deeper in the soil profile become limiting. The relationship is often such that as erosion continues through time to reduce topsoil thickness, yield losses may accelerate (Bakker et al. 2004). For the individual farmer, erosion increases the spatial variability of crop productivity, to the point where some areas of eroded fields may become unprofitable to cultivate.

Research on the agricultural implications of soil erosion to date have emphasized productivity. In the face of global change, however, this is a quite narrow view. Averaged over Wisconsin's farmlands, it seems likely that agronomic choices (variety, fertilizer, pest management) can largely compensate for productivity losses caused by soil erosion. However, the costs of this productivity in terms of net energy balance and greenhouse gas balance will likely be greater as a result of erosion. Future analyses of the costs of erosion must be broadened to include these sustainability issues (Bakker et al. 2007).

The amount of erosion from a field is often compared to that soil's "tolerable soil loss" (referred to as "T"), expressed in tons/acre. Concepts surrounding how much soil erosion loss might be considered acceptable emerged in the early 1940s, and became firmly established in soil conservation thinking in the late 1950s (Johnson 1987). Values of T are set and occasionally revised for soils widely used in agriculture by the United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS). The philosophical and scientific basis of T was disputed by the early 1980s and this criticism continues to the present (e.g., Montgomery 2007). Keeney and Cruse (1998) suggested that, "seldom has such an important policy been based on such a dearth of defensible facts." At the heart of the criticism is concern that values of T are too high to protect the soil resource for long-term productivity. Further, the concept of T was never intended to be protective of water resources. Nevertheless, virtually all existing state and federal regulations addressing soil erosion set T as a goal.

Why the Future Portends Problems

In the absence of appropriate adaptation actions, we expect that soil erosion in Wisconsin will more than double by 2050, compared with the 1990s, as a result of changes to hydroclimate (as discussed in more detail below). Farmers and conservationists have, as a result of many decades of experience, learned what must be done to keep the soil in place for the vast majority of rainfall events. This has been possible because of what is known as climate stationarity: the observation that, while variable, the climate remains within statistical boundaries. In the past decade, however, observations suggest that our knowledge of these boundaries, and perhaps the concept of stationarity itself, may no longer be reliable (Milly et al. 2008).

There is evidence that the hydroclimate is changing in ways that could increase soil erosion by water. Interpreting changes in heavy rainfall events and resulting soil erosion is not a straight-forward process. The relationship of soil erosion to hydroclimate is complex in that the total amount and maximum intensity of precipitation both play

significant roles. More general indications of a changing hydroclimate are increasing annual precipitation statewide and statistically significant increases in the number of days in which 1" or greater of precipitation occurred (Fig. 2, Kucharik et al. 2010).

Another relevant analysis of hydroclimate is the amount of precipitation experienced during the wettest 7-day period of each year (Fig. 3, Kunkel et al. 1999). These multi-day periods of rainfall potentially lead to saturation of the soil and thereby increased susceptibility to erosion by yet more rainfall.

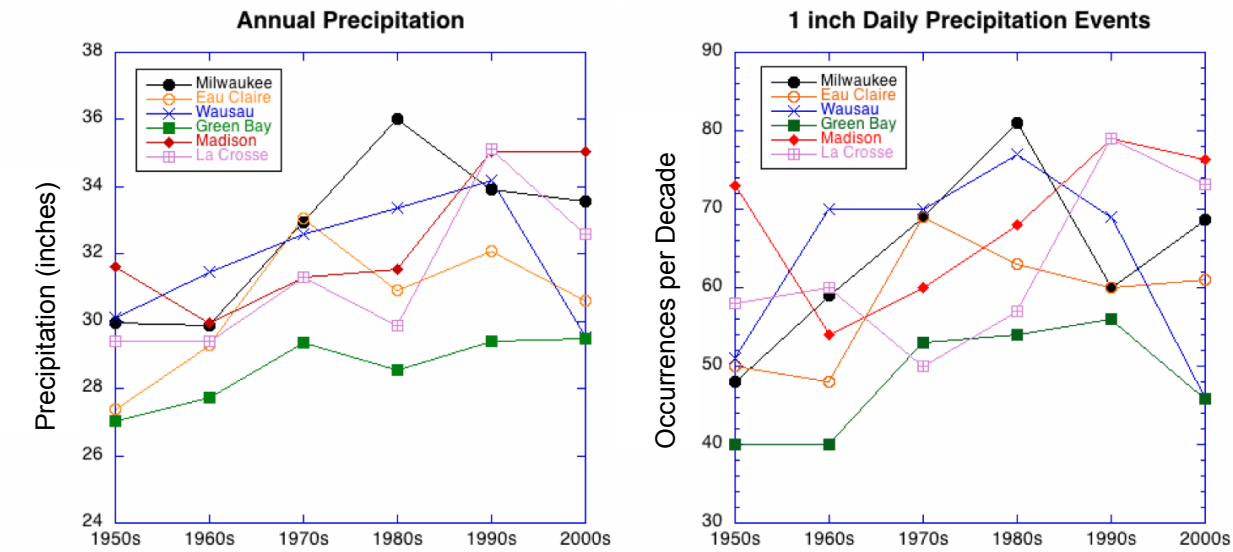

***Figure 2**. Precipitation trends at six Wisconsin cities, as analyzed by Kucharik et al. (2010). Annual precipitation has increased 5-15% since 1950 across the state. The occurance of daily precipitation events of 1" or greater was statistically significant only for Milwaukee and LaCrosse.*

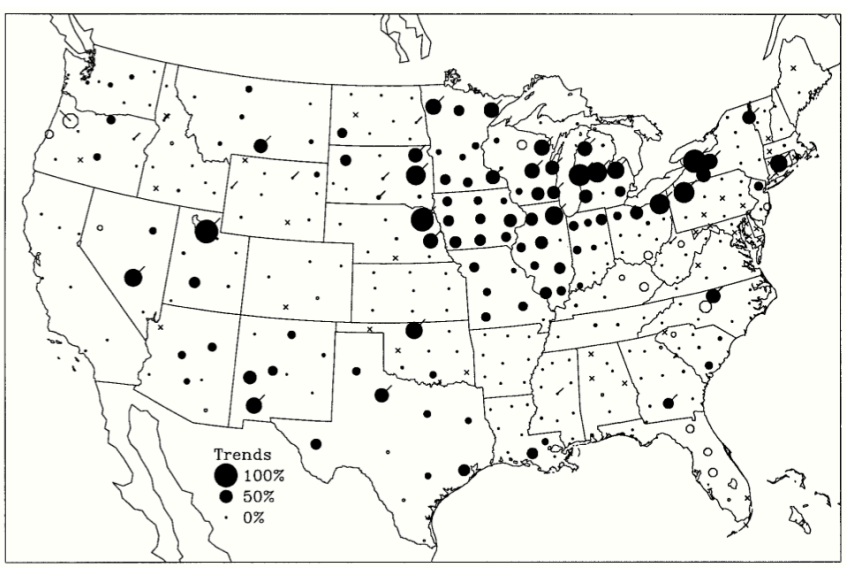

***Figure 3.** Changes in 7-day storm events with greater than 1-year recurrence intervals during the period 1931-1996, relative to the mean of the same period (Kunkel et al. 1999). In the upper Midwest, such events appear to be increasing in size.*

Some insight into the complexity of erosion is afforded by the Universal Soil Loss Equation (USLE - Wischmeier and Smith 1978). While the USLE has been superseded for most applications by the more realistic Revised Universal Soil Loss Equation version 2 (RUSLE2; Foster 2004), the simpler USLE considers essentially the same factors and is more easily envisioned. Predicted annual soil loss (A) with the USLE is a function of the equation:

$$A = R * K * LS * C * P$$

where R is the annual rainfall erosivity, which quantifies the effect of rainfall intensity, amount and seasonal distribution on soil loss; K is the soil erodibility, which indicates the soils inherent susceptibility to erosion; LS is a topographic factor that reflects the influence of slope length and steepness on soil erosion; C is a cover and management factor that characterizes the effect of cover and cropping system; and P is a factor that quantifies the effect of physical structures such as terraces or grassed waterways.

The expected change in future precipitation is reflected in the R factor. As a very rough approximation, R is equal to ¼ of the seasonal rainfall amount multiplied by the maximum 30-minute precipitation intensity; therefore, an increase in the size or intensity of storms could increase erosion even when the total seasonal precipitation is similar. The observed and projected increases in large storms suggest that substantial increases in R are likely.

There are a number of soil erosion models that have been used to assess possible impacts of changes to climate (e.g., Nearing et al. 2005). In perhaps the most relevant study for our purposes, O'Neal et al. (2005) used WEPP to consider (in USLE terms, although WEPP works differently) impacts on R from precipitation changes as well as planting date and crop rotation adjustments reflected in C. Their simulations anticipated new crop choices by farmers motivated by changing growing season length. (Future climates were based on simulations by the HadCM3 model running the IS95a scenario.) Results showed a likely increase in soil erosion for Wisconsin of 130 to 150% in the period 2040-2059 compared to 1990-1999. This 130-150% increase represents (to a first approximation) increases in the product R*C.

Vulnerability assessment for soil erosion in a changing climate requires ascertaining whether or not increased erosion potential associated with precipitation increases could be offset by decreases in C and P. Because factors K and LS are independent of storm climatology, and changes in P involve costly construction of physical structures, offsetting changes in C offer the best hope for compensatory action. An increase in residue cover from 30% (currently considered the minimum for soil conservation) to 70% can reduce the C factor by seven times (700%), while increasing cover from 0% to 70% leads to a 20-fold reduction in C (2000%). With a corn-soybean rotation, using no-till planting versus conventional tillage reduces the C factor by nine times (900%). Thus C is a powerful tool for reducing soil erosion. Changes to cropping in Wisconsin over the past decades (Fig. 4) however are increasing the potential for soil erosion. From the RUSLE2 model the C factor for fall-tilled soybean is about 0.3, while hay crops such as alfalfa-brome have C of 0.03 (averaged over the seeding and second year) and for continuous grass hay C is about 0.001. As shown above, erosion is to a first approximation a multiplicative factor of C, so crop choice can make orders-of-magnitude differences.

In summary, projections of global change simulations combined with erosion models indicate that in Wisconsin soil losses will more than double from that of the 1990s by 2050 without increased implementation of soil conservation practices.

Soil Conservation Work in Wisconsin

Conservation of the soil resource is an extraordinarily complex challenge that entails climatology, the physics, chemistry and biology of soil, geomorphology, economics, water quality criteria, and farmer behavior, both individually and collectively. The relative merit of proposed adaptations to climate change can only be considered in light of this

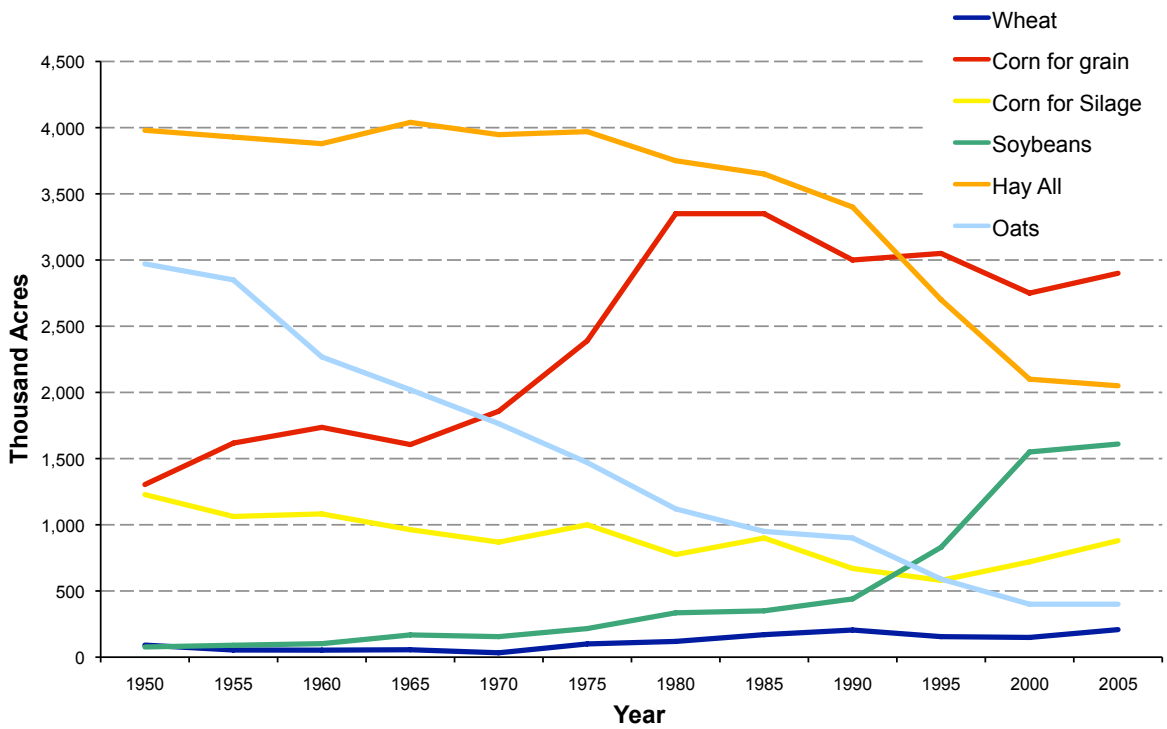

Figure 4. *Areas of major crops in Wisconsin, 1950-2005. The conversion of land planted in hay to corn and soybeans increases the potential for soil erosion.*

complexity, so here we provide an introduction to the multiple facets of soil conservation work in Wisconsin. We begin with the available measurements of erosion, and then review the institutional context of conservation policy, assistance, and education.

Quantifying soil erosion in Wisconsin: The USDA-NRCS conducts the National Resource Inventory (NRI; http://www.nrcs.usda.gov/technical/NRI/) to assess land use and soil erosion across the nation. The data are based on a series of fixed monitoring points established in 1980. At 5-year intervals the points are revisited to document changes in land use, cover and management. The most recent results available are for 2007, released in April 2010 (Table 1). Soil erosion by this measure decreased from 1982 through 1997, but has since been increasing. Work related to the Wisconsin Buffer Initiative (Diebel et al. 2008) delineated about 1,600 watersheds in the state and estimated annual sediment load to surface waters from each (Fig. 5). For comparison, 1 ton/acre (the common US measurement unit for soil erosion) equals 224 tonnes/km^2. The mapped loads are all considerably less than the average load estimated by the NRI, because much eroded

Table 1. *Sheet and rill erosion averaged across Wisconsin, USDA-NRCS-National*

Year	Avg. Soil Loss (tons/(acre*yr))
1982	4.64±0.13†
1987	4.11±0.08
1992	3.88±0.11
1997	3.72±0.08
2002	4.19±0.16
2007	4.44±0.25

†mean ± 95% confidence interval

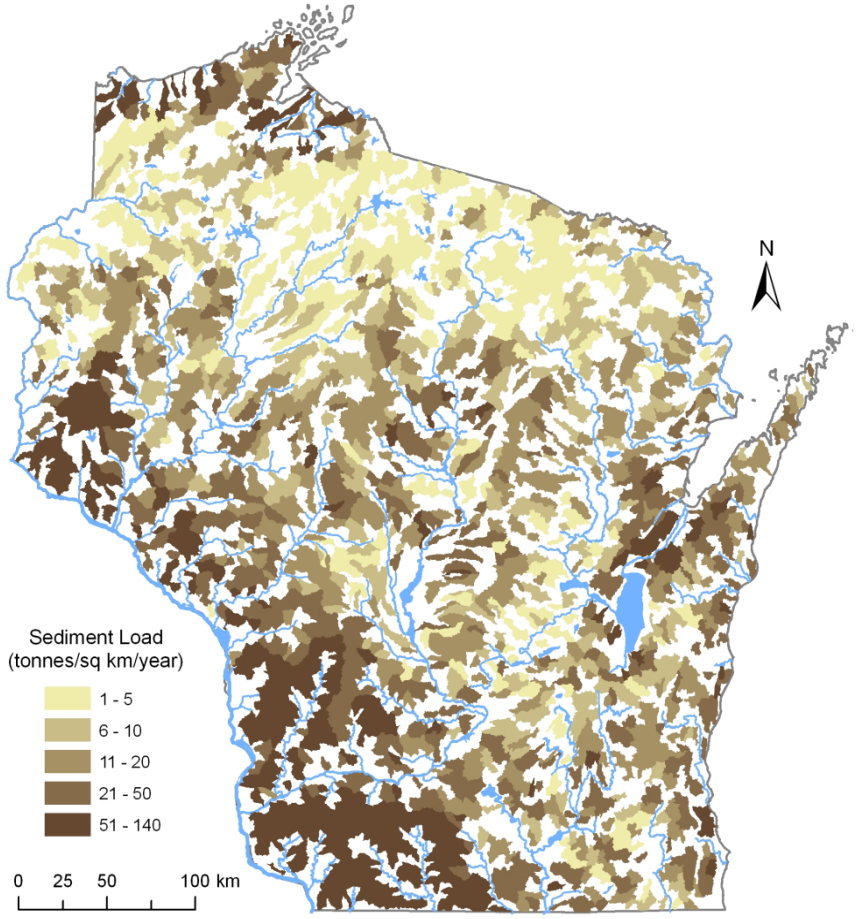

Figure 5. *Estimates by Diebel et al. (2009) of sediment delivery rates to watershed outlet (1 t/acre = 224 tonnes/sq km).*

soil is deposited elsewhere on the landscape before reaching a water body.

An additional measure of soil conservation in Wisconsin is provided by the "Transect" process administered by the Wisconsin Department of Agriculture, Trade, and Consumer Protection (DATCP) and conducted in the field on a county-by-county basis by local Land Conservation Department (LCD) employees. Here an analysis much like that for the NRCS NRI is performed, i.e., a sample of fields is visited, practices observed, and a model used to estimate erosion (Fig. 6). The fraction of sampled fields estimated to be eroding no more than T has remained steady at about 80%. Note that the number of counties participating in the Transect data collection is decreasing steadily.

At the core of soil conservation in Wisconsin (and the United States) is voluntary adoption of appropriate practices by farmers. The practices on the land that we refer to as soil conservation work include cropping and tillage practices, as well as laying-out of fields, land shaping, and engineered structures (Box 1, UWEX 1998). Beginning in the 1930s the federal government became engaged in the problem, through research, demonstration, education, and providing financial and technical assistance to individual farmers. To this day governments at the federal, state, and county level provide technical assistance (engineering design and consultations) and financial incentives, known as "cost-sharing." Cost-sharing provides incentive to adopt preferred practices by funding substantial fractions of capital investments, and in some cases for

Box 1. Soil Conservation Practices Common in Wisconsin (based on UWEX 1998).

Practice	Description
Crop rotation	Planting of a sequence of species through the years to reduce soil loss, but meet farm needs
Crop residue management	Tillage practices that leave residues on top of the soil, rather than bury it
Contour farming and strip-cropping	Tilling and planting across the slope, following the contours of the land, and planting crop in alternating bands of species that permit more or less erosion
Contour buffer strips[1]	Permanently planted strips along the contoured field
Cover crops	Temporary, fast-growing species that protect the soil between main crops
Field borders	Planting the ends of fields in perennial species
Grassed waterways[2]	Shaping a natural drainage-way and establishing grass to prevent gullies from forming
Grade stabilization structures[3]	An earthen, concrete, or other structure built across a drainage-way to prevent gully erosion
Water and sediment control basins	Small earthen embankments built at the bottom of a drainage-way to temporarily store run-off
Critical area plantings[4]	Planting perennial species in small, badly eroded areas
Diversion[5]	Earthen embankment and channel, constructed across the field slope, to collect and divert water to a stable outlet
Terraces	Earthen embankments that follow the hillside contour, breaking a long slope into shorter segments

Photos USDA-NRCS Wisconsin website

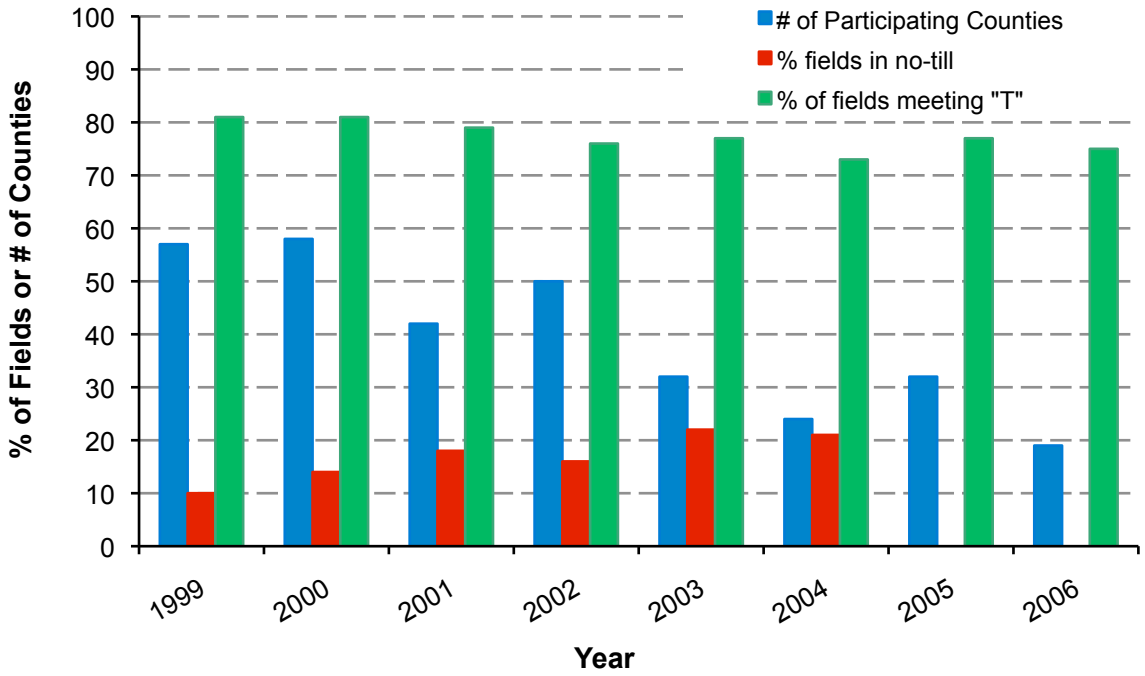

Figure 6. *Results of the WI-DATCP "Transect" survey.*

the extra time required to conduct the practice.

Public agencies engaged in encouraging soil stewardship in Wisconsin include:

- United States Environmental Protection Agency (EPA)
- United States Department of Agriculture-Natural Resource and Conservation Service (NRCS)
- United States Farm Service Agency (FSA)
- Wisconsin Department of Agriculture, Trade and Consumer Protection (DATCP)
- Wisconsin Department of Natural Resources (DNR)
- Land Conservation Departments based in county governments (LCDs)
- University of Wisconsin-Extension (UWEX)

Increasingly, civil society organizations, e.g., River Alliance of Wisconsin and Trout Unlimited, are playing a role in connecting farmers with government-provided assistance and cost-share funds. The roles and relationships of these actors overlap and slowly evolve with changing laws (Fig. 7).

At the federal level the agency responsible for soil conservation—originally the Soil Erosion Service, later the Soil Conservation Service, and now the Natural Resource Conservation Service—was formed in 1933 and did some of its earliest work in the Coon Creek watershed in Wisconsin. The EPA was given responsibilities related to soil erosion with the 1972 Clean Water Act, which charged the agency with monitoring and ameliorating water quality impairments arising from a wide range of sources. Some funding in support of soil conservation as related to water quality flows from EPA to DNR. The FSA administers the Conservation Reserve Program, which contracts with land owners to maintain certain lands in perennial vegetation cover.

Various Wisconsin laws and administrative rules grant responsibilities to DNR and DATCP to provide cost-share funds to landowners, financially support LCDs, and to enforce rules related to soil conservation. A review of state regulations and funding related to soil conservation programs is available in Pollek (2007). The state of Wisconsin has some limited power to intervene in the face of egregious soil erosion, but this is rarely exercised.

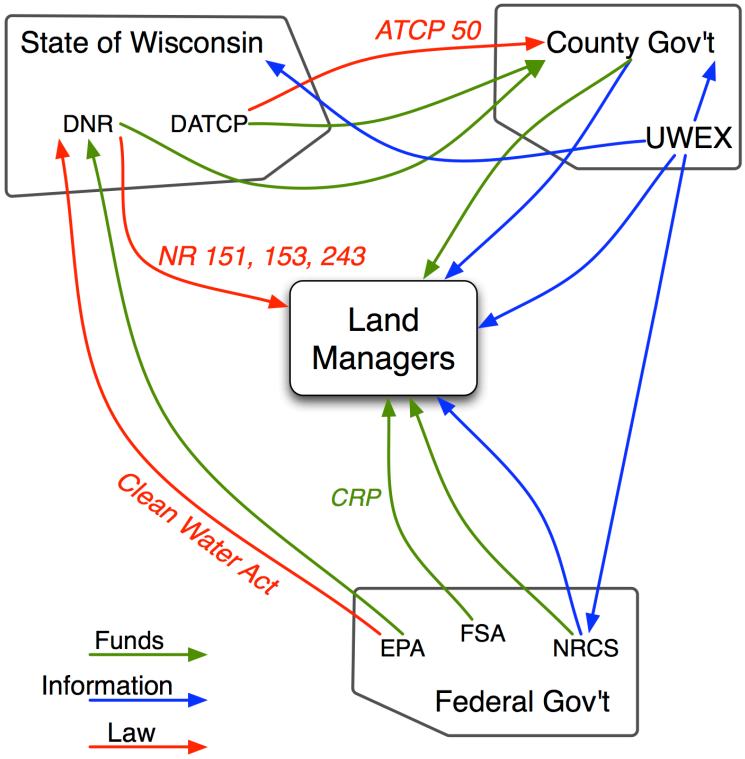

***Figure 7**. Institutional relationships in soil conservation work in Wisconsin. Federal agencies involved include the Environmental Protection Agency, the Natural Resource and Conservation Service and the Farm Service Administration. The Wisconsin Departments of Natural Resources and of Agriculture and Consumer Protection both play large roles. County government Land Conservation Departments work with farmers, and University of Wisconsin-Extension provides technical training to nearly all parties.*

The vast majority of one-on-one soil conservation work with farmers is done by employees of the county-based LCDs and by field personnel of the NRCS. County LCDs employed 371 staff members in 2008, although it is not possible to know how much of their time was spent on soil conservation work. The NRCS has about 180 field and area office staff members who directly assist landowners with design and installation of conservation practices, and helping these landowners avail themselves of financial resources in support of these practices.

The county programs are overseen by DATCP's Soil and Water Resource Management (SWRM) Program. Every five years each county is obliged to conduct a process to identify conservation priorities and plans for addressing these. The resulting document is a Land and Water Resource Management (LWRM) plan. Plans are created in consultation with DNR and must be approved by DATCP. The LWRM plans provide the vehicle by which funding (from federal and state agencies) is made available to the counties. Each county is also obliged to report annually to DATCP on soil conservation activities.

Human resources dedicated to soil conservation vary greatly among counties. State Statue 92.14(6)(b) contains a goal of three staff in each county, but this is far from being met, and the situation is worsening. Lack of staff is the most-commonly cited limitation to greater soil conservation effort by counties (Fig. 8).

The financial investment made in agricultural soil conservation has been reasonably stable for the past 10 years, at nearly $80,000,000 annually. Roughly half of this is in the form of land rental payments from FSA to landowners who have enrolled in the Conservation Reserve Program. Wisconsin

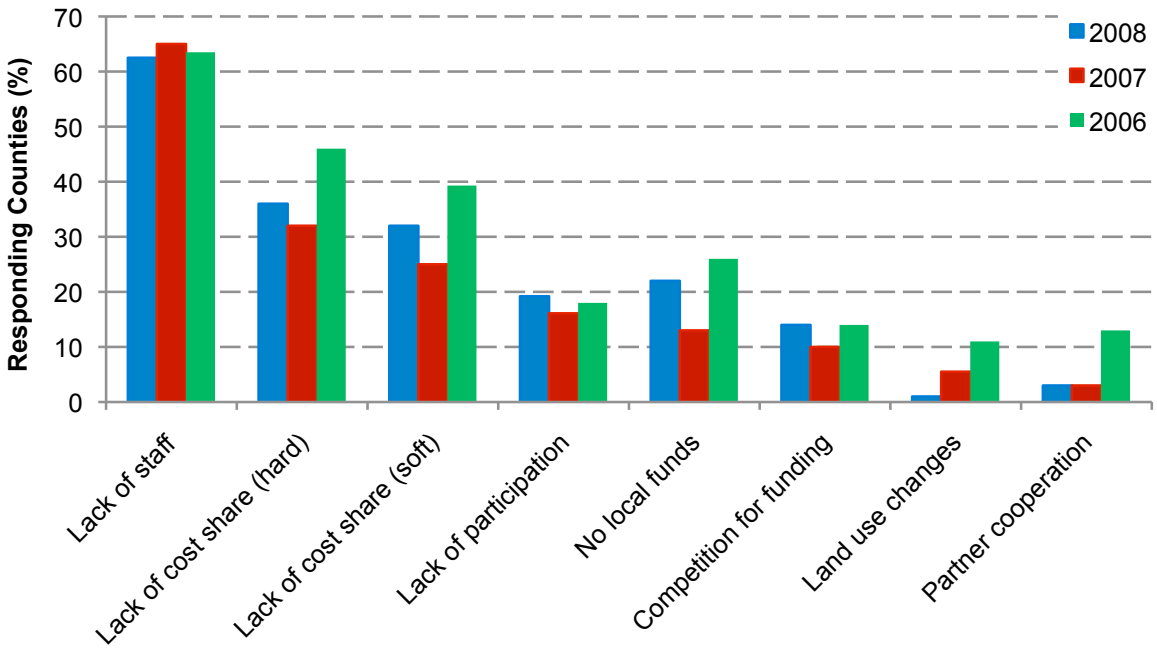

***Figure 8**. Frequency at which various categories of limitations to more effective soil and water conservation are cited by counties (Holden and Schell, 2008).*

DNR and DATCP spend about $20,000,000 annually for county staffing and payments to farmers for adopting practices ("cost-share" funds). Federal cost-share programs through NRCS contribute about $4,000,000 and county funding for staff is about $14,000,000 annually. Note that the staffing costs incurred by federal and state agencies and UWEX are not included here.

The University of Wisconsin-Extension has played various roles in soil conservation research and demonstration, although their work is now much reduced and consists primarily of providing training to staff of the other institutions involved. The early history of UW contributions (and more generally soil conservation in Wisconsin) was chronicled by Johnson (1991). He credits the effort of Professor Otto Zeasman who in the 1920's began working with farmers and others on erosion control, and secured the Upper Mississippi Valley Erosion Experiment Station that was located near LaCrosse. This station was instrumental in developing some of the early concepts of the Universal Soil Loss Equation.

In the late 1970's Dr. Tommy Daniel of the Soil Science Department utilized newly available funding from the state directed at non-point pollution to develop a program that included applied field research in tillage management and erosion control. His program also included an active outreach effort that resulted in the creation of numerous factsheets and journal articles on tillage management and nutrient runoff. Daniel was replaced by Dr. Wollenhaupt, who continued these efforts until 1995, after which his position was not refilled. Currently Dr. Richard Wolkowski, a staff member in Soil Science, includes in his diverse range of activities an applied research program promoting adoption of strip-tillage, a conservation tillage practice that capitalizes on the benefits of no-till and full-width tillage systems. Soil conservation extension programming is also conducted by Dr. Pete Nowak, a rural sociologist in the Nelson Institute for Environmental Studies, and by Drs. John Panuska and Matthew Digman in the Department of Biological Systems Engineering. However, there has not been a UW program dedicated to research and demonstration of soil conservation practices since 1995.

Adaptation Strategies

"I plead for positive and substantial public encouragement, economic and moral, for the landowner who conserves the public values—economic or aesthetic—of which he is the custodian. The search for practicable vehicles to carry that encouragement is a research problem, and I think a soluble one. A solution apparently calls for a synthesis of biological, legal, and economic skill, or, if you will a social application of the physical sciences….

"The private landowner would still decide what to use his land for; the public would decide merely whether the net result is good or bad for its stake in his holdings."

Aldo Leopold (quoted in Meine 1987)

Our long-term goal, even in the face of a changing climate and new demands of the land, should be to eliminate sediment and associated nutrient impairments of our surface waters and to maintain the productivity of Wisconsin's soil resource. Soil conservation and water quality are compatible with current and emerging expectations of Wisconsin's farmlands, **provided that practices we largely know how to do are widely implemented by our farmers.** The changing hydroclimate and increasing demands for food and energy crops makes this a considerable societal challenge, but one that appears doable, given the will.

Our adaptation strategies seek to **adjust and strengthen the public-private collaboration that since the 1930s has been central to minimizing soil erosion.** Experience demonstrates that land managers hold a wide range of attitudes about their roles in stewardship of soil and water resources. Today's agricultural economy often forces farmers to make short-term decisions that may be necessary for survival of their business, but are not protective of soil and water resources. Additionally, a substantial fraction of croplands (about 30% in 2007, Census of Agriculture) are now leased on short-term contracts, so many operators lack incentives for investments in soil conservation.

Adaptation is often narrowly conceptualized as "a set of technological or technical options to respond to certain risks" (Nelson et al. 2007). Indeed, in the face of a changing hydroclimate in Wisconsin it is logical to first consider the potential biophysical effects of that change, and the practices that can be deployed to prevent or counteract those effects. However, given the institutional complexity of soil conservation in the state (Fig. 7), this deployment is necessarily tied to organizations, policies, and their relationships with one another. Nelson et al. (2007) more broadly define adaptation as "the decision-making process and the set of actions undertaken to maintain the capacity to deal with future change or perturbations to a social-ecological system without undergoing significant changes in function, structural identity, or feedbacks of that system while maintaining the option to develop."

The reasoning behind our proposed adaptation strategies stems from an observed and expressed need to improve the adaptive capacity of our institutions to guide and support land managers as they work to conserve soil. In the context of climate change, "Successful adaptation in effect entails steering processes of change through institutions, in their broadest sense. For adaptation to be successful, institutions clearly need to endure and be persistent throughout the process of adjustment and change" (Nelson et al. 2007). This extends beyond the realm of climate change and into that of changing demands on the landscape for food and biofuel production. In light of both of these external forces, and the likelihood of others in the future, a strategy for soil conservation has institutions at its

core. This is not to say that the complex institutional landscape of soil conservation should be preserved as it is now, but rather that attention must be given both to enabling land owners and the institutions that serve them to adapt to future climates.

Our strategies address what we believe are four major components of any soil conservation effort: *Strategy*, *Practice*, *Monitoring*, and *Evaluation*. We found that this framework assisted us in granting appropriate attention to the diverse issues that appear relevant to adapting soil conservation to a changing climate, e.g., 'how effective is no-till?' and 'does county-based programming work?' Each is described briefly below, with examples of issues that might fall in each.

Strategy addresses the social processes and strategic choices made in designing and implementing a soil conservation program. Included are, for example, the planning processes used to establish goals and methods, the metrics used to determine success (e.g., erosion as estimated by RUSLE2), allocation of financial and human resources to the effort, and roles and relationships among governmental and civil society institutions and land managers. The design of compliance measurement systems might also be a part of the planning process.

Practices address the agronomic and engineering choices prescribed as soil conserving, and the degree to which they are adequate to reach the goals of the conservation program. These are field-level practices, including residue management, tillage, and contour plowing, as well as engineered landscape strategies including terraces, grassed waterways, and lanes (Box 1).

Monitoring seeks to determine the extent of the adoption of soil-conserving behaviors and the degree to which desired outcomes are met. Monitoring includes both measurement of adoption for program evaluation and compliance for enforcement purposes. As noted above, designing the compliance assessment methodology is part of program Strategy.

Evaluation: Because soil conservation is a complex biophysical and psychosocial phenomenon, more than monitoring data are required for informative assessment of programs designed to improve it. Program success is presumably a function of both the relevance and feasibility of the practices from the perspective of the farmer, and the appropriateness of the implementation strategy; evaluation seeks to provide insight into the relative importance of these factors. The contemporary practice of program evaluation seeks to provide decision makers with nuanced assessments of the degree to which outcomes were obtained, the unintended outcomes (good or bad), cost-benefit ratios by various measures, and important contextual issues that helped or hindered reaching stated objectives.

These four components of soil conservation work are interconnected in numerous ways (Fig. 9), and there are opportunities for adaptations based in each but with impacts on the others. *Strategy* specifies both practices and the monitoring programs that will measure compliance and, later, help evaluate the program in question. The specified *Practices*, if they are appropriate, enable compliance on the part of farmers. *Monitoring* data is essential for meaningful evaluation efforts. Finally, *Evaluation* work helps stakeholders (e.g., farmers, politicians, planners) assess the full range of components of a soil conservation program,

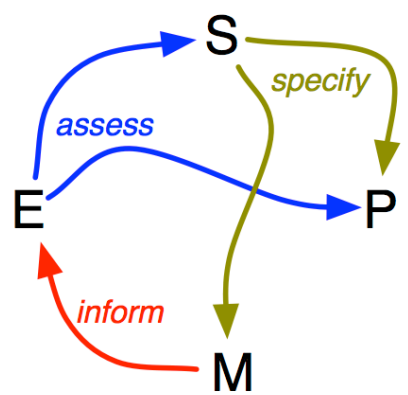

Figure 9. *Four components of soil conservation work: S-Strategy, P-Practices, M-Monitoring, and E-Evaluation. Holistic design and evaluation of any soil conservation effort should consider all four.*

from how the planning process was conducted to the performance of practices in the field.

Adaptation Strategy #1
Strategic Reconsiderations

1a. Develop new metrics for sustainability of soil and water resources. The current standard for acceptable soil erosion loss is the soil-specific value of T, the "tolerable soil loss," as estimated by NRCS. The T concept has long been debated, but arguably represents a compromise between what will actually sustain the soil resource and what is thought to be achievable in practice (Johnson, 1987). Refinements to the T concept (Larson 1981, Li et al. 2009) should become an area of active research, in light of changing hydroclimate and increased expectations about water quality. The research community should work diligently to come to agreement on new metrics.

Justification: On many soils a loss rate of T will result in soils being unsuitable for the cropping systems currently on those soils in a few generations. Using existing research knowledge from measurements and models of soil loss, profitable agriculture is possible with soil loss rates that are much less than T, so T should no longer be our goal. Additionally, there is no reason to assume that T is protective of water quality. County conservationists and others (Appendix) expressly mentioned the concern that T as currently defined is insufficient to meet water quality standards. We recognize, however, that we must continue to use T as an interim goal.

1b. Fully utilize and expand cross-compliance provisions and recognize that additional regulatory tools are required. Cross-compliance refers to provisions in law that require landowners who receive government benefits (e.g., crop price supports or preferential tax treatment) to meet specified soil conservation goals. Additionally, new regulatory tools are needed to improve our ability to identify and target poorly managed lands.

Justification: Both state and federal law specify cross-compliance requirements, but it is unclear that such programs are carried-out effectively (EWG 2007). Since government programs often subsidize agricultural activities, this financial investment should come with the expectation that recipients employ excellent soil conservation practices. Although soil conservation work is overwhelmingly voluntary, experience shows that there are inevitably some land managers who cannot or will not adopt practices protective of soil and water. Phosphorus and sediment loading to water bodies in a watershed occurs predominately from a relatively small portion of the landscape (e.g., Gburek et al. 2000), so cooperation of the managers of those portions is critical to the success of a soil conservation and water quality improvement effort. Cross-compliance has been part of federal soil conservation programs for decades. The newly-adopted Wisconsin Working Lands Initiative requires conservation compliance, including soil erosion control on cropland, in order to receive tax credits of up to $10/acre. Visits will be made to enrolled lands every four years by county personnel, and there will be DATCP audits of these visits. These conservation compliance requirements will apply to approximately 18,000 farms in WI (more than 50%).

1c. Provide the human resources necessary for facilitating broad adoption of the practices we know can reduce soil erosion, and to assure compliance with existing rules.

Justification: Implementation and compliance assurance of soil conservation programming is labor intensive. Counties consistently cite lack of staffing as the first impediment to greater success in broadening adoption of soil conservation. Additionally, assuring compliance of the regulations and programs already in place requires more field staff than most counties now have in place. If eliminating sediment impairment of waters and maintaining the soil resource are priorities of Wisconsin citizens, we must provide adequate expertise. Wisconsin's new Working Lands Initiative is an example of a new human resource-intensive program, and

Box 2. An Experiment in Targeted, Watershed-Based Programming

Photo: Bob Hansis

Pecatonica River: Wisconsin Buffer Initiative Pilot Project

An experiment is taking place in southwest Wisconsin that could improve water quality in streams more efficiently and effectively. One of the challenges facing landowners and managers in Wisconsin and nationwide is keeping sediment and nutrients on the land and out of streams. Is there a way to target efforts to improve water quality so they have the greatest impact at the lowest possible cost? Farmers, University of Wisconsin scientists, public agencies and The Nature Conservancy through the Great Rivers Partnership are working together to answer this question. Known as the Wisconsin Buffer Initiative (WBI), the group hopes to improve water quality by using science to target conservation efforts on those fields and pastures with the greatest potential for contributing nutrients and sediment to streams. WBI is testing this approach in one watershed—the Pecatonica River watershed in southwest Wisconsin. If successful, the partners will look for opportunities to implement it more broadly across the state.

Targeting Conservation Practices Where Most Needed

Using research by a University of Wisconsin-Madison graduate student and Dane County Land and Water Resources Department conservation staff, the partners have identified a handful of farms in one of the watersheds that contribute comparatively large amounts of phosphorus and sediment to the stream. Dane County conservation staff are working with these farm owners to identify alternative management practices, including different types of tillage, crop rotations and manure handling that will reduce the amount of sediment and nutrients entering the stream.

The goal is to identify conservation practices that are compatible with the farm's current cropping and livestock system and, where possible, increase or don't significantly reduce profitability. Dane County has secured funding to help farmers implement needed changes that aren't financially feasible. It will take several years for conservation practices to be fully implemented and begin to show results. Ultimately, however, the partners hope to demonstrate that targeting conservation practices where most needed will result in significant water quality improvements and be the most efficient and effective use of limited resources.

"It seems straightforward," says Pete Nowak, WBI Chair. "But it's actually a very innovative approach to water quality improvement that is not currently being utilized in the United States."

If they are successful, the partners believe their research will create tools that streamline implementation of targeted conservation efforts in other watersheds. Their data will also be valuable to the agricultural community and other decision-makers in re-shaping public policy related to water quality management not only in Wisconsin but across the nation.

Condensed from: http://www.nature.org/wherewework/northamerica/states/wisconsin/files/pecatonica_river_fact_sheet.pdf

it is not clear that staffing is adequate to meet these expectations, in the counties or at the state level.

1d. Revisit public policy surrounding subsidies for soil conservation practices. How much other sectors of the economy should pay farmers (or contribute to costs) through cost-share programs is a challenging philosophical question. There is no right or wrong answer, but the debate should be revisited regularly.

Justification: Financial incentives for land managers to follow some practices (and so avoiding others) has a long tradition in soil conservation efforts at the federal, state, and county levels. In spite of over $80 million in annual expenditures directed primarily at sediment and P loading reductions, erosion rates are increasing (Table 1) and little, if any, progress is being made on removing impairments from water bodies. Additionally there is concern that requirements for cost-sharing may limit implementation of improved practices if requests for assistance were to increase. Perhaps subsidies should be for permanent changes to land management only, with adequate enforcement to assure that these public expenditures continue to deliver public good.

1e. Expand watershed-based programming efforts, with appropriate targeting of hydrologic units, farms, and fields. A targeted watershed strategy firstly places priority on those water bodies that most urgently need improved soil and water conservation, then further focuses resources on lands in the watershed that most affect water quality.

Justification: The alternative to watershed, farm, and field tageting is what is largely done now, that is to work with the land managers in a political jurisdiction who are willing and interested in taking advantage of soil conservation activities. This tends to scatter accomplishments over multiple watersheds (Nowak 2009). Unfortunately, water quality is a highly non-linear response to land management, so we cannot expect clear improvement until a quite high adoption rate of necessary practices is attained. Diebel et al. (2009) estimated that targeting soil conservation practices in the 10% of Wisconsin watersheds yielding the most sediment could reduce the statewide loading of this contaminant by 20%. Thus targeting can dramatically improve cost-effectiveness of soil conservation. Finally, the watershed approach focuses on the stakeholder group whose widespread cooperation is essential—the landowners. The creativity and local knowledge of this group should be encouraged and made a central part of planning to reach water quality objectives. Thus there are both biophysical and social reasons that a watershed-based strategy offers the best chance of attaining water quality goals.

Adaptation Strategy #2
Practices

2a. Expand adoption of accepted soil conserving field practices. We currently possess a powerful set of tools to minimize soil erosion, but these are not near fully exploited.

Justification: The projection of more than a doubling of erosion from the O'Neal et al. (2005) study may seem large to the uninitiated; however, this projection is based on the assumption that tillage practices remain unchanged. Even modest changes in tillage and surface-residue management could easily offset this projected increase.

Clearly the projection of increased erosion in the future is something we should take seriously, because our current soil loss rates are excessive and greater loss will be more so. A greater effort should be made to implement practices that we already know are capable of reducing soil loss to T/5 or T/10. For example, converting a conventional tillage system to no-tillage can reduce soil loss by a factor of 3 to 10 in the first year and by another factor of 2 over the next 7 years; this amounts to roughly a 1000% decrease in soil erosion. Note, however, that this assumes a permanent conversion to no-tillage farming, with attendant changes to soil structure. Policies should recognize and encourage such permanence. Even without

eliminating tillage, increased residue cover can accomplish similar reductions in erosion.

Perhaps an important tool for this proposal is expanded research and demonstration of alternative soil management methods in portions of the state in which adoption of newer technologies lags. No-till equipment continues to evolve and more widespread research and demonstration may be quite cost-effective in helping farmers discover technologies that will work for them. We note that UW-Extension has dramatically reduced its work in this area in the past two decades (Nowak 2009).

2b. Research strategies for objectively and efficiently identifying portions of the landscape that should be maintained in healthy, full-cover perennial vegetation, and develop programs to encourage returning these areas to this condition. Specific portions of the landscape contribute disproportionately to water quality degradation, and planting these lands to perennial vegetation may be by far the best strategy for eliminating the pollution from these areas.

Justification: The Conservation Reserve Program and the practice of critical area plantings seeks to eliminate tillage on these highly erodible parts of the landscape. Unfortunately, CRP contracts are only for 10 or 15 years. Permanently eliminating tillage on highly-erodible lands could be fostered by developing alternative enterprises such as bioenergy feedstocks or managed livestock grazing. Bioenergy strategies will complement public policy and emerging markets for biomass supplies. Likewise, consumer interest in grass-fed beef provides a market premium for the products of carefully-managed grazing. Both opportunities will require research, demonstration, and organizing partnerships that would make them attractive to a neighborhood of farmers. Additionally, enforcing water quality standards will help foster appropriate action.

2c. Undertake research to enable more inclusive accounting of the costs and benefits of soil management choices. Soil management decisions have implications for greenhouse gas and energy balances of agriculture, infiltration of precipitation into soil, and interannual variation of yield in the face of hydroclimate variability. A richer understanding of these interactions is needed to inform policy related to public investments in soil conservation and management.

Justification: Research in soil conservation to date has focused on the erosion-productivity relationship and the efficacy of practices at reducing erosion. In the face of climate change we need to broaden our understanding of the costs of soil erosion in terms of greenhouse gas and energy balances, as influenced by, e.g., fertilizer use, tillage. Further, potential increases in erosion resulting from residue removal for bioenergy purposes has been identified as a concern (Cruse and Herndl 2009), but this biomatter may have other impacts on soil dynamics, e.g., meiofauna dynamics and infiltration, that are not yet adequately appreciated. Soil management choices—such as harvesting crop residue, or not planting crops along field contours—may also have implications for yield stability in the face of hydroclimate variability. It is time to broaden the soil management research agenda to capture more of the complexity of provisioning our species and mitigating greenhouse gas emissions.

Adaptation Strategy #3
Improve Monitoring

3. Develop systematic, transparent, and accessible monitoring programs for soil conservation and its impacts on water quality. Currently available data are inadequate to know what we are doing well and where our greatest failings are. Federal, state, and county governments all make modest investments in monitoring, but a lack of accessibility and uniform participation across the state greatly reduces the value of the results.

Justification: Soil conservation is a spatially-distributed, temporally-dynamic endeavor. Understanding what managers are doing across the landscape is a large challenge,

but such data are essential for both checking on compliance with legal agreements, and for subsequent evaluation of conservation programs. Current systems are inadequate. Wolf (1995) noted that most participation in voluntary non-point source pollution prevention programs is only evaluated immediately after the sign-up period and thus only measures *intended* participation, while not all participants implement the practices for which they are contracted. The USDA-NRCS NRI results could be more readily accessible to the public, and participation by Wisconsin counties in the "Transect" assessment has decreased markedly in recent years. The WDATCP's "T-by-2000" report made a similar call and Nowak (2009) pointed out that data on adoption of no-till are not available, for example.

The nature of this monitoring system will require careful study and design. Geomorphologists argue that the models most commonly used to estimate erosion often overestimate the rate of net loss from fields, and newer sediment-budget-based techniques are needed (Trimble and Crosson 2000; Boomer et al. 2008). Programs designed around observations of in-field practices and then estimating erosion using the RUSLE2 model do not account for formation and growth of gullies, a form of erosion that delivers large loadings to waterbodies. The DNR's water quality monitoring program provides the framework of a systematic approach to measuring sediment and P load, but there is no systematic way of relating these observations to soil conservation (or the lack thereof). More powerful monitoring systems might emerge from new efforts to link diverse measurements, e.g. residue cover in fields and sediment concentrations in streams.

Adaptation Strategy #4 Evaluation

4a. Conduct more evaluation work related to soil conservation. The biophysical and institutional complexity of soil erosion means that assessment of success and shortcomings requires thoughtful analysis. The tools of evaluation should more frequently be brought to bear on soil conservation challenges. Specifically, it is now time for an evaluation of state-funded, county-based soil and water conservation programs in Wisconsin.

Justification: The substantial public expenditures, institutional complexity, and evolving hydroclimate and policy contexts of soil conservation justify greater effort in understanding what works and why. The "Conservation Effects Assessment Project" (CEAP) is a large USDA effort at demonstrating the effectiveness of decades of soil conservation work. An external review of CEAP (SWCS 2006) concluded that, "…a coherent and science-based assessment and evaluation system is urgently needed…," but that the present effort was focused rather on performance measures. The goal of adaptive institutions and practices that meet our aspirations for clean water and conservation of the soil resource can only be realized if the feedback loop provided by evaluation is completed.

4b. Initiate an ongoing analysis of how bioenergy policies and changing production practices influences efficacy of soil conservation programs. An important driver of vegetation management on the landscape will continue to be bioenergy markets and policy, and its effects on soil conservation be given as much attention as changing hydroclimate (Cruse and Herndl 2009).

Justification: The corn ethanol industry grew rapidly and substantially increased corn demand, and, likely, resulted in setbacks in soil conservation. Similar progress toward cellulosic fuels or biomass combustion offers both potential and dangers to soil conservation. Perennial vegetation cover can protect soil, but excessive removal of biomass reduces crop residue and may impact soil structure and function. The policy, markets, and technologies associated with bioenergy must be appraised in an on-going way for their effects on soil conservation.

Summary and Conclusions

Soil conservation is a complex biophysical, social, and economic challenge. Recent measurements indicate that soil erosion losses are increasing, probably caused by a combination of cropping system changes, relatively erodible land being returned to cultivation, and, perhaps, changing hydroclimate. The major interactions in play are diverse and interconnected (Fig. 10). Climate change, both in temperature and precipitation has direct negative impacts on soil conservation, but new cropping options opened by changes to growing season length and temperature could conceivably contribute in positive ways. Expanded opportunities for bioenergy from croplands has both potential negative and positive impacts. Greater market value from perennial plantings has the theoretical possibility of encouraging this choice on erodible lands.

However, residue removal, expanded cropping onto highly erodible lands, and displacement of hay crops by annual crops can increase erosion.

Conservation research, education, and policy have the potential to improve soil conservation, through broadening the range of options available to land managers. New conservation reserve programs in a context of comprehensive enforcement of existing regulations might reduce cultivation of highly erodible lands. Perhaps land grant universities must return to programs of research, demonstration, and education on soil conserving practices.

While climate change and bioenergy endeavors appear on balance to negatively impact soil conservation, there are many on-the-ground practices and policy decisions that can prevent these issues from exacerbating soil erosion. The richness of this complex field promises as much opportunity as reason for concern—we have the ability to adapt soil conservation to a changing climate.

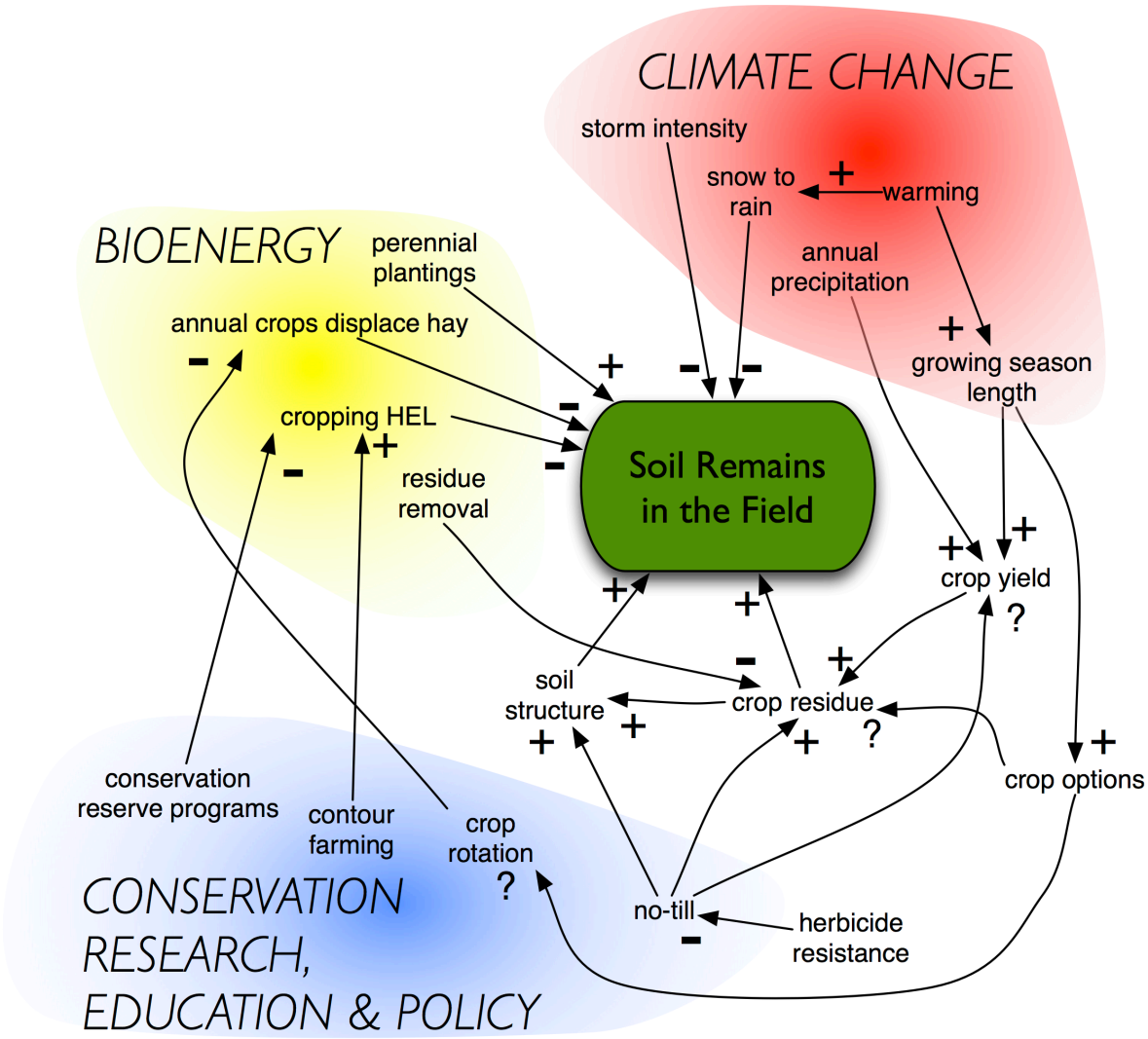

Figure 10. *Influences on the objective of soil conservation, i.e., keeping soil in the field and out of waters, indicated in the central green box. Factors that influence this goal directly, or indirectly through impacts on other factors, are connected by arrows. Arrows indicate the direction of influence, e.g., storm intensity influences the goal of keeping soil in the field, and the (+) or (-) sign by the arrowhead indicates the nature of that influence. Increasing storm intensity negatively impacts the goal of keeping soil in the field. In another example, soil structure has a positive influence on keeping soil in the field, and no-till croppping has a positive influence on soil structure. However, resistance of weed genotypes to the herbicides that are central to no-till systems negatively impacts no-till, and this negative influence propagates through to become a negative influence on soil conservation. Drivers of change are grouped into three major domains: Climate Change, Bioenergy, and Conservation Research, Education and Policy. The Bioenergy domain includes factors that policy and market choices can potentially impact. Investments and choices on the factors grouped in Conservation Research, Education and Policy can have a considerable impact on success toward the goal of soil conservation. (HEL refers to highly-erodible land.)*

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Appendix: Gathering Perspectives on Soil Conservation and Climate Change

Following the release of historical climate analyses and model projections of future climate change for Wisconsin, the WICCI Soil Conservation Working Group deemed it important to assess the concerns of a diverse set of actors throughout the state regarding soil conservation in the face of climate change. Beginning with interviewee suggestions from Working Group members, a snowball approach was used to identify additional participants. All interviews were conducted in October and November of 2009.

METHOD

Participants were asked the following five open-ended questions:

- How are you currently involved in soil conservation in Wisconsin?
- What is your understanding of how farmers are currently informed and incentivized to protect soil in the state?
- Given the latest data about the changing hydro-climate and future projections, what do you think will be the major impacts on soils in the state?
- What challenges will the changing conditions pose?
- From a soil conservation standpoint, what will be the most important issues to address moving forward?

Participants were allowed to respond as they saw fit, and some additional clarifying questions were asked.

In total, 17 individuals were interviewed, representing UW professors and researchers, UW-Extension staff, County Conservationists, DNR, NRCS, Wisconsin Land and Water Conservation Association, and two NGOs.

RESULTS

All participants believed that a changing hydro-climate, particularly increasing frequency of high intensity precipitation events, would lead to higher soil erosion rates, especially gully erosion on agricultural lands. After large storm events in the last three years, gullies are already forming in places they didn't exist previously. Other concerns mentioned were: loss of soil porosity; changes in soil chemistry with more or less percolation through the soil profile; resulting changes in vegetation and native plant communities; rate of organic matter decomposition in very wet/very dry soils and fertility implications. Some counties are seeing less overall rainfall, and thus concerned with lower soil moisture levels and less recharge to groundwater. However, as climate changes are not predicted to be uniform throughout the state, a significant emerging consideration is which parts of the state stand to be most severely affected by the changing climate with regards to soil conservation.

Economic and other pressures have resulted in changing land uses and cropping systems, often to the perceived detriment of soils. These include: CRP to row-crop/cash grain; dairy (alfalfa) to row-crop/cash grain and vice versa (depending on locale). There is concern that such transitions will continue, especially with high biofuel demand and an ailing dairy industry. In the context of anticipated climate changes, shifting cropping patterns and increased demand on the land base elicited comments from several participants about the long-term viability of keeping highly erodible lands in production.

All participants mentioned the abundance of programs and policies designed to protect soil in the state. While many of the federal and state programs and laws require land managers to have conservation plans and nutrient management plans (Farmland Preservation Program, CRP, CSP, CREP,

EQIP, Commodity benefits), many plans are outdated and there is generally poor enforcement. This is usually attributed to lack of human resources, particularly at the county level. Future concerns about institutions and policies centered on the adequacy of metrics used to write conservation plans, and whether required cost-sharing in the face of increasing requests for many practices would limit their implementation. Over half of the participants mentioned the Priority Watershed Program and watershed-level programs as an effective way of tackling the soil conservation challenge. They are concerned that the end of the PWP will only hinder future soil conservation efforts.

There is disagreement about the efficacy of specific types of practices for preventing or minimizing soil erosion. Particularly, the divide falls between field level management or “soft” practices and structural or “hard” practices. Most participants cited the importance of conservation tillage, mulching, contour cropping and/or strip cropping, and two went so far as to say given the age of these practices, they should be the minimum standard for at least corn and soy production. However some individuals voiced a strong opinion that structural practices like tile drains and various types of concentrated flow channels are ultimately the most important when anticipating high intensity precipitation events and that gully erosion will be the most significant problem (as opposed to sheet or rill erosion).

An additional area of disagreement is whether current standards, particularly for structural practices, are ample to withstand higher intensity events and only allow tolerable soil loss. As already mentioned, there is concern and uncertainty about who should bear the burden of the expense if standards are increased.

The need for comprehensive monitoring and assessment was repeatedly emphasized. We need to establish a standard measure or benchmark of where we are now, both with regards to soil erosion rates, and overall soil health. The state should then commit to not falling below those levels. A proposed institutional-based monitoring effort would monitor soil condition over time, to enable truly adaptive management. This would include establishing criteria to define overall soil health. The monitoring network could begin with plot work at the agricultural research stations and state scientific areas. However participants expressed uncertainty about which institution(s) should shoulder the responsibility.