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Soil erosion prediction for shaping conservation policy and practice

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In memory of Candace

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ABSTRACT

Scientific evidence guides public policy for improving the management of soil and water resources. With stronger scientific evidence, more informed public policy will lead to desired outcomes. The studies described in this dissertation use the Water Erosion Prediction Project (WEPP) computer model to address two soil erosion modeling issues. First, a statewide analysis of soil erosion in Iowa resulting from different corn stover removal rates is modeled to produce maps of soil erosion risk under various management scenarios. The results indicate that no–till is an effective practice for soil erosion control on sloping soils when maximum amounts of corn stover are removed from the field. However, maintaining adequate levels of soil organic carbon may be more of a constraint for stover harvesting than soil erosion on flat soils. Modifications to the WEPP user interface are needed to simplify soil erosion modeling with corn stover removal and site specific conditions. The second soil erosion modeling issue addressed in this dissertation is uncertainty of soil erosion and sediment load delivery predictions. The paper in Chapter 3 of this dissertation demonstrates a novel stochastic approach for explicitly quantifying prediction uncertainty using WEPP. Uncertainty of sediment load predictions is explicitly calculated using Monte Carlos simulation with stochastic climate variable inputs. Scientists, environmentals and farmers commented in focus group interviews that the stochastic analysis results helped them to better understand the uncertainty of soil erosion and sediment delivery predictions used to design control measures.

CHAPTER 1. GENERAL INTRODUCTION

Introduction

Soil erosion affects onsite agricultural productivity and offsite water resources. Computer simulation models of soil erosion and sediment transport help quantify the impacts, both positive and negative, of land management practices. The science behind soil erosion models, however, is tremendously complex and rot with uncertainty. Still, land managers need the best information possible to make good decisions.

The purpose of this dissertation and the individual papers contained in it is to provide new information about soil erosion potential in the emerging bioenergy landscape of Iowa through innovative application of existing modeling technology, to compare different methodologies for soil erosion prediction uncertainty, and to investigate the role that uncertainty plays in land management decisions on the farm and within the conservation policy arena. The Water Erosion Prediction Project (WEPP), Version v2006.5, computer simulation model (Flanagan et al. 2007) was the model chosen for this work. In the first phase WEPP is used to evaluate the impacts of corn stover removal in the state of Iowa using the Natural Resources Inventory (NRI) database for input parameters at the township level scale. The second phase of this dissertation is the development of a methodology for explicit quantification of uncertainty of sediment load delivery estimates using the geospatially interfaced version of WEPP, called GeoWEPP (Renschler 2003). Finally, a focus group study was conducted to gain insight into stakeholder perceptions of soil erosion prediction uncertainty. The results of this work are intended for an audience with interests in soil and water resources management and policy. One goal is to understand if and how different stakeholders use scientific information to support or oppose conservation policy positions. This effort will contribute to our community's better understanding of this complex issue, promote cooperation and provide an impetus for action to maintain soil productivity and improve surface water quality.

This General Introduction reviews the WEPP and modified Universal Soil Loss Equation (MUSLE) technologies, explains stochastic techniques and describes the NRI input data sources used to estimate soil losses and sediment load delivery. Lastly, a brief description of the focus group study method is included. This information provides fundamental concepts needed to understand the approaches used in the subsequent papers.

Soil Erosion Modeling

The complexities of natural systems present a great challenge for science. Soil erosion and sediment transport through the hydrologic system is particularly difficult to model because of the variability of soil and sediment particles themselves. Unique soil characteristics manifest themselves through particle size distribution, organic matter content and structure under different management conditions. Climate also affects soil properties in ways that influence its movement from the field and within streams and lakes.

The classical soil erosion prediction approach of the Universal Soil Loss Equation (USLE) is empirical, based on decades of data collected from research plots at various locations (USDA ARS 1996). The data reveal tremendous variability. Variability of soil erosion data results from the natural system itself, as well as from measurement variability. Understanding the limitations imposed by variability of soil erosion data, conservation science often depends on long term average soil erosion estimates in order to minimize the influence of individual event uncertainties. Annual soil loss tolerance (T) is most often used as a guide for meeting conservation goals. This approach may serve soil productivity interests if long term production is the primary concern. T, however, may not provide adequate protection against overall resource degradation due to soil erosion (Mann et al. 2002). Water quality is an important example. Nonpoint source (NPS) pollution by sediment and adsorbed chemicals resulting from individual storm events can create lasting effects on water quality. A new standard for acceptable rates of soil loss for water quality protection should be considered.

The empirical approach of the USLE requires exhaustive amounts of field data. Resources for collecting soil loss data for every condition are not available. The development and use of models based more on physical erosion processes and hydrological science has proved useful. The Water Erosion Prediction Project model, known as WEPP, is one example of a process–based model. WEPP allows the evaluation of soil erosion and sediment transport where site specific field data has not been collected, but where parameters can be estimated from data sources such as the soil survey. WEPP was selected for this work as the erosion prediction tool.

WEPP–The Water Erosion Prediction Project

WEPP is a physical process erosion prediction model that incorporates stochastic weather generation and is based on fundamentals of infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics (Flanagan et al. 1995). It estimates spatial and temporal distributions of soil erosion, sediment deposition and sediment delivery to a designated outlet. WEPP can be used to estimate responses to single storm events or compute daily, monthly, and average annual erosion by water. WEPP has been shown to predict soil erosion at least as well as USLE technology (Laflen et al. 2004). Because the model is process-based it can be extrapolated to a broader range of conditions that may not be practical or economical to field test (Flanagan et al. 1995).

The soil erosion and sediment delivery computation process begins with detachment and movement of soil from the soil surface area between the rills (interrill) into rills. In WEPP, sediment delivery from the interrill areas to the rills is proportional to the product of the rainfall intensity and the interrill runoff rate. The interrill erodibility constant is based on extensive field testing (Laflen et al. 1987). Soil erodibility and other constants must be measured calibrated and tested within the model. Once runoff is concentrated in the rills, soil particles are either transported through the rill or deposited. Detachment of soil particles from the rill may also occur. Erosion and deposition within the rills depend on the hydraulic shear stress of the rill flow relative to the critical shear stress of the soil. If the hydraulic shear stress is greater than the soil critical shear stress, then rill erosion will occur. Deposition occurs when the sediment load is greater than the sediment transport capacity of the flowing water. A detailed description of the hillslope erosion component of WEPP can be found in Foster et al. (1995)

Beyond the hillslope, channel hydrology governs the sediment transport process. Channels considered by WEPP are permanent grassed waterways, terrace channels or similar size channels. Ephemeral gullies are also included. Detachment, transport and deposition of sediment within permanent channels or ephemeral gullies are estimated using a steady-state solution to the sediment continuity equation. Sediment deposition and transport through large and small impoundments are calculated by WEPP using a continuity mass balance equation (Ascough et al. 1995).

WEPP is capable of simulating soil erosion processes associated with single hillslopes or small watersheds. The WEPP watershed consists a combination of hillslopes routed through impoundments and into channel segments leading to the watershed outlet. The Geo-spatial interface for WEPP (GeoWEPP) enables input data to be assembled for watershed analysis of soil erosion and sediment delivery (Renschler 2003). As a process-based model, WEPP computes the important soil erosion and sediment transport mechanisms as hydraulic forces carry the soil particles down the hillslope, through channels and impoundments, and out of the watershed. Runoff from precipitation, snowmelt, and irrigation provides energy which moves the sediment load down the hillslope. The dynamic hydrologic process is converted to a steady state process by assuming a constant duration of the peak flow rate at the end of each overland flow element (OFE) or channel segment. The duration of the peak flow equals the time required to discharge the total runoff volume from the storm event. WEPP calculations are based on a daily time step for continuous simulations and each runoff event is assumed to occur completely within a day's time. Single storm events for specific field conditions can also be simulated given the proper initial condition input data.

In the watershed analysis method of GeoWEPP, a flow path profile representative of each hillslope area is determined by aggregating information from individual grids. A representative flowpath is used to estimate sediment lost from the respective hillslope. A flowpath may have various overland flow segments or elements (OFE). Each OFE is homogeneous in every respect except for topography. Sediment movement from the hillslope is assumed to be uniform across the entire hillslope. It is the product of the flowpath sediment transport (mass/length) and the rill spacing (length). The method reports the amount of sediment leaving the hillslope. For this reason it is called the offsite assessment method. The onsite assessment method of GeoWEPP, on the other hand, calculates sediment deposited or leaving each individual grid, and therefore requires much more computer processing capacity (Minkowski and Renschler 2008).

Limitations of WEPP must be acknowledged and care must be taken to use the model within its constraints. Classical gullies with headcuts and streambank sloughing are not simulated by WEPP. Also, there is no mechanism to account for multiple storm events. Each daily runoff event is treated independently from the next. Therefore, simulations are limited to individual hillslopes or small watersheds, typically not larger than about 260 ha (1 square mile). Also, sediment transported by perennial streamflow is not included (Ascough et al. 1995).

Factors affecting the potential for soil erosion change continually and are interacting. Crop management activities such as tillage and harvest affect soil properties and residue cover which, in turn, affect soil infiltration rates and runoff. Climate affects plant growth, soil consolidation, residue and canopy cover. WEPP calculates changes to these parameters on a daily basis. Soil erosion and transport is then computed by WEPP based on conditions on the day of each runoff event occur

Two components of WEPP are of particular interest for this dissertation work; biomass management and tillage. The first phase of this work studies the impact that corn stover removal from the field may have on the potential for in field soil erosion. Yields computed by WEPP depend on stochastically generated climate data, a harvest index, a biomass/energy ratio parameter, and a crop growing degree days parameter. Plant growth is affected by two climatic stress factors, water and temperature. WEPP considers growth variation due to nutrient, pest or other management factors through adjustments to the biomass/energy parameter (Arnold et al. 1995).

There are several approaches to simulating biomass removal from the cropping system in WEPP, each with its own set of working assumptions and programming caveats. Residue management options are described in Stott et al. (1995) and Arnold et al. (1995). The biomass management editor in WEPP facilitates the generation of parameter files for scenarios with differing rates of biomass removal. Using this approach, WEPP simulates removal of the designated percentage of the *total flat* above ground biomass after harvest. For example, a WEPP simulated removal rate of 100% leaves only standing crop stubble in the field. Standing residue is simulated by WEPP as a separate biomass pool that is not available for removal. In reality, no biomass harvesting operation will remove 100% of the *total flat* above ground biomass. It is important to understand the processes of the model, make adjustments to better reflect realistic processes, and carefully interpret model output in order to draw valid conclusions from simulation results.

In the second phase of this dissertation, the GeoWEPP delineated watershed offsite assessment was used to compare sediment delivery estimates from two tillage intensities and explicitly quantify prediction uncertainty. Different tillage implements affect hydrology and the erosion process in different ways. Soil random roughness, ridge height, bulk density, and effective hydraulic conductivity are four influential variables affected by field operations. A variety of field activities using specific implements have been parameterized and are accessible in the WEPP database (Alberts et al. 1995). Multiple batch runs of WEPP, using data compiled by Geo WEPP, generate a distribution of sediment yields based on stochastic weather inputs from CLIGEN, the WEPP weather generator.

Stochastic Weather Generation

Climate is a key component of the WEPP model. The WEPP weather generator, known as CLIGEN, uses statistical parameters of commonly measured climatic variables to produce daily weather data for input into the WEPP program (Nicks et al. 1995). If available, actual historical weather data is useful for simulation of actual erosion and sediment transport events at specific sites. This is an option in WEPP. However, prediction of soil erosion likely to occur in the future requires weather data, not just from historical records, but a range of weather data reflecting the probability of what will occur based on statistical parameters from past records. The prospect of climate change complicates this task, but CLIGEN considers weather data from past records to be indicative of future weather patterns.

CLIGEN generates daily weather data stochastically, based on climatic variable distributions calculated from historical records. It will generate the same data for a given station or parameter file unless the seed number to the random numbers generator algorithm is changed. Random changes of the seed number for various CLIGEN runs will generate daily weather data that mimic the data distributions of the historical record, but not the actual weather station data. Generation up to 100 years of data is typical so that variable distributions may be well represented (Meyer et al. 2008). However, Baffaut et al. (1996) found some locations required more than 100 years of simulation to reach a stable running annual mean soil erosion when using CLIGEN V-4.2. A quality control method included in version 5.x improved CLIGEN performance significantly (Meyer et al. 2008). While the generation of multiple climate sets stochastically by randomly changing the seed number provides data for a more robust statistical analysis, often it is useful to generate a single set of weather data for comparison of management scenarios.

MUSLE

As an empirical model, MUSLE has the advantage of requiring only simple computations compared to the complex process computations required by WEPP. Also, the wider range of watershed size makes it applicable to larger watersheds. MUSLE, however can only be applied for a designated runoff event with specific land cover conditions at the time of the event. Past studies suggest that data from CLIGEN may be adapted to generate the R-factor for USLE and RUSLE (Nicks and Gander 1994, Renard and Freidmund 1994, Yu 2002). A CLIGEN generated R-factor for MUSLE, if validated, would be useful for empirical estimation of sediment delivery from watersheds caused by individual storms. Daily changes in cover conditions that affect soil erosion because of the climate would replace the need for an assumed C-factor at an arbitrary time in the cropping cycle. An advantage of empirical models like MUSLE is computational efficiency. A limited number of empirical equations makes for speedy computation. The computations of the process–based WEPP model are much more intensive. If the goal is to improve computation efficiency, little is gained by applying MUSLE with stochastic climate data. The daily calculations of the C-factor may counter the reduction in computations by using MULSE for sediment delivery. Also the spatial information provided by GeoWEPP would not be available.

The Universal Soil Loss Equation (USLE) was developed from field data to provide estimates of average annual soil loss (A) from hillslopes:

$$A = RKLSCP \tag{1}$$

where R is the annual rainfall erosivity factor, K is a soil erodibility factor, LS is a factor for slope length and steepness, C is a cover management factor, and P is a supporting practice factor. LS, C and P are dimensionless. K values are given in the soil survey in U.S. customary units. U.S. customary units for the soil erodibility are converted to metric units by multiplying K by 0.1317 (Foster et al. 1981).

The erosivity factor of USLE (R) reflects the average annual rainfall erosive energy and is a function of location. MUSLE uses the erosivity factor (R_w) proposed by Williams (1975) to improve the USLE individual–storm soil loss predictions (Laflen et al. 1985):

$$R_w = 27.06A^{0.12}Q^{0.56}q_p^{0.56} \tag{2}$$

where A is the watershed area (ha), Q is the volume of runoff (mm), and q_p is the peak flow rate ($mm\,h^{-1}$). Q and q_p must be estimated from an hydrologic analysis such as the SCS (NRCS) curve number method. R_w, as determined by Equation 2, is in metric units ($MJ\,mm\,ha^{-1}\,h^{-1}$). Equation 2 was developed from data from 18 watersheds ranging in size from about 3 acres to over 4000 acres and includes the effect of a sediment delivery ratio (Williams 1975).

The NRI

The National Resources Inventory (NRI) is conducted on non-federal lands by the USDA Natural Resources Conservation Service (NRCS) in cooperation with the Iowa State University Statistical Laboratory. The NRI provides data for scientific investigations to guide natural resources management decisions and public policy. The national sample is a stratified two-stage unequal probability area sample. The NRI sample design achieves specific national survey objectives and can also be used as a frame for special studies (Nusser and Goebel 1997).

The NRI has evolved over many decades since the collection of anecdotal information by the USDA in 1934. The 1934 study, called the National Erosion Reconnaissance Survey, led to the Soil conservation Act of 1935. Over the decades, USDA natural resource surveys improved in design and scope. Further improvements can be expected as geographic information systems, satellite imagery and LIDAR (LIght Detection and Ranging) have great potential to provide more timely data and rapid processing of information for use by land managers.

Primary sampling units (PSU's) for the NRI follow the structure of the Public Land Survey (PLS) system, which, in Iowa and other midwest states, established a grid system of counties, townships and sections (Nusser and Goebel 1997). The standard PLS county is a 24 mile by 24 mile square tract. The county is divided into 16 square township tracts of 36 square miles. One section is one square mile. Three NRI strata, each 2 sections by 6 sections, comprise one township. The most common NRI PSU is one quarter section (160 acres). A sampling rate of about 4% is obtained by selecting two PSUs in each 2 by 6 square mile stratum. Within each PSU, three sample points are selected. Information is collected for the PSU as well as for the individual sample points. Nusser and Goebel (1997) provide more detailed descriptions of NRI sample designs and variables collected for PSUs and sample points.

Studies of corn stover supplies conducted generally use publicly available county level location information (Graham et al. 2007, Nelson 2002, Nelson et al. 2004, Sheehan et al. 2004, Wilhelm et al. 2004). Information from the NRI at resolutions higher than the county level is confidential. The Iowa Daily Erosion Project (IDEP), however, is one study which uses township level NRI data. Information at the township level was obtained for the IDEP through a special confidentiality agreement with NRCS (Cruse et al. 2006). An amendment to this agreement permitted the use of this data for studying the impacts of corn stover removal in Iowa, resulting in the first paper (Chapter 2) of this dissertation.

Focus Groups for Environmental Science

Scientific knowledge, in general, should be pursued for the sake of improving the lives the people in the community. Too often, important scientific knowledge and understanding remains within the circles of a very specific scientific community. Individuals and groups may have vested interest in scientific work even if they do not have intimate knowledge of the science behind the service or product. Focus groups can be used to gain insight into the perceptions of a particular sector of the community on environmental science issues which may affect them. A focus group study of soil erosion and sediment delivery stakeholders is included in this dissertation work for additional perspective of erosion prediction science.

The focus group methodology is planned and systematic. A focus group consists of people that share certain characteristics. The group provides qualitative data in a focused discussion in order to better understand a topic of interest (Krueger and Casey 2009). They have a variety of applications. Among these are decision making, product development, determining customer satisfaction and employee concerns. Properly conducted, focus groups provide useful information about the perceptions of an issue of interest to the participants. Focus groups should be used with other research methods to verify or challenge findings.

The methodology of a focus group study must be well planned. At least three distinct focus groups are required for obtaining valid information (Krueger and Casey 2009). As with any scientific work, the purpose of the focus group study must first be well defined. If the focus group method is determined appropriate for the study objective, the criteria for selecting participants should be clear. For example, if the purpose of the study is to understand public perceptions of the usefulness of a technology for control

A skilled moderator of a focus group meeting will have a pre-prepared set of questions to guide the discussion. Each group would address the same questions according to their particular perspective of the issue. The initial questions introduce the topic of discussion broadly and encourage conversation. Subsequent questions narrow the topic of discussion. The final questions will be quite specific to the purpose of the study. All questions to the group should be open–ended to allow the participants to express their views without moderator influence. An environment of open

Data analysis should also be systematic and consistent. Individuals of a research team should analyze all of the data from each focus group independently. Once independent analysis has been documented, the research team meets to discuss findings and reconcile differences. The process helps minimize bias and misunderstandings of individual researchers.

Properly conducted, a focus group provides collective insights into perceptions of the community. Focus groups results are different from individual interviews, which provide individual perspectives. The focus group approach is often the precursor to development of survey research designed to provide generalized results (Krueger and Casey 2009).

Focus groups studies are common and an accepted method in the social sciences. Investigation of stakeholders of physical sciences research is less popular. However, focus group studies can be used to gain insight into the needs of particular interest groups and their perceived usefulness of any scientific information. In the field of natural resources management, different interest groups may disagree about how to manage our soil and water resources most effectively. The focus group study approach can involve stakeholders of soil and water conservation science and help reach common goals.

Organization of the Dissertation

This dissertation is organized into four Chapters. Chapter 1 provides general information about soil erosion and sediment transport modeling. It reviews literature and gives an overview of WEPP, CLIGEN, MUSLE and the NRI. It also introduces the focus group study method. Chapter 2 applies WEPP across the state of Iowa to address the risks of soil erosion as affected by corn stover removal. Chapter 3 explores sediment load prediction uncertainty and stakeholder perceptions of soil erosion prediction science. General conclusions drawn from the work of the previous chapters and recommendations for future work are presented in Chapter 4.

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CHAPTER 2. SOIL EROSION HAZARD MAPS FOR CORN STOVER MANAGEMENT USING NRI DATA AND WEPP

A paper accepted for publication in the Journal of Soil and Water Conservation

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Abstract

Corn stover is promoted as a readily available feedstock for biofuel production, potentially adding value to Iowa's corn harvest. However, soil productivity and water quality could be adversely affected by poor residue management practices. This paper presents the results of computer simulations of soil loss by water under various corn stover harvesting and management scenarios applied universally across the state of Iowa. The WEPP (Water Erosion Prediction Project) computer model was used to simulate soil erosion in Iowa at 17,848 agricultural point locations of the 1997 National Resources Inventory. Location information at the township level of 9.66 km by 9.66 km (6 by 6 miles) for the NRI points allows for presentation of results in the form of gridded color-scale maps. The maps indicate corn stover removal risk at the following levels; Extreme, High, Medium, or Low. Risk categories are based on the soil loss tolerance (T) and 1/2 T as constraints. This paper presents simulated impacts of corn stover removal on soil erosion only. Important considerations for maintaining soil organic carbon are reviewed and discussed. The simulation results suggest that no-till is necessary to maintain soil erosion below permissible levels of T and 1/2 T in regions with steeper slopes. Maps and corresponding analyses of this paper help guide policy pertaining to the harvest of corn stover in Iowa.

Key words: cellulosic ethanol—corn stover—soil erosion—soil loss tolerance—WEPP

Introduction

The United States Congressional Research Service has concluded that cellulosic feedstocks "have the potential to dramatically improve the benefits of fuel ethanol"(CRS 2007) and the renewable energy industry hopes to use corn stover as feedstock for fuel production. Advocates of cellulosic biofuel claim that a large amount of corn stover is already available on corn farms for use as biofuel feedstock. Corn provides more crop residue than other grain crops (Allmaras et al. 2000) and is perceived as the most readily available cellulosic fuel resource in Iowa. An estimated 8.7 million metric tons of corn stover was available for harvest annually in Iowa during the 95-97 crop years without exceeding soil loss tolerance levels (T) (Nelson 2002). This represents 20% to 25% of the total above ground corn stover produced in the state, depending on crop yield. Total corn stover production in Iowa has increased steadily from 41.7 million metric tonnes in 1997 to 60.7 metric tonnes in 2007, a result of increased acreage and yield (USDA NASS 2009). Wilhelm et al. (2004) concludes that ethanol from corn stover produced in Iowa alone could supply 12.6% of U.S. renewable motor fuel required by 2012 if 30% of the stover produced in the state is used. The state of Iowa leads the U.S. in production of corn and is at the center of the cellulosic ethanol for fuel debate.

Environmental concerns associated with use of fossil fuels have, in part, driven investment in renewable energy, but the exploitation of cellulosic biomass for fuel comes with its own environmental tradeoffs. Removing corn stover from the field for renewable biofuel production would decrease net nonrenewable fuel consumption while increasing the risk of contamination of water bodies due to soil erosion (Kim and Dale 2005). The amount of corn stover that can be removed without exceeding T, estimated at 20% to 25% by Nelson (2002), is not uniformly distributed across the state of Iowa. Even within field availability may be non-uniform. High amounts of corn stover removal may be acceptable for flat conditions under conservation tillage (Johnson et al. 2006; Wilhelm et al. 2007), but steeper conditions may not tolerate any residue removal regardless of tillage practices. More site specific evaluation of the impacts on soil and water quality caused by corn stover removal are needed to protect productivity and limit environmental costs.

This paper focuses on corn stover harvest as it affects soil erosion by water in Iowa. However, soil erosion is one of several potentially limiting factors in determining a sustainable rate of corn stover removal. In addition to reducing sheet and rill erosion, corn stover left in the field helps to maintain soil moisture and reduce wind erosion. According to Graham et al. 2007, however, wind erosion is not a constraint to corn stover harvesting in Iowa. Crop residues are also a primary source of soil organic carbon (SOC) inputs. Wilhelm et al. (2007) concluded that SOC, not soil loss, is a greater constraint to corn stover removal for sustainable cellulosic feedstock production. This conclusion may be too general where field slopes are variable. The specifics of slope steepness and length used to estimate soil erosion by water in Wilhelm et al. (2007) are not detailed in their paper. Also, SOC depletion and soil erosion are not independent of one another. Unfortunately, a model which considers the SOC/soil erosion interaction has yet to be validated.

Site-specific guidelines for determining appropriate biomass removal rates are not yet available. To date, studies of corn stover availability and the consequences of its removal from the field make very broad assumptions regarding field conditions such as slope, rate of biomass removal, tillage practices and acceptable soil losses. These studies use T as the limiting criterion for sustainability (Christensen et al. 1983; Nelson 2002; Sheehan et al. 2004; Kim and Dale 2005; CRS 2007; Johnson et al. 2006; Graham et al. 2007). Although T may be an imperfect value for maximum permissible soil loss rates, it is still a frequently used, accepted and relatively consistent benchmark for developing soil conservation policy.

Field research on the effects of biomass removal will be slow and costly. Computer simulation provides more timely information to producers and policymakers regarding removal of corn stover for sale to the biofuel industry. Past studies linking corn stover removal to soil erosion concentrate on determining state or regional corn stover production levels. They rely on county level data for model input, assume continuous rotations of corn under no-till, and estimate total removable corn stover without exceeding T (Nelson 2002; Sheehan et al. 2004). Graham et al. (2007) and Nelson et al. (2004) broaden the analysis by considering three tillage scenarios for corn-corn, corn-soybean and corn-wheat rotations. They all report corn stover availability at the county level. These works provide important information for national policy, and again point to Iowa as the leading state for corn stover production potential.

In this study we do not seek precise estimates of available corn stover. We identify stover removal risk areas for soil erosion by water in Iowa using township level input data in a simulation model. We consider three levels of tillage intensity for continuous corn and for corn-soybean rotations (Tables 1 and 2). The scenarios are similar to those evaluated by Graham et al. (2007). We also use T as the basis for the soil erosion constraint and include a second analysis using 1/2 T for comparison. Two important differences in the approach used here as compared to Graham et al. (2007) and Nelson et al. (2004) are; 1) The township rather than county level analysis allows for improved spatial resolution, and 2) The simulation of corn stover removal rates from 0% to 100% at 10% intervals rather than a single maximum removal rate provides a measure of soil loss sensitivity to different rates of stover removal. The objective is to identify and map soil erosion risk areas for a variety of Iowa-relevant corn stover management options at a higher spatial resolution than previous studies. We also evaluate the adequacy of NRI township level input data and the soil erosion simulation model used.

Methods

This project uses the Water Erosion Prediction Project (WEPP), Version v2006.5, computer simulation model (Flanagan et al. 2007) for estimating average annual soil erosion under hypothetical management scenarios at 17,848 National Resources Inventory (NRI) data points across Iowa. The NRI is conducted by the USDA Natural Resources Conservation Service (NRCS) in cooperation with the Iowa State University Statistical Laboratory and provides data for scientific investigations to guide natural resources management decisions and public policy. Of the more than 30,000 surveyed NRI data points in Iowa, only the 17,848 representing agricultural land use were used in this project. The use of only agricultural survey points allows township mean soil loss estimates for universally applied cropping scenarios to be interpreted as representative of agricultural land in the township. NRI survey design details can be found in Nusser and Goebel (1997). Information from the NRI database pertaining to the field conditions (soils, slope steepness and slope length) provides the input necessary for simulating soil erosion at each agricultural data point. Only county level NRI data is available publicly.

However, NRI survey point location information at the township level was made available to this project for Iowa through an amendment to the confidentiality agreement between NRCS and the Iowa Daily Erosion Project (Cruse et al. 2006). Township location for each NRI point in Iowa provides improved spatial resolution while maintaining an acceptable level of landowner confidentiality. WEPP estimates of soil erosion at each NRI point were aggregated to the township level for statistical analysis and mapping.

WEPP is a physical process erosion prediction model that incorporates stochastic weather generation and is based on fundamentals of infiltration theory, hydrology, soil physics, plant science, hydraulics, and erosion mechanics (Flanagan et al. 1995). It estimates spatial and temporal distributions of soil loss, sediment deposition and sediment delivery. WEPP can be used to estimate responses to single storm events or compute daily, monthly, and average annual erosion by water. WEPP has been shown to predict soil loss at least as well as USLE technology (Laflen et al. 2004). Because the model is process-based it can be extrapolated to a broader range of conditions that may not be practical or economical to field test (Flanagan et al. 1995). The WEPP model was chosen for this study because the WEPP parameters at each NRI point were previously determined for the Iowa Daily Erosion Project (Cruse et al. 2006). Universal changes in tillage and biomass management parameters allowed statewide application of each of six scenarios developed for this study.

Climate parameter files for each of the ninty-nine Iowa counties, interpolated using the Fourier method at the county centriod from actual weather stations, were created using the WEPP climate input file builder interface. Stochastically generated climate data from CLIGEN Version 5.2 (Nicks et al. 1995) provide county-level weather information used by WEPP in all scenario simulations. For each NRI data point, soil erosion is simulated daily by WEPP and then summed over each simulation year. Total annual soil erosion estimates, using the stochastically generated, county level climate dataset of 100 years, are averaged to obtain an average annual soil erosion rate at each NRI point. Township mean soil erosion rates and within township variability are used for map development.

Land Management

The land management reported by the 1997 NRI was not used in this study. Instead, several distinct hypothetical management scenarios involving corn were developed for simulation. Soil erosion simulations were then run for each management scenario at each NRI data point with corn stover removal rates of 0% to 100%, at 10% increments. In these simulations only corn stover is removed, while soybean residue is left in the field after soybean harvest. WEPP parameters describing crop management were adjusted for each distinct scenario simulation. These adjustments include variations in crop rotation, tillage, planting and harvesting activities performed throughout each crop year.

This paper presents two corn cropping scenarios without a cover crop, each under three different tillage systems, for a total of six hypothetical statewide scenarios. The intent is to make a comparison of broad but realistic and common management practices. The two cropping systems presented compare soil loss of continuous corn and corn–soybean rotations. The three tillage systems are heavy (conventional) tillage, intermediate (conservation) tillage, and no-till. Tables 1 and 2 list each of the six scenarios with corresponding field operations.

Stover Removal

There are several approaches to simulating biomass removal from the cropping system in WEPP, each with its own set of working assumptions and programming caveats. Residue management options are described in Stott et al. (1995) and Arnold et al. (1995). We used the biomass management editor in WEPP to generate parameter files for scenarios with differing rates of corn stover removal, applying each scenario universally to all 17,848 NRI points across the state. Using this approach, WEPP simulates removal of the designated percentage of the *total flat* above ground biomass after harvest. A WEPP removal rate of 100% leaves only standing corn stocks in the field. Standing stalks are simulated by WEPP as a separate biomass pool that is not available for removal. The one-pass harvester recovers only corn stover cut at the time of harvest, and does not collect flat residue already on the ground from senescence or prior year crops. To correct for this discrepancy, the WEPP removal rate must be set at some value less than 100% to simulate all of the corn stover truely available for harvest (*harvestable*). Likewise, to simulate the removal of half of the *harvestable* corn stover, WEPP requires a removal setting at some value less than 50% of the *total flat* amount. Plant production output data from WEPP were used to determine the relationship between the WEPP removal rate and the percentage of above ground flat corn stover actually available for removal. Management was found to be the primary factor affecting the relationship between WEPP simulated above ground *total flat* residue and *harvestable* stover. Figure 1 illustrates this relationship for an example NRI sample point under continuous corn with intermediate tillage. Data from Lindstrom (1986) suggests that 30% stover removal or less has little impact on soil erosion by water (USDA NRCS 2006). We chose stover removal rates of 100% and 50% as criteria for risk categories in subsequent maps. Table 3 gives approximated WEPP removal fractions to simulate 100% and 50% of the *harvestable* corn stover for each of six cropping and tillage scenarios. We used the WEPP removal fractions corresponding to 100% and 50% *harvestable* stover for mapping and analysis.

In this project we simulate corn stover removal using one-pass harvesting equipment, as described by Hoskinson et al. (2007). Using the selected modeling approach, WEPP does not allow for simulation of grain harvest and stover harvest on the same day, so corn grain harvest is simulated on October 20, and a percentage of flat residue is removed on the following day, October 21 (Tables 1 and 2). In practice, the single-pass harvesting system harvests both corn grain and residue simultaneously (Hoskinson et al. 2007, Shinners et al. 2009). The additional day of stover biomass simulated as flat residue on the ground is assumed to have an insignificant effect on average annual soil loss estimates. In these simulations, the cut height during the harvest pass was maintained at 40 cm. This is considered the “normal” cut height for the prototype single-pass harvester and proved to be the most efficient setting in the Hoskinson et al. (2007) study. A lower cutting height creates equipment operational difficulties while a higher cutting height reduces the stover harvest potential and risks leaving more grain in the field (Hoskinson et al. 2007).

The collection efficiency for the prototype one-pass harvester at the normal cut height of 40 cm was reported by Hoskinson et al. (2007) to be about 76% of the total biomass production. Shinners et al. (2009) measured stover collection efficiencies of about 86% with a cutting height of 25 cm. The corn stover collection efficiency as modeled by WEPP at a 40 cm cut height averaged about 84%. Therefore, WEPP simulates less stover in the field after harvest than might be expected in practice.

Stover Yield

Yields computed by WEPP depend on stochastically generated climate data, a harvest index, a biomass/energy ratio parameter, and a crop growing degree days parameter. Climate data were generated for each county. Plant growth is affected by two climatic stress factors, water and temperature. WEPP considers growth variation due to nutrient, pest or other management factors through adjustments to the biomass/energy parameter (Arnold et al. 1995). The biomass/energy ratio and the growing degree day parameters used were calibrated by Cruse et al. (2006) to simulate average yields in Iowa. These two parameters vary with 9 regions of Iowa defined by a north–south and east–west 3 by 3 grid. A constant harvest index of 0.5 was used. Corn harvest indices for corn have increased with the development of improved genetics (Johnson et al. 2006), and the value of 0.5 used in our simulations may slightly overestimate stover production.

Important climatic factors such as precipitation can vary significantly among regions during a given year and affect regional yields, but annual average computations attenuate differences. Therefore, simulated average annual grain and stover yields are essentially uniform for all regions of the state (between 10.6 Mg ha^{-1} and 12.2 Mg ha^{-1}). Actual state average yields reported by USDA NASS (2009) for the 2007 and 2008 crop years were 10.7 Mg ha^{-1}.

NRI Data

The NRI database provided township location, soil type, slope, and length of slope for each of the 17,848 data points. The average number of NRI points per township is approximately eleven, but no points are included in four urban townships (Council Bluffs, Des Moines, Cedar Rapids and Davenport). A handful of townships, mostly at the state border, contain only a small number (2 to 4) of data points. The distribution is shown in Figure 2.

Soil properties provided by the NRI allowed the determination of necessary soil parameters used for WEPP simulations. The same soil parameters developed and used by Cruse et al. (2006) in the Iowa Daily Erosion Project were used in this project. WEPP uses these parameters to quantify soil particle detachment and deposition. A single constant slope segment with a length equal to that reported by the NRI is assumed. Sediment delivery ratios for offsite impacts were not considered. Therefore, the analysis is limited to soil loss estimations and does not consider in-field deposition nor should it be interpreted as offsite sediment delivery.

Township Mean T Values

We chose T and 1/2 T as constraining soil erosion rates for the development of risk maps. The soil resource is considered to be at risk when erosion rates exceed the constraining rate. T values used in this study were from the SURGO soil database (USDA NRCS Soils Staff 2008) based on the soil series name and texture of each NRI point. The SURGO database provides additional sub-classifications of each soil of the NRI database for non-eroded, moderately and severely eroded conditions (different T values). Where the NRI database and texture corresponded to more than one T value in the SURGO database, the non-eroded T value was used. This selection would err on the side of tolerating higher rates of soil erosion in some cases but never more than the maximum T value in Iowa of 11.2 tonnes ha^{-1} yr^{-1} (5 tons ac^{-1} yr^{-1}).

As the criterium for a sustainable rate of soil erosion, T must be used with discretion. T may not provide adequate protection against resource degradation due to soil erosion (Mann et al. 2002). Lal (1998) argues that the approach for determining the value of T is “narrow” and “imperfect”, resulting in “perhaps excessive” value for permissible soil erosion. Lal (1998) suggests broadening the objective of T, from the existing criteria of mitigating some limited onsite impacts, to include costly offsite impacts and more comprehesive soil productivity issues. This would include the need to maintain or increase SOC levels. Soil erosion of the C-rich soil surface layer at even low rates ($<$T) may contribute to diminished SOC levels. As a result, SOC depletion may well be the greater constraint to corn stover removal, not entirely because of lower C inputs, but because of preferencial C loss via erosion of C-rich topsoil. Nonetheless, for the purposes of this study, T provides a benchmark for comparing soil erosion estimates.

Map Development

Risk categories for soil erosion as affected by corn stover removal were determined for each township under each management scenario at the following levels; Extreme, High, Medium, or Low. The four categories are defined in Table 4. The mean average annual soil erosion for each township in Iowa was statistically evaluated for each of the six hypothetical scenarios. Paired t–tests were performed for each township to test the hypothesis that the township mean soil erosion rate, as simulated by WEPP, is greater than the corresponding erosion constraint at each point within the township. The analysis requires the assumption of normality of the differences between the simulated soil erosion and the corresponding T value. The category definitions apply at a confidence level of 80%. Townships whose mean simulated soil erosion rate was not significantly different from the contraint are categorized as "Inconclusive".

Results and Discussion

The maps presented in Figures 3 and 4 show the risk categories by township as defined in Table 4. These images paint a picture of corn stover removal "risk zones" in the state of Iowa for soil erosion by water. Of the six scenarios presented in this paper, rotations under high and low tillage intensities represent extreme and opposing management situations. The intermediate tillage intensity is one example of many intermediate tillage options adopted by producers in Iowa.

Four important observations can be made from the results of the soil erosion simulations and corn stover removal risk maps. First, Iowa has well defined regions where soil erosion by water may not be a primary concern for stover harvest, while other regions are at great risk for soil erosion. Second, no-till systems demonstrate a reduced risk of soil erosion in Iowa landform regions where steeper slopes dominate the landscape, regardless of corn stover removal rates. Third, continuous corn appears to provide more protection against soil erosion than the corn–soybean rotation at intermediate tillage intensities. No-till appears to be equally effective in controlling soil erosion in both cropping systems. Finally, the township level NRI data used in this study provides improved resolution for analysis compared to county level studies. It is important to note that under conditions where soil erosion does not appear to be a problem, corn stover removal may be constrained by SOC. Lower C inputs due to stover removal combined with relatively little erosion of C–rich topsoil could reduce SOC significantly in the long term.

Soil Erosion Hazard Regions

Figure 5 depicts an overlay of the Iowa landform regions (Iowa Geological Survey 2006) and township mean slope as calculated from the NRI data. The Northwest Iowa Plains, Des Moines Lobe, and Iowan Surface regions are dominated by fairly flat topography. Gentle slopes are also characteristic of the Alluvial Plains of the Mississippi and Missouri Rivers. By contrast, the Loess Hills, Southern Iowa Drift Plain, East-Central Drift Plain, and the Paleozoic Plateau have soils with much steeper slopes.

Soil erosion corresponded to landforms in Iowa (Figures 3 and 5). The amount of com stover that can be safely removed without exacerbating erosion by water depends on slope in the various geographical regions. Under the most intensive (heavy) tillage systems, four landform regions (Northwest Iowa Plains, Des Moines Lobe, Iowan Surface, and Alluvial Plans) stand out as areas where soil erosion rates rarely exceed T, even with high rates of corn stover removal. However, when 1/2 T is used as the constraining soil erosion rate, only the Des Moines Lobe region appears at low erosion risk. SOC levels will be the primary sustainability concern limiting stover removal in this part of the state. By contrast, the Loess Hills, Southern Iowa Drift Plain, East-Central Iowa Drift Plain, and Paleozoic Plateau under heavy tillage contain mostly townships that have soil erosion rates above T even with no removal of corn stover. Regional differences can be attributed to field slope. Areas of "Low" soil erosion risk generally have mean township slopes of five percent or less while areas of "Extreme" or "High" risk generally have mean township slopes above five percent.

Under the heavy tillage continuous corn scenario, 70.0% of townships fall in one of the two most opposing categories when T is the constraint; 40.0% fall under "Extreme" and 30.0% are in the "Low" category (Table 5). In the corn–soybean rotation under heavy tillage scenario, 79.0% of the townships are in one of these two categories when T is the constraint; 54.0% are in the "Extreme" category and 25.0% are in the "Low" category. This suggests that, based on soil erosion only, about half of the agricultural land in Iowa may not be capable of producing corn stover sustainably for biofuel if heavy tillage is practiced. When 1/2 T is used as the constraint the percentage of townships in the "Extreme" risk category increases to 74% and 82% for continuous corn and corn-soybean, respectively.

The intermediate tillage intensity scenarios positively affect the potential for corn stover production compared to heavy tillage, reducing but not eliminating the risk for soil erosion in the most susceptable regions of Iowa. However, nearly 20% of the townships fall into the "Inconclusive" category under the intermediate tillage scenarios when T is used as the constraint. It is inappropriate to assess these areas at the township scale for sustainable corn stover harvest with this methodology. Site specific inventories and analyses will better guide management decisions in these areas.

Under the most effective tillage scenario for soil conservation, no-till, regional patterns are not discernable (Figures 3 and 4). Even when 1/2 T is used as the constraining erosion rate, the model predicts that no-till controls soil erosion throughout the state when 100% of the harvestable corn stover is removed. Under conditions where the criteria for minimal erosion risk is achieved, corn stover biomass removal will likely be constrained by SOC rather than soil erosion.

No-Till Scenarios

The no-till management scenarios demonstrate a significant reduction in the risk of soil erosion by water in regions where steeper slopes dominate the Iowa landscape. In regions characterized by primarily flat slopes, the soil erosion hazard is low regardless of tillage intensity. Under no-till continuous corn, 79.0% of all townships fall in the "Low" erosion risk category with 1/2 T as the constraint. Under the no–till corn–soybean rotation, 95.0 % of all townships fall in the "Low" category.

Soil erosion may be affected more by tillage than by removal of surface residue cover (Ghidey and Alberts 1998). Reduced tillage provides more soil cover (Guy and Cox 2002), but increased soil cover is not the only soil conservation benefit of no–till. Enhanced soil quality factors resulting from no-till work together with ground cover to control soil erosion by water (Dabney et al. 2004).

The model results suggest that essentially all regions in the state may be able to remove all *harvestable* corn stover without exceeding T under no-till management. However, field research shows that soil conservation benefits of reduced tillage systems may be lost if excessive amounts of residue biomass are removed (Dabney et al. 2004). Residue removal from no–till corn plots have resulted in soil losses similar to conventional fall moldboard plowed fields (Lindstrom 1986). In the Lindstrom (1986) study the rates of soil erosion were limited to near or below T.

No-till reduces erosion risk on sloping soils, but excessive removal of biomass can cause simulated soil erosion to increase to rates greater than T. In the absence of tillage, soil erosion initially is low but increases exponentially when harvest rates exceed 60% (Figure 6). In contrast, soil erosion risk is high with little or no stover harvest and increases linearly when soils have heavy tillage. The examples in Figure 6b and 6d show soil erosion increasing under no–till management from below T to just above T as biomass removal rates increase. Note, however, that maximum removable biomass fraction of 0.86 for no-till prevents exceeding T in these cases.

Despite the strong evidence that no-till reduces soil erosion and improves soil quality (Dabney et al. 2004), Iowa farmers often use more intensive tillage systems. In the 2007 Amendment to the National Crop Management Survey conducted by the Conservation Technology Information Center, only 13% of the total reported corn acres and 41% of soybean acres in Iowa used no–till. Tillage practices in Iowa are as diverse as its farmers, their financial situations, available equipment, and the landscape. Each land manager operates within these confines, and tillage practices change from farm to farm. Some level of chisel tillage is probably now most prevalent in Iowa, but the data is poor.

Continuous Corn and Corn–Soybean

Model simulations suggest that continuous corn provides more protection against soil erosion than corn-soybean rotations when soil had intermediate tillage, but only when corn stover harvesting is limited. Less than 2.5% of the townships fall in the category “Extreme” or “High” under the intermediate tillage continuous corn scenario, compared to 23.0% for corn–soybean under intermediate tillage when T is used as the permissible rate of soil erosion (Table 5). When 1/2 T is used as the constraining soil erosion rate the proportion of Iowa townships at “Extreme” risk jumps to nearly 40% under the corn–soybean rotation with intermediate tillage, compared to just 5.0% for continuous corn (Table 6). However, differences between the two cropping systems are not as apparent under heavy tillage and no-till. Also, removal of corn stover clearly reduces cropping differences in soil erosion risk. Under intermediate tillage with T as the constraint, the proportion of townships at “Low” risk for soil erosion is 50.0% and 43.0% for continuous corn and corn–soybean, respectively. With 1/2 T as the constraint, the proportions are 29.0% and 23.0%. While the proportion of low risk townships is higher for continuous corn, the trend is weak.

Previous crop type has been shown to affect soil erosion. soil erosion following soybeans is significantly greater than that following corn in both corn-soybean and continuous corn rotations (Laflen and Moldenhauer 1979). However, tillage effects dominate soil erosion for no–till and heavy tillage in the simulations. This may be because tillage intensity has a greater effect on residue cover than previous crop type (Guy and Cox 2002), but only under the lightest and heaviest tillage intensities. Only under the intermediate tillage scenarios is crop type obviously a more dominant factor for soil erosion in the simulations. Similarly, in a study of field data to evaluate the long-term (12-yr) effects of continuous corn and continuous soybean cropping systems under conventional, chisel, and no-tillage methods on runoff and soil losses, Ghidey and Alberts (1998) found a significantly higher ($p<0.05$) mean average soil loss in soybean for the chisel method only. These studies did not consider corn stover removal. The interacting effects of tillage intensity, previous crop and corn stover removal on soil erosion complicate management decisions. Our simulations suggest that excessive corn stover removal is a concern for much of Iowa under both continuous corn and corn–soybean management systems.

NRI

The township level NRI data provides improved resolution for analysis compared to county level studies. However, high variability and small sample sizes within many townships render the mean soil erosion rate inconclusive for determining a risk category with confidence. Nearly twenty percent of the township t-tests resulted inconclusive at an 80% level of confidence under high and intermediate tillage intensities with T as a constraint. In contrast, very few townships had mean soil erosion values that qualified as inconclusive under the no-till scenarios (Table 5). This is a reflection of consistently low soil erosion rates simulated under the no–till scenarios that rarely approach or exceed T. The inconclusive results remind us again of the need for more site specific technologies for managing corn stover in Iowa.

Soil Erosion and SOC

Wilhelm et al. (1986) have shown crop production decreases in subsequent years following removal of crop residues. Wilhelm et al.(2007) conclude that SOC constrains corn stover harvest for sustainable celulosic feedstock more than soil erosion by water. However, this is not always the case under all conditions. Figure 7 compares data from Wilhelm et al.(2007) with example soil erosion results from our study at points with 1% and 12% slopes under different management. The WEPP estimated amount of stover needed to limit water erosion to T exceeds the simulated stover production amount of 10.9 Mg ha^{-1} under the heavy tillage scenarios on 12% slopes. This suggests that water erosion can be more of a constraint to corn stover harvesting than SOC under certain field conditions. Again, SOC and soil erosion are not independent of one another and soil erosion may result in preferencial loss of SOC.

SOC and soil erosion interact in complex ways and SOC may limit the amount of corn stover that can be removed. SOC prediction models must adequately consider SOC depletion, soil erosion processes, and their interacting affects on one another. CENTURY5, the most recent version of the CENTURY soil organic matter model, includes algorithms for simulating the effect of soil erosion and deposition event inputs (CENTURY5 2009). However, the soil erosion component in CENTURY5 has not yet been validated. No model has been shown to adequately address the interaction between SOC and soil erosion.

Conclusions

Iowa has well defined regions of high and low risk for soil erosion which will influence biomass management decisions and impact the cellulosic biofuel industry. Regions most at risk for soil erosion are the Southern Drift Plain, the Loess Hills, the Paleozoic Plateau of northeast Iowa and the East-Central Iowa Drift Plain. Average annual soil erosion under heavy tillage scenarios exceeds T where slopes are greater than four or five percent, even when little or no corn stover is removed. Regardless of tillage system, the flat terrain of the Northwest Iowa Plains, Des Moines Lobe, Iowan Surface and Alluvial Plains produce the greatest amount of available corn stover at low risk for erosion. SOC will likely constrain corn stover removal more than soil erosion on these flat soils. By contrast, tillage and residue management systems significantly impact the amount of available corn stover biomass in regions having steeper slopes. No-till is shown to be an effective practice for controlling soil erosion even at 100% corn stover removal. However, T can be exceeded if high amounts of corn stover are removed from sloping fields under no-till management. Continuous corn may reduce soil erosion under intermediate tillage intensities, compared to corn–soybean. Even at high corn stover removal rates, our simulations suggest that corn residue remaining in tilled fields provides more soil erosion protection than unharvested soybean residue under the same tillage intensity.

Soil erosion and biomass production are not the only considerations for the farmer, and the net benefits of high levels of biomass production from continuous corn compared to a corn–soybean rotation must be carefully considered in the greater context of soil quality, pest management, and the general farm economy. Enhanced soil quality, disruption of pest cycles and increased corn production resulting from more diverse cropping systems may compensate for the value of decreased amounts of harvestable corn stover (Blanco-Canqui and Lal 2009). Better understanding of the impacts of corn stover removal through field research and improved models will guide sound decisions.

Thoughtful choices by producers and wise farm policy will be vital to the health and sustainability of soil resources. Field studies and computer simulation studies on the effects of biomass removal add to our understanding of the impact of land management practices influenced by the bioenergy economy. The results of this study may be used for estimating potential corn stover production at regional scales in Iowa, but site specific consideration is still needed. Farm and field scale decision makers may gain insight into the consequences of corn stover removal based on how their individual farm and field conditions compare to the mean township and regional conditions in this analysis. Individual fields may not follow the norm of the region and should be treated accordingly. Better, more versatile site-specific evaluation technologies for soil management need to be developed and made accessible to individual farmers.

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Tables and Figures

Table 1 Field operations for simulated continuous corn management scenarios in northcentral (NC) Iowa at 100% harvestable stover removal.

Tillage	**Date**	**Operation Type**	**Name**	**Comments**
Heavy	1/1/1	Initial Conditions	After corn, fall plow	
Tillage	4/23/1	Tillage	Disk	Depth: 5 cm; Type: Sec[a]
	4/25/1	Tillage	Disk	Depth: 5 cm ; Type: Sec
	4/27/1	Tillage	Field cultivator	Depth: 5 cm; Type: Sec
	4/30/1	Tillage	Planter	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/1	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=98%	
	11/1/1	Tillage	Plow, Moldboard	Depth: 20 cm; Type: Pri[b]
Intermed.	1/1/1	Initial Conditions	After corn, fall chisel	
Tillage	4/27/1	Tillage	Field cultivator	Depth: 5 cm ; Type: Sec
	4/30/1	Tillage	Planter	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/1	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=92%	
	11/1/1	Tillage	Chisel plow	Depth: 20 cm; Type: Pri
No-Till	1/1/1	Initial Conditions	After corn no tillage	
	4/30/1	Tillage	Planter-no-till	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/1	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=86%	

[a] Secondary Tillage [b] Primary Tillage

Table 2 Field operations for simulated corn-soybean management scenarios in northcentral (NC) Iowa at 100% harvestable stover removal.

Tillage	**Date**	**Operation Type**	**Name**	**Comments**
Heavy	1/1/1	Initial Conditions	After soybeans, fall plow	
Tillage	4/23/1	Tillage	Disk	Depth: 5 cm; Type: Sec[a]
	4/25/1	Tillage	Disk	Depth: 5 cm; Type: Sec
	4/27/1	Tillage	Field cultivator	Depth: 5 cm; Type: Sec
	4/30/1	Tillage	Planter	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/1	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=98%	
	11/1/1	Tillage	Plow, Moldboard	Depth: 20 cm; Type: Pri[b]
	4/29/2	Tillage	Disk	Depth: 5 cm; Type: Sec
	5/1/2	Tillage	Disk	Depth: 5 cm; Type: Sec
	5/3/2	Tillage	Field cultivator	Depth: 5 cm; Type: Sec
	5/5/2	Tillage	Planter	Depth: 5 cm; Type: Sec
	5/5/2	Plant - Annual	Soybeans for NC Iowa	Row Width: 75 cm
	9/30/2	Harvest - Annual	Soybeans for NC Iowa	
	11/1/2	Tillage	Plow, Moldboard	Depth: 20 cm; Type: Pri
Intermed.	1/1/1	Initial Conditions	After soybeans, fall chisel	
Tillage	4/27/1	Tillage	Field cultivator	Depth: 5 cm; Type: Sec
	4/30/1	Tillage	Planter	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=95%	
	11/1/1	Tillage	Chisel plow	Depth: 20 cm; Type: Pri
	5/3/2	Tillage	Field cultivator	Depth: 5 cm; Type: Sec
	5/5/2	Tillage	Planter	Depth: 5 cm; Type: Sec
	5/5/2	Plant - Annual	Soybeans for NC Iowa	Row Width: 75 cm
	9/30/2	Harvest - Annual	Soybeans for NC Iowa	
	11/1/2	Tillage	Chisel plow	Depth: 5 cm; Type: Sec
No-Till	1/1/1	Initial Conditions	After soybeans, no fall till	
	4/30/1	Tillage	Planter-no-till	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/1	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=86%	
	5/5/2	Tillage	Planter-no-till	Depth: 5 cm; Type: Sec
	5/5/2	Plant - Annual	Soybeans for NC Iowa	Row Width: 75 cm
	9/30/2	Harvest - Annual	Soybeans for NC Iowa	

[a] Secondary Tillage [b] Primary Tillage

Table 3 Approximate WEPP removal fractions to simulate 100% and 50% of the harvestable corn stover for each of the six crop and tillage scenarios. Values represent the means and coefficients of variability (CV) of 9 randomly selected data points, one from each geographic region.

	Continuous Corn				**Corn–Soybean**			
	100%		**50%**		**100%**		**50%**	
	Mean	**CV**	**Mean**	**CV**	**Mean**	**CV**	**Mean**	**CV**
Heavy	0.98	0.0007	0.49	0.0007	0.98	0.0007	0.49	0.0007
Intermed.	0.92	0.0032	0.43	0.0081	0.95	0.0043	0.47	0.0049
No-till	0.86	0.0084	0.34	0.0219	0.86	0.0181	0.41	0.0249

Table 4 Definition of soil erosion risk categories for corn stover removal (at 80% confidence)

Soil Erosion Risk Category	**Definition**
Extreme	Mean township soil erosion is significantly greater than the erosion constraint at 0% stover removal.
High	Mean township soil erosion is significantly greater than the erosion constraint at 50% harvestable stover removal and not in “Extreme” category.
Medium	Mean township soil erosion is significantly greater than the erosion constraint at 100% harvestable stover removal and not in “Extreme” or “High” categories.
Low	Mean township soil erosion is significantly less than T at 100% stover removal.
Inconclusive	The paired t-test result is inconclusive for each of the four categories above.

Table 5 Percentage of Iowa townships in each soil erosion risk category for simulated continuous corn and corn-soybean management scenarios using T as the constraining soil erosion rate.

	Continuous Corn					**Corn–Soybean**				
	Extr. Risk	High Risk	Med. Risk	Low Risk	In-Concl.	Extr. Risk	High Risk	Med. Risk	Low Risk	In-Concl.
Tillage										
Heavy	40.0	6.0	6.0	30.0	18.0	54.0	1.0	3.0	25.0	17.0
Inter.	<0.5	2.0	29.0	50.0	19.0	15.0	8.0	16.0	43.0	18.0
No-till	0.0	0.0	<0.5	99.0	1.0	0.0	0.0	0.0	>99.5	<0.5

Table 6 Percentage of Iowa townships in each soil erosion risk category for simulated continuous corn and corn-soybean management scenarios using 1/2T as the constraining soil erosion rate.

	Continuous Corn					**Corn–Soybean**				
	Extr. Risk	High Risk	Med. Risk	Low Risk	In-Concl.	Extr. Risk	High Risk	Med. Risk	Low Risk	In-Concl.
Tillage										
Heavy	74.0	3.0	3.0	8.0	12.0	82.0	1.0	2.0	6.0	9.0
Inter.	5.0	17.0	32.0	29.0	17.0	39.5	6.0	14.5	23.0	17.0
No-till	0.0	0.0	4.0	79.0	16.5	0.0	0.0	<0.5	95.0	5.0

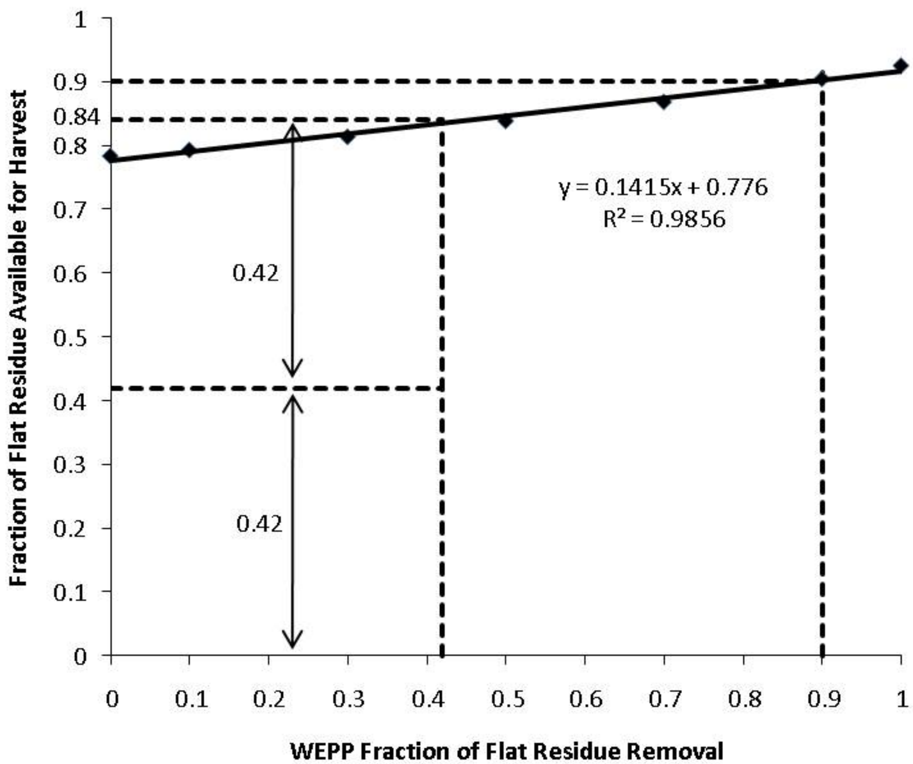

Figure 1 Example relationship between WEPP simulated above ground flat residue removal and the stover actually available for harvest (*harvestable*) for intermediate tillage, continuous corn for a random data point in north-central Iowa. The points of interest are where the WEPP fraction of flat residue removal equals the *harvestable* stover fraction and half the *harvestable* stover fraction (dashed lines). These points are at the 0.90 and 0.42 WEPP fractions, respectively.

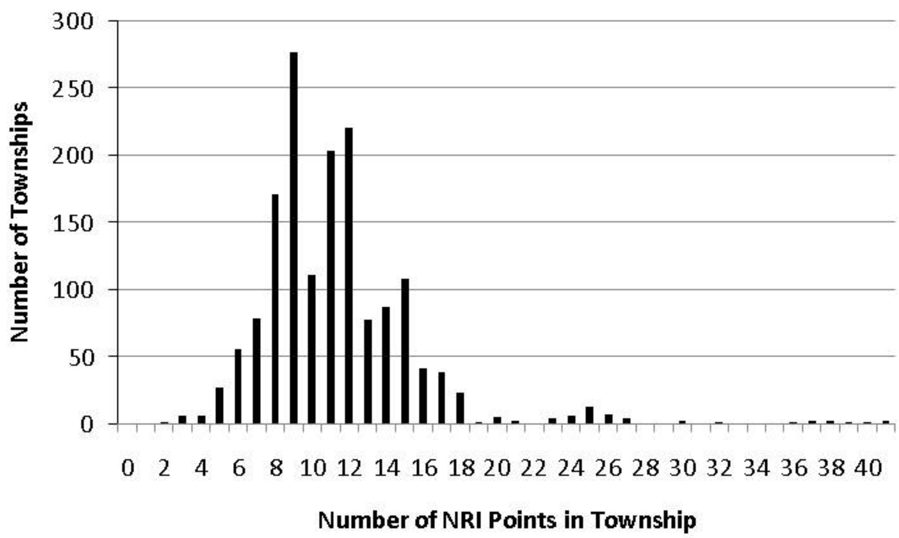

Figure 2 Distribution of the number of agricultural NRI points located within each Iowa township used in the simulations.

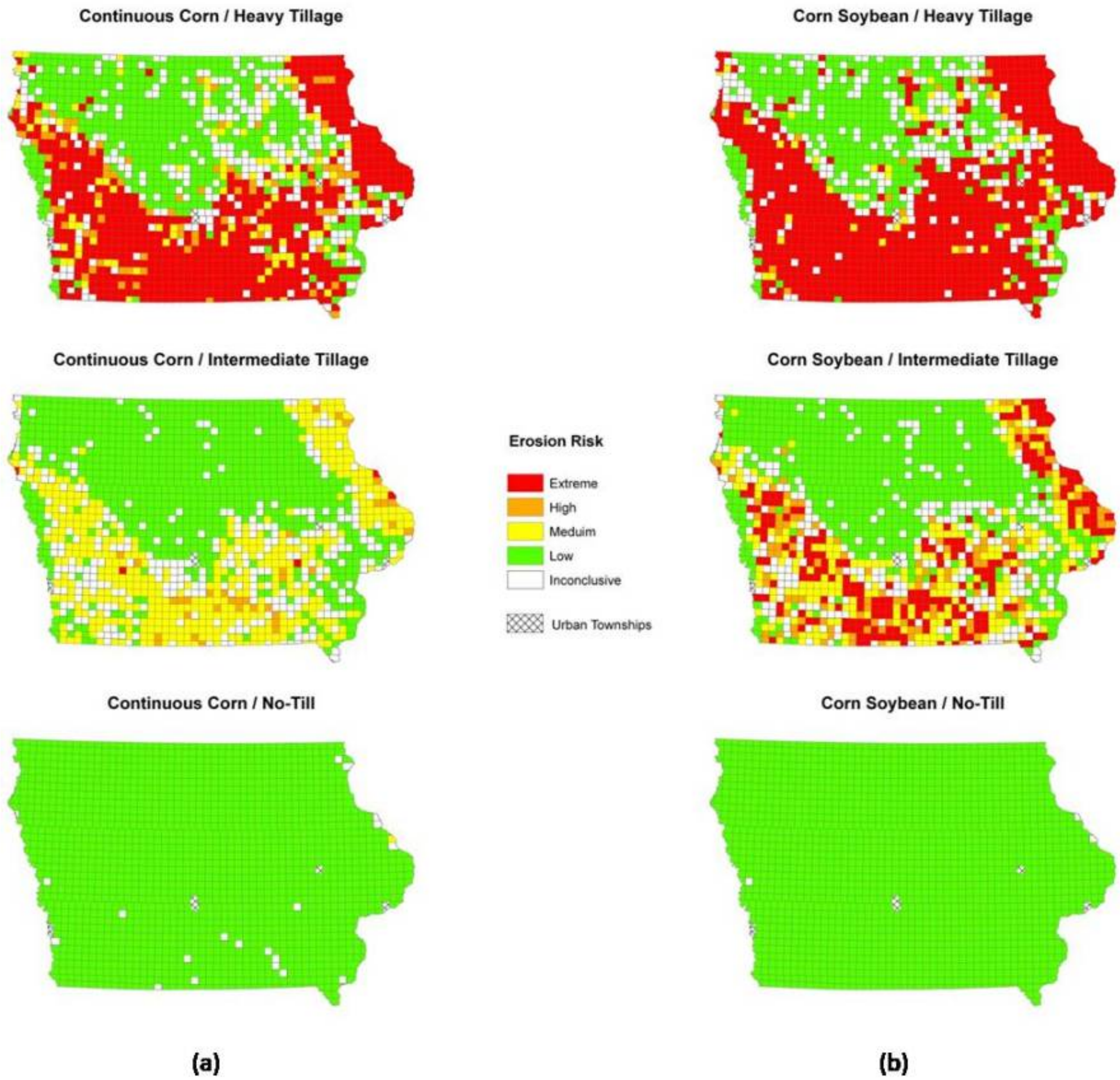

Figure 3 Soil erosion risk for corn stover removal based on T for: (a) continuous corn under heavy tillage, intermediate tillage and no-till management scenarios; and (b) corn–soybean rotation under heavy tillage, intermediate tillage, and no-till management scenarios.

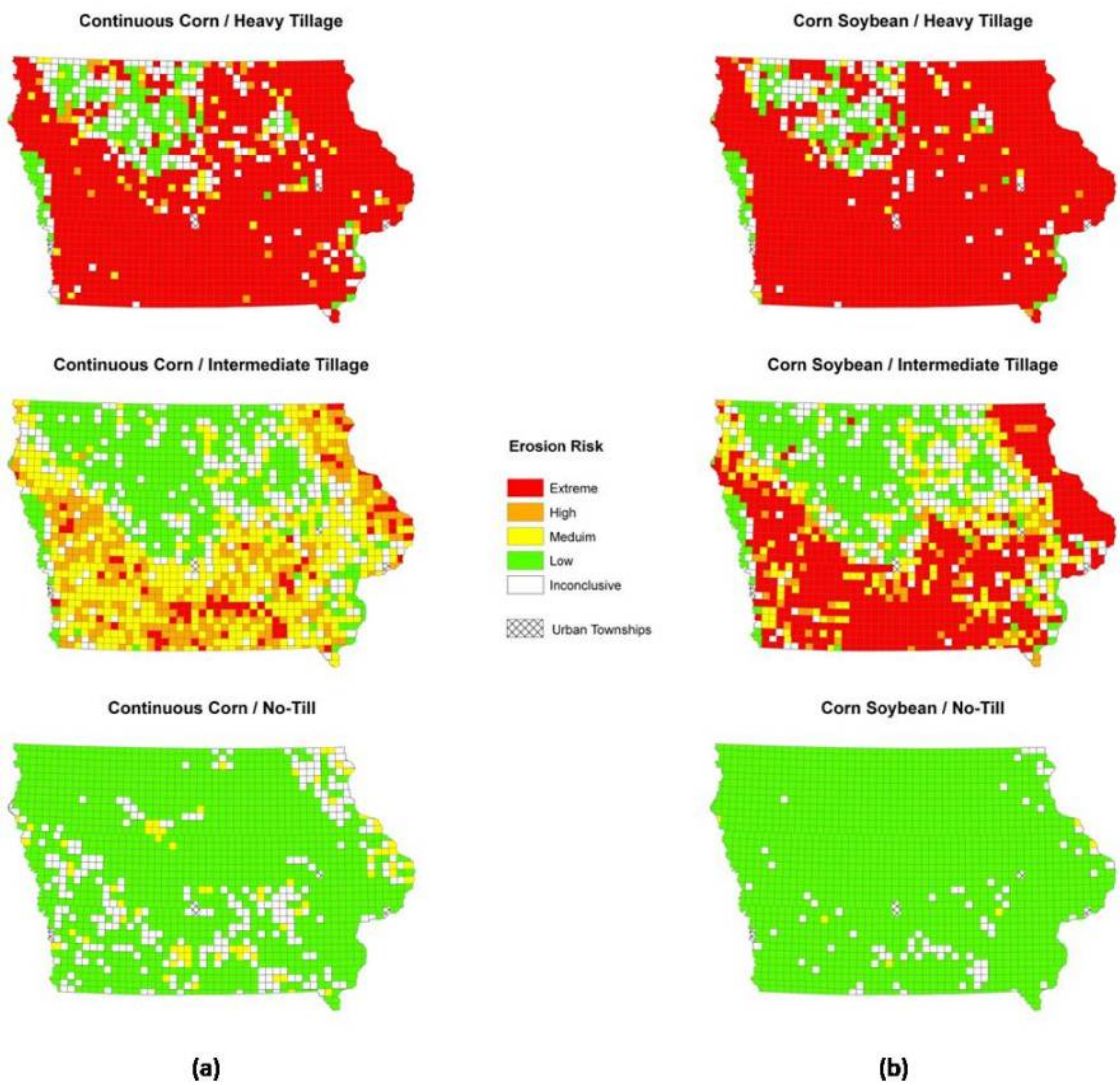

Figure 4 Soil erosion risk for corn stover removal based on 1/2 T for: (a) continuous corn under heavy tillage, intermediate tillage and no-till management scenarios; and (b) corn–soybean rotation under heavy tillage, intermediate tillage, and no-till management scenarios.

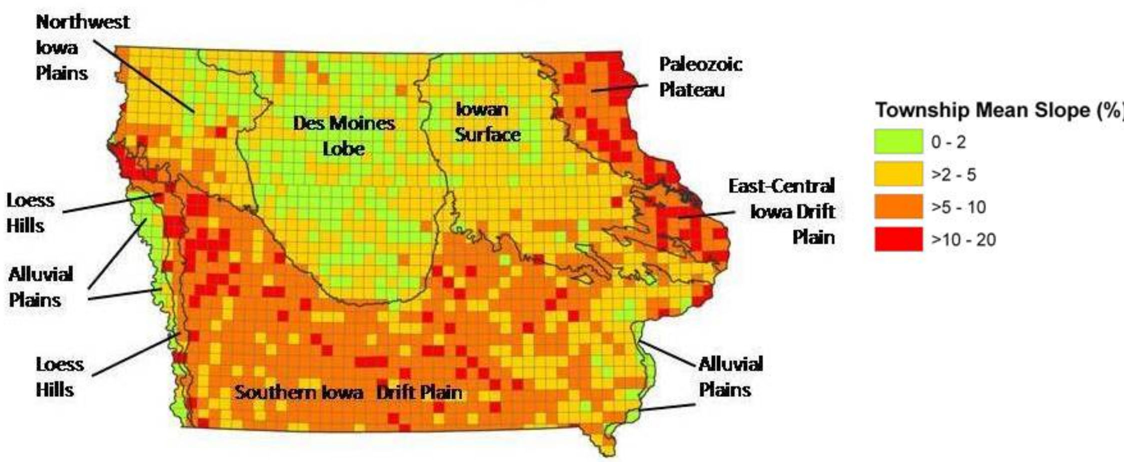

Figure 5 Iowa landform regions and mean slopes for NRI townships (Iowa Geological Survey 2006).

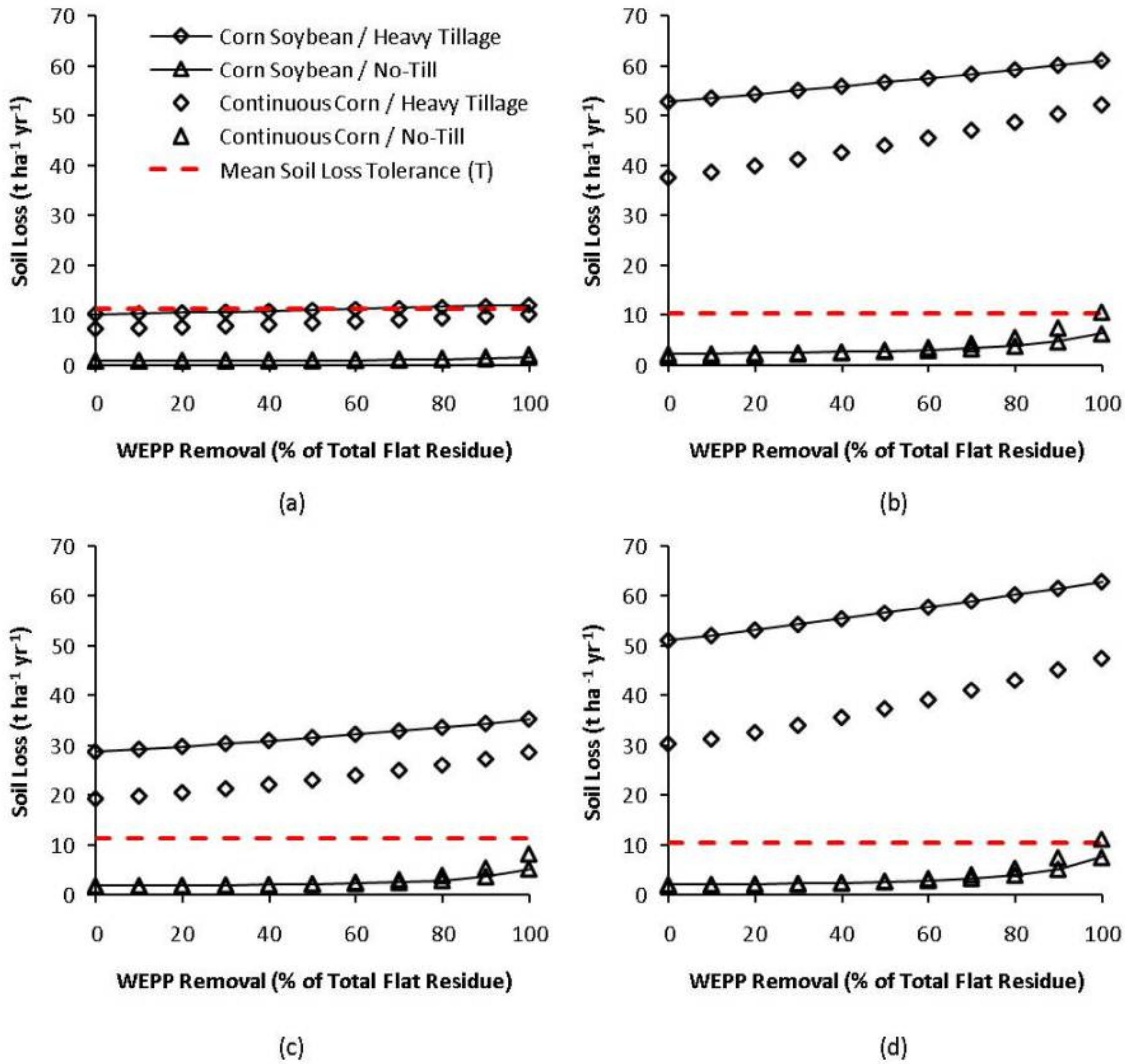

Figure 6 Comparison of different management scenarios in a sample township of: a) Des Moines Lobe, Mean township slope = 3.5 percent; b) Southern Iowa Drift Plains, Mean township slope = 7.3 percent; c) Loess Hills, Mean township slope = 9.7 percent; d) Paleozoic Plateau, Mean township slope = 11.9 percent

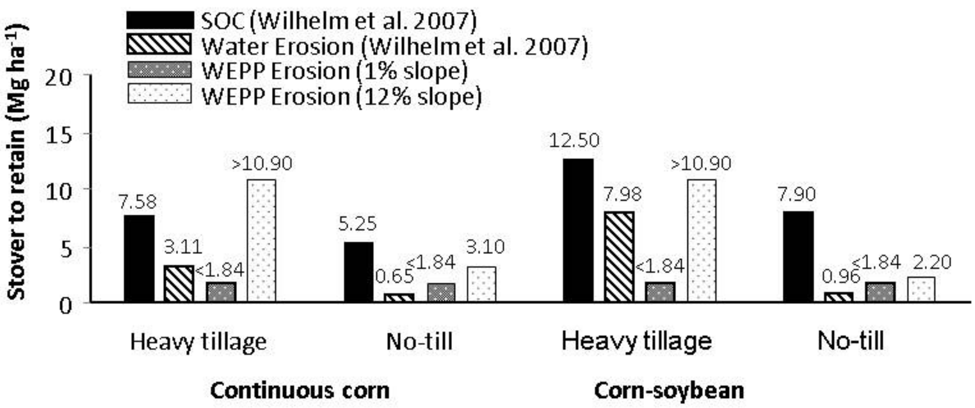

Figure 7 Johnson et al. 2006 estimated amount of corn stover needed to maintain soil organic carbon (SOC) (Wilhelm et al. 2007)[solid black bars]; Revised Universal Soil Loss Equation, version 2(RUSLE2)(USDA-ARS, 2003) estimated amount of corn stover needed to limit water erosion within the accepted tolerance, T (Wilhelm et al. 2006)(bars with diagonal lines);Water Erosion Prediction Project (WEPP)(Flanagan et al. 2007) estimated amount of corn stover needed to limit water erosion within the accepted tolerance, T, on 1% slope (grey bars with white dots); Water Erosion Prediction Project (WEPP)(Flanagan et al. 2007) estimated amount of corn stover needed to limit water erosion within the accepted tolerance, T, on 12% slope (White bars with black dots).

CHAPTER 3. UNCERTAINTY OF SEDIMENT LOAD ESTIMATES AND STAKEHOLDER PERSPECTIVES

A paper to be submitted to the Journal of Environmental Engineering

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Abstract

According to the National Research Council, improved uncertainty analysis for TMDLs will advance the goals of this and other water quality programs. Sediment is one important NPS parameter because deposition in streams and lakes adversely affects aquatic ecosystems. Equally important, suspended sediment is a transport mechanism for many nutrients, pesticides and pathogens. This study develops and demonstrates a novel stochastic approach to sediment load prediction uncertainty using WEPP, compares it to the traditional deterministic approach of MUSLE, and researches sociological implications. The stochastic methodology permits explicit mathematical calculation of sediment load prediction uncertainty as recommended by the National Research Council. A focus group study investigates stakeholder perceptions of these stochastic and deterministic methods for sediment load prediction. The focus groups agreed that more information provided by the stochastic method was helpful for decision–making. However, the complexity of the analysis is a concern for practical use. The natural resource sciences and the social sciences will need to further engage each other for erosion control efforts to respond with ever increasing demands on the soil resource.

Keywords: focus groups–GeoWEPP–Monte Carlo simulation–sediment delivery–uncertainty analysis

Introduction

The Federal Water Pollution Control Act of 1972 became law with the goal of reducing water pollution to acceptable levels. Amended in 1977, this law became known as the Clean Water Act (CWA). As the federal agency responsible for administrating the CWA, the US Environmental Protection Agency (EPA) initiated point source regulatory programs mandating National Point Discharge Elimination System (NPDES) permits for waste discharge into US waterways. The Total Maximum Daily Load (TMDL) program set limits for pollutant loading of waterbodies.

Water quality of many U.S. streams and lakes has improved greatly since the 1970's as a result of the implementation of the CWA (Andreen 2004). The TMDL program has been effective for point sources through the implementation of NPDES permit regulations. However, nonpoint sources (NPS) contribute the greatest amounts of phosphorus, nitrate, pathogens and sediment to our waterbodies. The TMDL program has been less effective in agricultural regions because of the complex nature of NPS pollution and the unpredictability of important climatic factors. The CWA does not provide for directly regulating NPS pollution. As a result, NPS pollution has become the primary obstacle to improving water quality (Andreen 2004).

The EPA compiles TMDL implementation rules and guidelines for state development of TMDL plans. A TMDL plan must be developed for each parameter (i.e. contaminant) determined to cause impairment of a designated water body. Sediment is one very important water quality parameter because deposition limits stream flow capacity, reduces water storage in lakes and reservoirs, and adversely affects aquatic ecosystems. Equally important, suspended sediment is a transport mechanism for many nutrients, pesticides and pathogens.

Improved uncertainty analysis and statistical techniques for TMDLs has been identified as an immediate TMDL development and implementation science need by the National Research Council's *The Twenty Needs Report: How Research Can Improve the TMDL Program* (USEPA 2002). Following the Council report, an effort was made to explicitly quantify TMDL uncertainty for NPS pollutants (e.g. Benaman and Shoemaker 2004; DePinto et al. 2004; Dilks and Freedman 2004; Novotny 2004; Zhang and Yu 2004). Freedman et al. (2004) describe adaptive watershed management as a way to avoid unproductive debate over uncertainty of the TMDL target and allow managers to "proceed with controls in a progressive manner". The hope for adaptive watershed management is that through improvements in monitoring, modeling and controls, the goal of improved water quality can be achieved.

While better uncertainty analysis and statistical techniques have been proposed for NPS pollutants, the impact of these technical advances on water quality is not clear. The TMDL program and the science which supports it has been at a loss of how to deal with the most important source of NPS load uncertainty, the weather. Also *The Twenty Needs Report* is "limited to analysis and recommendations concerning scientific issues". The report focuses on the physical natural resources sciences affecting water resources to the exclusion of the social sciences.

Two methodologies for predicting soil erosion and sediment load delivery are presented in this paper. The first approach demonstrates the use of the Water Erosion Prediction Project (WEPP), Version v2006.5, computer simulation model (Flanagan et al. 2007) with stochastically generated climate data from CLIGEN Version 5.2 (Nicks et al. 1995). This stochastic approach using WEPP never before been executed. It allows development of Monte Carlo distributions, giving quantified levels of uncertainty for sediment delivery estimates. Monte Carlo simulation uses input data randomly selected from a known distribution (i.e. climate data) to generate an unknown output distribution of sediment yield from a model (i.e. WEPP). The second approach demonstrates the traditional deterministic approach using a modification of the Universal Soil Loss Equation called MUSLE (Williams 1975) to estimate sediment delivery caused by a single precipitation event. Recent sediment TMDL plans developed by the Iowa Department of Natural Resources (IDNR) use the 2–year, 24–hour storm event in MUSLE to estimate allowable sediment delivery to the outlet of the watershed (IDNR 2007a) or other modifications of USLE technology (IDNR 2007b). Both WEPP and MUSLE methodologies provide sediment delivery estimates. However, the stochastic approach using WEPP provides vast amounts of output data for statistical evaluation. In contrast, the MUSLE approach provides a single estimated value by adopting multiple assumptions regarding field condition and timing of the event.

Natural systems are very complex, but social system dynamics and the placed-based variation in civic structure are also difficult to understand, predict and influence. McCown (2005) argues that “interventions to change land management practices must address the decision–makers subjective beliefs”. Physical scientists and engineers have little use for subjectivity and, as a result, we often fail to incorporate the social aspects of our work. However, the application of the natural resource sciences for improving the environment can benefit greatly from collaboration with the social sciences. Incorporating knowledge from the social sciences can guide conservation policies that encourage responsible behavior through incentives that promote more effective conservation.

Understanding the uncertainties of NPS pollution prediction may encourage more cooperation with, and support for, control programs. This hypothesis is tested using focus group interviews of different stakeholder types. The focus group approach provides a means for gaining insight into the collective views of the participants regarding a specific issue (Krueger and Casey 2009). The objective of this study is to a) compare a novel stochastic method to a deterministic method for predicting soil erosion and sediment delivery and; b) to explore stakeholder perceptions regarding uncertainty through focus group interviews. The strength of the science behind the TMDL target influences the enthusiasm with which control alternatives are accepted by stakeholders. Therefore both scientific and social aspects have value and are best understood when considered together.

Methods

We selected a 296 ha agricultural watershed (Figure 1) in Tama County, Iowa, as the example for this study. This 296 ha area is a sub-basin of the Four Mile Creek watershed which was the subject of years of soil erosion and sediment transport monitoring by Iowa State University scientists from 1975 to 1979. The example 296 sub-basin is small compared to typical TMDL watersheds, speeding computations for demonstration of methodology.

For comparison of the stochastic approach and the deterministic approach to sediment delivery prediction two universally applied management scenarios are modeled. The two management scenarios evaluated for demonstration are corn-soybean rotations under no-till and corn-soybean rotations under a conventional spring chisel system (Table 1). We compare our WEPP stochastic approach, detailed below, to the deterministic MUSLE methodology. Stakeholder perceptions were sought by asking three different focus groups questions about variability and uncertainty with reference to the above comparison of prediction methodologies. Participants in each of the three focus groups were invited based on their professional interests and perspective of soil erosion and sediment load delivery. The focus groups provided collective insights from different stakeholder types regarding the usefulness of improved uncertainty analysis and statistical techniques.

WEPP Stochastic Approach

We used stochastically generated climate data from CLIGEN as input into the Water Erosion Prediction Project (WEPP) for Monte Carlo simulation of sediment load delivery to the outlet of the watershed. Daily sediment yield output generated by WEPP permits mathematical quantification of the probability for achieving a target load. The GIS interfaced version of WEPP, GeoWEPP, adds a spatial dimension for identifying areas of concern and treatment (Renschler 2003). Climate was chosen as the variable input for the Monte Carlo simulation because sediment delivery is most sensitive to attributes of the storm event, particularly rainfall depth (Nearing et al. 1990, Tiscareno-Lopez et al. 1993). In fact, precipitation is the single most important source of uncertainty contributing to physical simulation model output variance (Zhang and Yu 2004).

Model parameter values for soils and topography were obtained from the best available digitized data. During the Monte Carlo simulation, land feature data and the crop management scenario for the study watershed was maintained constant while the stochastically generated climate input parameters vary with each simulation. For this project, 5000 random daily climate sets of 20 years in length were generated from climatic parameter distributions of the Grundy Center weather station, located about 13 km north of the example watershed.

Important assumptions of the WEPP stochastic approach are: that precipitation is the dominant source of variability in sediment delivery; past measurements of daily precipitation adequately represent future daily rainfall event probability; individual storm events affect sediment delivery independently; the daily precipitation event occurs uniformly over the watershed; and stream bank and classical gully erosion do not contribute significantly to the sediment delivery. In other words, we assume that WEPP can accurately describe the sediment delivery from this watershed.

For explicit quantification of TMDL uncertainty, both the pollutant load and an acceptable frequency of exceeding the load must be defined. The maximum load should reflect an amount of sediment that would cause significant damage to water quality should it be exceeded. Because climate is uncontrollable, severe events that exceed the target maximum load can occur from time to time, so an acceptable frequency of the maximum loading must also be established. The acceptable frequency of a defined load is a function of water system resilience. The target includes both the defined load and the defined frequency of exceedence.

For the purpose of illustration, we define the target maximum event sediment load to be 300 tonnes delivered to the outlet and calculate the probability of exceeding the maximum more than once during a 20–year period. This single event is approximately one tenth of an average annual soil loss tolerance of 11.2 tonnes ha^{-1} yr^{-1} (5 tons ac^{-1} yr^{-1}). The 300 tonne target maximum event sediment load is compared to a lower event sediment delivery load of 100 tonnes not to be exceeded more than 20 times during a 20–year period.

Figures 2a and 2b show the sediment yield output for each precipitation event during one example 20–year period stochastically generated by CLIGEN for the spring chisel and no–till scenarios, respectively. Because of the stochastic nature of each climate data set, each simulation yields a different sediment delivery output. The data generated from many simulations (5000) can be used to construct a probability distribution as presented in the Results and Discussion section.

MUSLE Deterministic Approach

As an empirical model, MUSLE has the advantage of requiring only simple computations compared to the complex process computations required by WEPP. Also, the wider range of watershed size makes it applicable to larger watersheds. MUSLE, however can only be applied for a designated runoff event with specific land cover conditions at the time of the event. Past studies suggest that data from CLIGEN may be adapted to generate the R-factor for USLE and RUSLE (Nicks and Gander 1994, Renard and Freidmund 1994, Yu 2002). A CLIGEN generated R-factor for MUSLE, if validated, would be useful for empirical estimation of sediment delivery from watersheds caused by individual storms. Daily changes in cover conditions that affect soil erosion because of the climate would replace the need for an assumed C-factor at an arbitrary time in the cropping cycle. An advantage of empirical models like MUSLE is computational efficiency. A limited number of empirical equations makes for speedy computation. The computations of the process–based WEPP model are much more intensive. If the goal is to improve computation efficiency, little is gained by applying MUSLE with stochastic climate data. The daily calculations of the C-factor may counter the reduction in computations by using MULSE for sediment delivery. Also the spatial information provided by GeoWEPP is not be available.

The estimate of sediment yield for similar conditions of 296 ha watershed in Tama County Iowa using MUSLE for the 2–year, 24–hour rainfall event follows.

The Universal Soil Loss Equation (USLE) was developed from field data to provide estimates of average annual soil loss (A) from hillslopes:

$$A = RKLSCP \tag{1}$$

where R is the annual rainfall erosivity factor, K is a soil erodibility factor, LS is a factor for slope length and steepness, C is a cover management factor, and P is a supporting practice factor. LS, C and P are dimensionless. We used township level data from the National Resources Inventory (NRI) to estimate the average values of K, L and S for MUSLE calculations. U.S. customary units for the soil erodibility are converted to metric units by multiplying K by 0.1317 (Foster et al. 1981).

$K = 0.0373\, t\, ha\, h\, ha^{-1}\, MJ^{-1}\, mm^{-1}$ $(0.283\, t\, ac\, h\, hundreds\text{–}of\text{–}ac^{-1}\, f^{-1}\, tonf^{-1}\, in^{-1})$

$L = 71\ m$ $(233\ f)$

$S = 0.04$ (unitless)

$LS = 0.6$ (unitless)

We assume the event occurs on July 15 in corn after soybeans and determine the cover and management factor (C) according to the procedure described in Laflen et al. (1985).

Spring Chisel $C = 0.39$ (unitless)

No-Till $C = 0.08$ (unitless)

The erosivity factor of USLE (R) reflects the average annual rainfall erosive energy and is a function of location. MUSLE uses the erosivity factor (R_w) proposed by Williams (1975) to improve the USLE individual–storm soil loss predictions (Laflen et al. 1985).

$$R_w = 27.06 A^{0.12} Q^{0.56} q_p^{0.56} \tag{2}$$

where A is the watershed area (ha), Q is the volume of runoff (mm), and q_p is the peak flow rate (mm/h). R_w, as determined by Equation 2, is in metric units ($MJ\,mm\,ha^{-1}\,h^{-1}$). Equation 2 was developed from data from 18 watersheds ranging in size from about 3 acres to over 4000 acres and therefore includes the effect of a delivery ratio (Williams 1975).

The 2–year, 24–hour storm event in Tama County, Iowa is 81.3 mm (Hershfield 1961). Using the NRCS curve number method, Q=32.4 mm and q_p= 11.0 mm h^{-1}. Therefore
R_w = 1439 M$J\,mm\,ha^{-1}\,h^{-1}$

We used a curve number (CN) of 78 (USDA NRCS 1986) for both the spring chisel scenario and the no–till scenario in the determination of Q and q_p. The CN for each of the two scenarios is dependent on antecedent conditions for which we have no information. There is evidence that runoff is higher for no-till in the long term (Dabney et al. 2004), which would indicate a higher CN value. However, runoff resulting from single storm events is highly variable and inconsistent (Ghidey and Alberts, 1998). Antecedent conditions that influence the curve number must be assumed in a deterministic model such as MUSLE. We choose consistency in the assumed CN value for the two tillage scenarios over assumed CN differences in order to make the broader comparison between the stochastic and deterministic methods.

Substituting the factors into Equation 1, we estimate the event sediment delivery for the two management scenarios. These estimates from MUSLE are shown graphically with the stochastic data from WEPP in Figures 2a and 2b.

Spring Chisel $A = 3730\ tonnes$ ($4112\ US\,tons$)

No-Till $A = 770\ tonnes$ ($849\ US\,tons$)

Stakeholder Focus Groups

Scientists have convincingly argued for improved NPS modeling and better statistical methods for quantifying prediction uncertainty (USEPA 2002), yet little evidence exists showing that these technical improvements result in better land management. Uncertainty is a vague concept, involves risk, and different people respond differently to risk. Stronger scientific evidence should result in better application. The focus group study of soil erosion and sediment delivery stakeholders is included as part of this work for additional perspective of erosion prediction science and real world outcomes.

The focus group study was organized and conducted following the guidance of Krueger and Casey (2009). Three stakeholder types define the makeup of each focus group. The focus group method requires homogeneity with respect to the topic under discussion. The participants may be diverse in other respects but must have a common interest in controlling soil losses from agricultural lands. When properly conducted, focus groups provide collective insights into perceptions of the community. Focus group results are different from individual interviews, which provide individual perspectives (Krueger and Casey 2009).

This focus group study was organized into three stakeholder types; science professional, environmental and producer. These three types have different relationships with the land and suffer different consequences from excessive soil erosion and sediment transport. All three groups have an interest in reducing soil erosion as much as possible, yet they have been known to disagree about actions to take to address the soil erosion problem. By questioning the three groups independently regarding soil erosion and sediment transport uncertainties, common and conflicting perceptions can be revealed.

The science professional focus group consisted of five individuals charged with studying and improving surface water quality. A second focus group was attended by eleven individuals with "environmental interests" and a third group consisted of five individuals with "agricultural production interests". Individuals in the technical professional group represented government and academic entities. The environmental interest group was represented by local, state and national environmental organization members. The participants of the production interest group were individual farmers and representatives of agricultural production organizations. All individuals that participated in each of the three focus group meetings were college educated and well informed regarding soil erosion and sedimentation processes.

Each of the three meetings was held at a neutral and convenient location for the participants. The discussion was recorded by audio tape and transcribed to written text for analysis. The moderator of the meeting posed questions to each group as the conversation proceeded. The following questions were prepared in advance and used as a guide for each meeting discussion:

1. How can we control soil erosion and sediment loss under agricultural land uses?

2. What is meant by "the 2 year precipitation event?" How does it differ from "the 2 year erosion event"?

3. What methods of erosion prediction are you familiar with? What do you use erosion models for? What are their strengths and weaknesses?

4. How important is it that prediction of future soil erosion be accurate (that what really happens matches what was predicted) when you install or recommend the best practices mentioned before?

5. How useful is it to know the probability that the soil erosion goal will be met?

6. (Display and explain Figure 3) What questions come to your mind as you compare these two? How much do the differences matter to you?

7. When you evaluate soil erosion and sedimentation what other kind of information would be useful to you?

The focus group meetings took place in the fall of 2009, with about one month between the meetings. The technical professionals met first followed by the environmental group. The production interests group met last in early December of 2009. A research team consisting of a PhD student, one associate professor of agricultural and biosystems engineering and one associate professor of sociology analyzed the focus group meeting transcripts independently. After the independent analyses, the research team members met to discuss and document key themes from each of the focus group discussions. A qualitative analysis of the focus group data and further discussion of implications follows in the Results and Discussion section.

Results and Discussion

The sediment yield estimates from the GeoWEPP stochastic method and the MUSLE deterministic method are presented for the example watershed. Next the analysis of the focus group interviews is discussed. Because climatic factors, particularly rainfall depth, are the greatest source of uncertainty in sediment yield predictions (Nearing et al. 1990, Tiscareno-Lopez et al. 1993, Zhang and Yu 2004), we first present the results of sediment prediction with precipitation as the independent variable of interest (Figure 2).

WEPP Stochastic Method

The output from the Monte Carlo simulations of WEPP generated 5000 sets of 20 years of sediment yield for the example watershed. The data presented in Figure 2a is just one of the 5000 potential outcomes from the spring chisel scenario. It shows the sediment yield estimate for each precipitation event during one example 20–year period stochastically generated by CLIGEN. Because of the stochastic nature of each climate data set, each simulation yields different sediment delivery output.

Figure 2b shows the sediment yield estimate for the no–till scenario using the same climatic data set. In this simulation, no–till clearly reduces sediment delivery compared to the spring chisel plow scenario (Figure 2a). The data generated from each of 5000 simulations is used to construct a probability distribution as presented in Figures 4 and 5.

Criteria for developing a meaningful distribution must be consistent and depend on the target. As discussed before, the target has two components; the defined load and the acceptable frequency of exceeding the load. Figure 2a illustrates that, under the chisel plow scenario, the probability that the target maximum daily load of 300 tonnes will be exceeded in this 20–year simulation is high; the target was exceeded at least 23 times in each of 5000 simulations. In contrast, in the no–till scenario, the target was exceeded the 14 times or less in each of 5000 simulations. Even more, 2226 20–year simulations (about 45%) did not exceeded the target more than once under the no–till scenario for the same climate dataset input. Of these, 803 simulations (16%) never exceeded the 300 tonne target in 20 years. We compare all 5000 climatic datasets by counting the number of events that exceed the target during each 20–year simulation. The resulting Monte Carlo distribution is shown in Figure 4.

This stochastic approach provides data for a probability distribution histogram from which uncertainty can be explicitly quantified. Under the conditions of the chisel plow scenario, we compute a 100% probability of exceeding the specific target of 300 tonnes more than once in 20 years. Under no–till scenario, we compute a probability of exceeding this target as approximately 55%.

Consider a lower maximum sediment event load target of 100 tonnes not to be exceeded more than 20 times in 20 years (Figure 5). As 100 tonnes is lower than the previous example, this target is more likely to be exceeded, and accordingly, the histograms respond by shifting to the right. Under these new target criteria, the chisel plow scenario again has a 100% probability of exceeding the 100 tonne target more than 20 times in 20 years. The probability that the 100 tonne target will be exceeded more than 20 times in 20 years under the no–till scenario is about 10%. The two examples of uncertainty calculations presented are from the same climate data input and sediment yield output. Only the criteria for the target has changed.

The example watershed of 296 ha (1.14 square miles) used for development of this procedure required 3 to 4 days of computation time to complete 5,000 simulations using an Intel Core 2 processor at 2.4 GHz with 3 GB of RAM. Adequate statistical rigor may be achieved with less iteration. Analyses of the mean and standard deviation of the Monte Carlo distribution show that these parameters stabilize after only about 100 to 200 simulations in our example (Figures 6). This would reduce the analysis time to hours rather than days. The speed of computation would need to be reduced further, to seconds or minutes, for the analysis and comparison of multiple management scenarios in a time frame conducive to stakeholder decision–making. Significant computational efficiency improvements need to be made for such a method to be considered practical and useful beyond the research setting.

MUSLE Deterministic Method

The MUSLE approach using a precipitation event frequency of 2 years and a 24 hour duration provides a single predicted value of sediment yield for the two management scenarios (Figures 2a and 2b). The MUSLE predictions are well within the range of sediment yield predictions from WEPP. However, beyond the knowledge of the precipitation event probability, no other quantifiable measure of uncertainty can be inferred from the MUSLE solution.

The timing of the storm event used in the MUSLE analysis can affect the predicted amount of sediment delivery significantly. For intensive tillage systems, the cover conditions that determine the C–factor in MUSLE vary greatly throughout the year. For example, the C–factor at May planting of continuous corn after moldboard plow and disk has been estimated to be 0.52. By mid July of the same year the C–factor for the same cropping system would be expected to decrease by more than half to a value of about 0.20. Cover conditions in no–till corn of a corn–soybean rotation follow a similarly trend, the C–factor decreasing from 0.17 in mid May to 0.08 in mid July (Laflen et al. 1985).

In the past, the IDNR has relied on MUSLE as a deterministic model for sediment TMDLs. However, the stochastic method using WEPP and CLIGEN provides more information for explicit uncertainty analysis as recommended by *The Twenty Needs Report* (USEPA 2002). The usefulness of one prediction method over the other may be perceived differently by different stakeholders. The focus group component of this study provides some insight into how different stakeholders in the community are influenced by the different types of uncertainty information.

Stakeholder Focus Group Perceptions

The questions posed to the stakeholder focus groups of this study were designed to guide each conversation toward the issue of sediment delivery prediction uncertainty, exceedance probabilities and a comparison between the stochastic and deterministic methods. The focus group discussion transcripts reveal important perceptions of each of the three groups which, if clearly understood, may be useful for improving the TMDL program and NPS pollution control in general.

The general consensus of each of the three focus groups was that more data provided by the stochastic approach helps to understand the highly variable nature of sediment delivery events and the difficulty of predicting sediment loads. Despite the variability of the output data, all three groups expressed that the stochastic comparisons between the two management scenarios provide a more convincing argument for the implementation of no–till rather than spring chisel (Figure 2). One participant from the environmental interest group commented the following with regard to the prediction method comparison:

> "Having the extra data points makes a huge difference...I'd like to see another 57 conservation practices all analyzed this way with the stochastic method..."

Such enthusiasm for the stochastic approach, while welcomed by those of us dedicated to NPS modeling, were tempered by concerns of the science professionals group regarding excessive computations demanded by Monte Carlo simulations. The producer group was initially cautious in expressions of approval for quantified probabilities. However, after more discussion about the data, the producer group appreciated how the stochastic approach better explains the risk of failure, even with the best erosion control practices in place.

Interest in the statistical analysis and comparison of stochastic and deterministic methods was overshadowed by a stronger desire on the part of all three focus groups to express their concern, even frustration, with the persistent reality of soil erosion, sedimentation and other NPS pollution problems. For all three focus groups in this study, statistically computed quantified uncertainty of model predictions was of secondary importance. The primary issue discussed was technical complexity of NPS transport processes and social obstacles inhibiting significant changes needed for improving soil management and offsite effects.

Both science professional and producer groups spoke frequently of the complexity of researching, and the difficulty of controlling, soil erosion and other NPS pollutants. These two groups expressed frustration over the inability of the broader public, including policy-makers, to understand the dilemmas faced by technical professionals and producers. The science professional group referred to the recently published State-EPA Nutrient Innovations Task Group August 2009 report "An Urgent Call to Action" (USEPA 2009) as a good example of these misunderstandings. The report states that nutrient application does not match crop needs and a "proper rate and timing" for nutrient application can "reduce the amount of nutrients released from farm fields". While the report is factually correct, this is an over–simplification of a very difficult problem. It implies that clear technical solutions exist for reducing nutrient loads, much of which is carried by sediment. This is in direct contrast to views expressed by the technical professionals focus group:

> "The technical arenas are quite confusing. They are not clear at all, particularly when it comes to water quality and nonpoint source landscapes."

In the context of the same issue, the production group spoke similarly:

> "That's very important because a lot of times they just, you know, somebody says if they just do that, that will fix the problem and it's not anyway near that simple."

The environmental interest group spoke less of the difficulties brought on by the complexity of soil erosion control. The tone was more forgiving of the scientific shortcomings. The group was willing to accept and eager to deal with the realities of this complex problem:

> "...it doesn't matter that its accurate, ... it's a guide. It's not going to be the final product. For us it's more important the money is there to continue the refinement of the model."

The environmental focus group more often spoke of social factors such as peer pressure and guilt at the local coffee shop for gaining community support for natural resources stewardship. Interestingly, the production group also spoke of using the farmer's social network as an effective way to motivate less progressive land managers.

Just as engineers have often fail to consider the social aspects of technological applications, social scientists find it difficult to keep pace with the physical science disciplines. For example, the science professionals group spoke of the relatively advanced understanding and prediction capabilities for in–field movement of soil particles for sheet and rill erosion, but that our prediction capabilities fall short under conditions of classical gully erosion, streambank and perennial streambed erosion:

> “There are examples...where they maybe put thirty to forty percent of a ten thousand acre watershed into native prairie and we don’t see any change in sediment discharge from that watershed; where the models, the very simple models, would tell us we’d see a huge decrease in sediment from that watershed, but because we’ve not accounted for all the sources, particularly probably bed and bank sources,...we see no change after a ten year period”

Sediment load prediction for watersheds that approach the typical TMDL area of many square miles are weakened by assumptions of streambank and streambed contributions or by neglecting them entirely. This weakness in simulating in–stream processes may often be poorly understood by sociologists working on water quality issues. Technical shortcomings should be communicated better to those outside the technical arena.

> “...as technical people we could provide a clear message and clearer technologies and more understandable approaches and practices and what they will achieve.”

The focus group discussions suggest that the difficulties of effectively controlling NPS pollution, be it insoluble sediment particles, pollutants adsorbed to the sediment, or soluble pollutants, go well beyond the issue of statistical quantification. They suggest that NPS control strategies, as they exists today, fail to consider the very complex nature of NPS pollution. These complexities are still poorly understood and communicated. They include not only complexities of the physical system but also complexities of our social structure. Careful thought and caution on all sides are advised for the next generation of conservation policies:

> “It’s not so much the will to do it, ... it’s so difficult. How do you do things? And you have to be very careful not to go down the wrong path and do something that does no good, costs a lot, and builds ill will.”

Conclusions

This study used GeoWEPP and the stochastic climate generator CLIGEN to develop a valid stochastic method for quantifying sediment load prediction uncertainty. The stochastic method allows an improved analysis of uncertainty compared to the deterministic approach of MUSLE. The stochastic approach provides sufficient output for the generation of sediment yield and exceedance frequency distributions. The deterministic MUSLE approach, on the other hand, gives a single sediment yield data point. While both approaches give sediment yield estimates, statistically, they are different. Clearly, the WEPP stochastic approach better illustrates the degree of variability and level of uncertainty in sediment delivery estimates.

The focus group component of this study suggests that communicating uncertainty may better help the general public understand the difficulties of controlling soil erosion and sedimentation. Rigorous statistical analyses using stochastic models can help stakeholders better understand uncertainty. However, the value of very specific and detailed statistical information must be balanced with the value of the resources required to generate it, and the ultimate influence it has on land stewardship and erosion control.

Complexity of the soil erosion process, rather than uncertainty quantification, was the primary concern for the technical professional and production focus groups. A concern that environmentalists lack an understanding of the complex problem was expressed by these two groups. The environmental interest group, however, expressed understanding of the complexities of soil erosion and sediment delivery, but encouraged a continued effort for step–by–step improvements.

More knowledge and better understanding of social attitudes and behaviors are key to maintaining sustainable food production systems that limit soil and nutrient losses to our waters. It is time for a new look at the National Research Council report on TMDL needs (USEPA 2002) with greater consideration of the social obstacles to TMDL program success.

Aknowledgements

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Tables and Figures

Table 1 Field operations for simulated corn-soybean management scenarios.

Tillage	**Date**	**Operation Type**	**Name**	**Comments**
Spring Chisel	1/1/1	Initial Conditions	After soybeans, fall plow	
	4/23/1	Tillage	Disk	Depth: 5 cm; Type: Sec[a]
	4/25/1	Tillage	Disk	Depth: 5 cm; Type: Sec
	4/27/1	Tillage	Field cultivator	Depth: 5 cm; Type: Sec
	4/30/1	Tillage	Planter	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/1	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=98%	
	11/1/1	Tillage	Plow, Moldboard	Depth: 20 cm; Type: Pri[b]
	4/29/2	Tillage	Disk	Depth: 5 cm; Type: Sec
	5/1/2	Tillage	Disk	Depth: 5 cm; Type: Sec
	5/3/2	Tillage	Field cultivator	Depth: 5 cm; Type: Sec
	5/5/2	Tillage	Planter	Depth: 5 cm; Type: Sec
	5/5/2	Plant - Annual	Soybeans for NC Iowa	Row Width: 75 cm
	9/30/2	Harvest - Annual	Soybeans for NC Iowa	
	11/1/2	Tillage	Plow, Moldboard	Depth: 20 cm; Type: Pri
No-Till	1/1/1	Initial Conditions	After soybeans, no fall tillage	
	4/30/1	Tillage	Planter-no-till	Depth: 5 cm; Type: Sec
	4/30/1	Plant - Annual	Corn for NC Iowa	Row Width: 75 cm
	10/20/1	Harvest - Annual	Corn for NC Iowa	
	10/21/1	Residue Removal	Biomass Removal=86%	
	5/5/2	Tillage	Planter-no-till	Depth: 5 cm; Type: Sec
	5/5/2	Plant - Annual	Soybeans for NC Iowa	Row Width: 75 cm
	9/30/2	Harvest - Annual	Soybeans for NC Iowa	

[a] Secondary Tillage [b] Primary Tillage

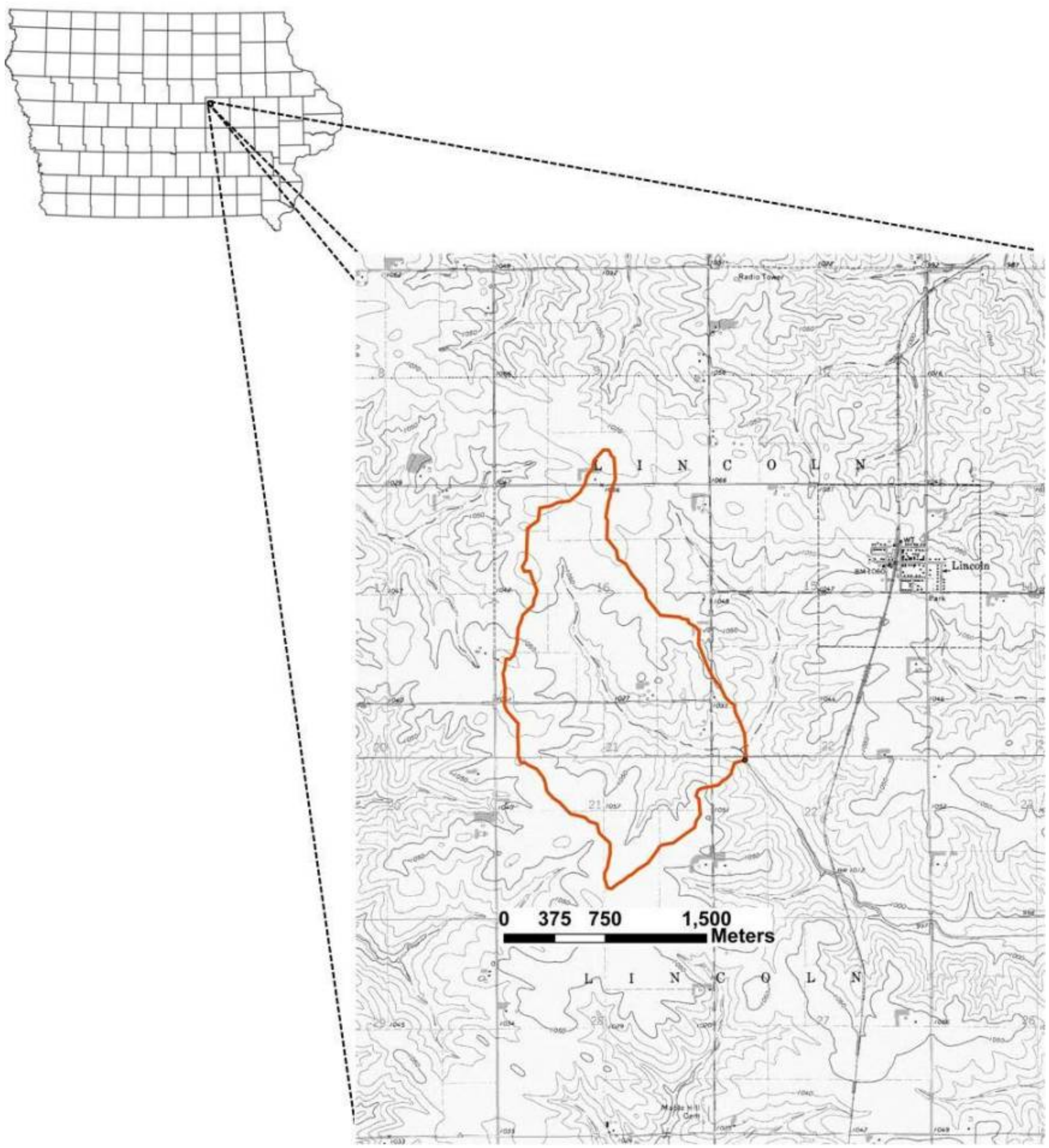

Figure 1 Example 296 ha watershed in Tama County, Iowa, used for model simulations.

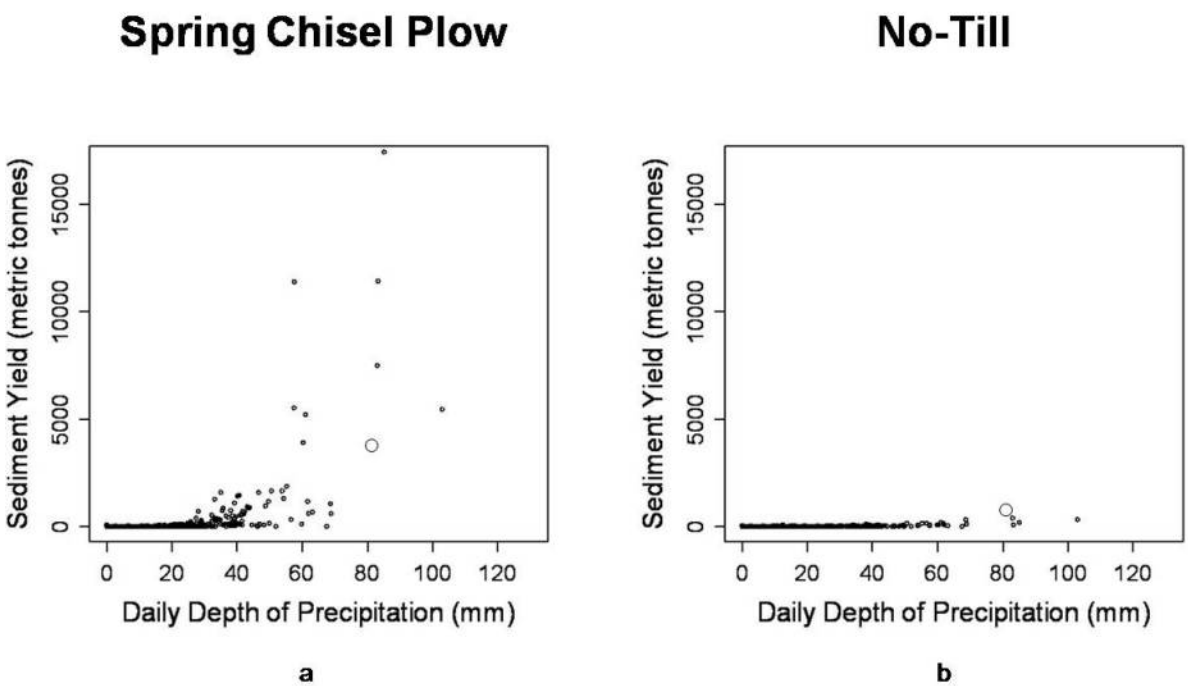

Figure 2 Comparison the deterministic output of MUSLE for the 2–year, 24–hour single event (open circles) and 20 years of stochastic output from WEPP (solid dots) for spring chisel plow and no–till scenarios.

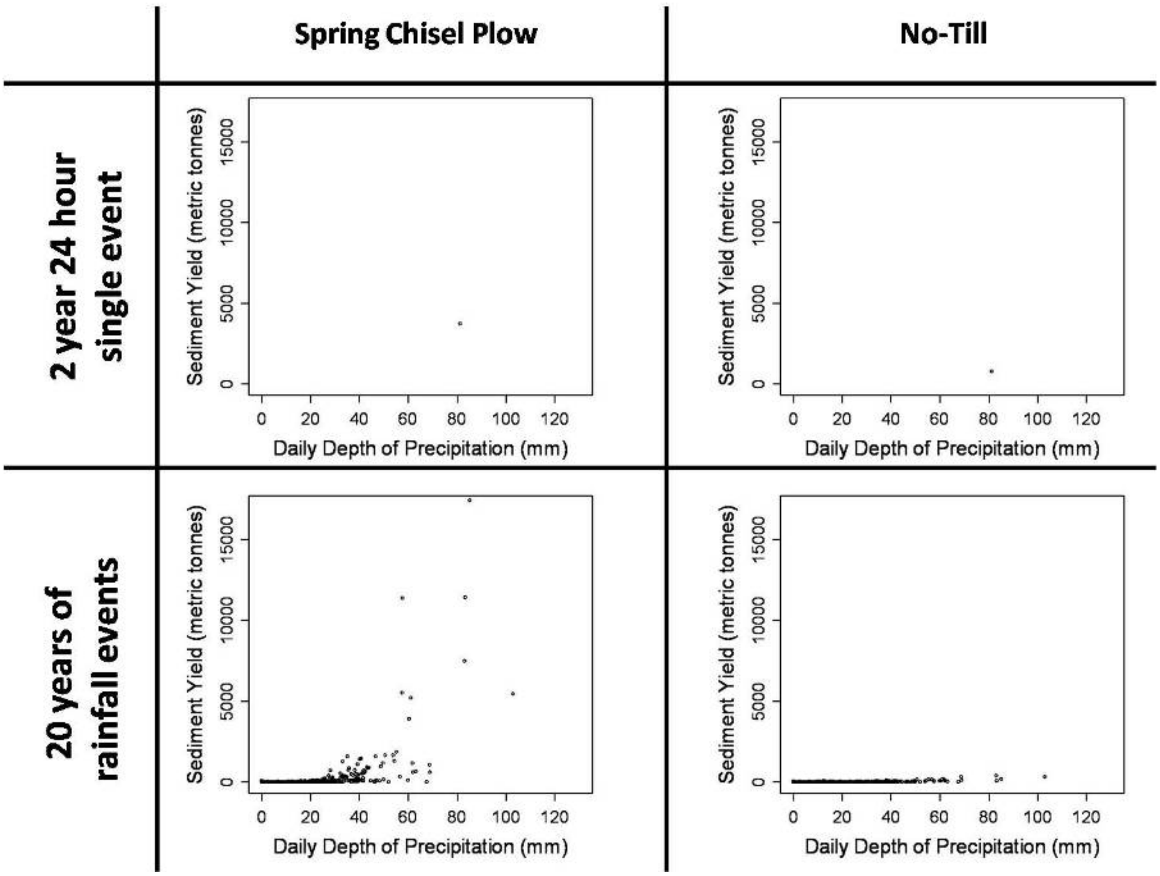

Figure 3 Graphic presented to focus groups: Comparison the deterministic output of MUSLE for the 2–year, 24–hour single event (top) and 20 years of stochastic output from WEPP (bottom) for spring chisel plow and no–till scenarios.

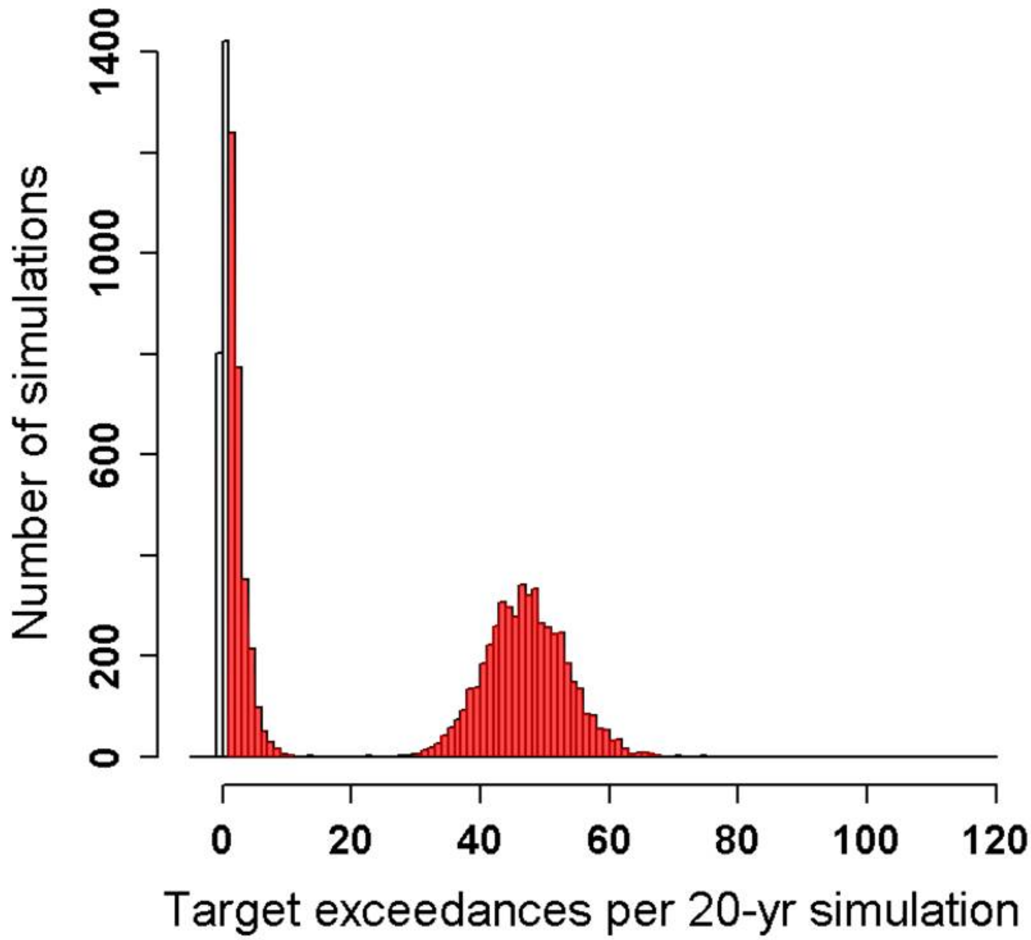

Figure 4 Histograms showing distribution of 20-year simulations for spring chisel plow (right) and no–till (left) scenarios that exceed a 300 tonne per event delivery more than once per 20–year simulation.

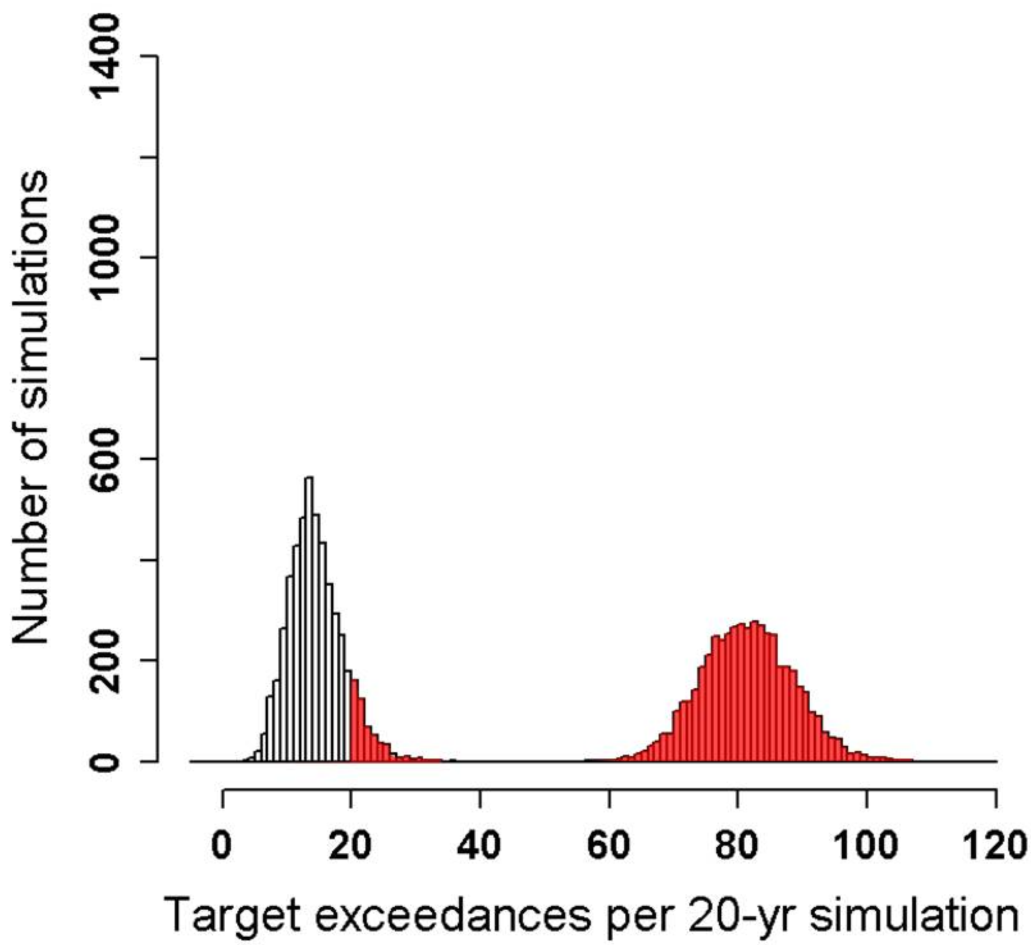

Figure 5 Histograms showing distribution of 20-year simulations for spring chisel plow (right) and no–till (left) scenarios that exceed a 100 tonne per event delivery at least 20 times per 20–year simulation.

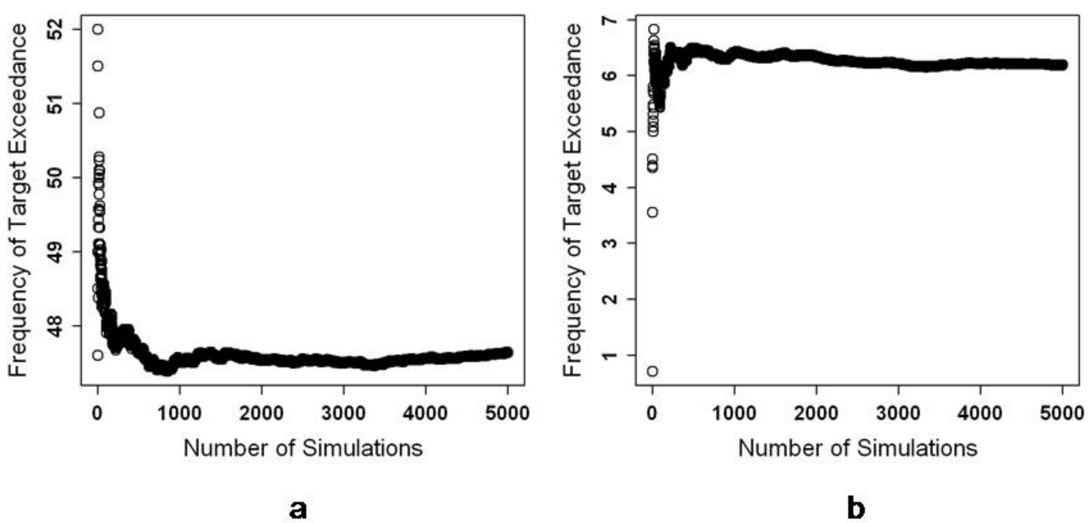

Figure 6 Plots of: a) running mean of frequency of 300 tonne target exceedance; b) running standard deviation of frequency of 300 tonne target exceedance—per 20–year simulation for chisel plow scenario.

CHAPTER 4. GENERAL CONCLUSIONS

General Discussion and Recommendations

Soil erosion prediction models play an important role in shaping conservation policy and practice. The traditional USLE empirical model technology compliments and validates the more process–based WEPP model. As computing efficiency improves and more precise digitized field data become available, the more process–based WEPP model will likely become the preferred tool for evaluating soil management scenarios.

Process–based models like WEPP have to make many calculations, often in a step–by–step sequence, consuming large amounts of computer processing resources and time. Still, the advantages of WEPP are considerable. WEPP has been shown to estimate soil erosion as well as USLE technology, automated linkage with stochastically generated climate exists, and the WEPP–GIS interface, GeoWEPP, is already established. Hopefully, new computer technology will improve processing speed, and we will continue to integrate the best physical process models with established empirical science to produce tools for NPS control and broader environmental management.

Should corn stover become a profitable commodity in Iowa as a feedstock for cellulosic ethanol, improvement to the WEPP code and user interface will be an important contribution. The existing WEPP biomass management editor option of removing a percentage of the total flat biomass after harvest has been found through the peer review process of the paper of Chapter 2 to be unrealistic. The single pass harvester recovers standing stover cut at the time of harvest, leaving residue from senescence and previous crop years on the ground. Analysis of WEPP biomass pools, beyond the standard WEPP biomass pools tracked by WEPP was required make a realistic analysis of residue amounts remaining after harvest. Adding biomass harvesting scenario to the WEPP biomass editor dedicated to the processes of a single pass harvester could be useful for future analyses.

The township level resolution NRI data used in Chapter 2 is an improvement to past county level studies of corn stover availability. However, improving GIS technology, digitized soils data and digital elevation models now make field and small watershed scale studies feasible and cost effective. The challenge now is to improve usability and processing efficiency such that watersheds of significant area can be simulated in a time frame that is practical for providing information to decision-makers. The modeling work in Chapter 3 uses the latest GIS technology interfaced with WEPP to perform an analysis of the example 296 ha watershed. User competence and computational efficiency are still the greatest obstacle to the application of a GIS interfaced model like GeoWEPP for evaluating multiple management scenario options. Significant effort is required up front to prepare the files needed to run the GeoWEPP model. Fortunately, this prep work need be performed only once for stable soil and topographic conditions. In time, state and nationwide coverage of GeoWEPP digitized watershed data will be made available from public websites, allowing users to advance the analysis of watersheds under varying management scenarios.

Clearly, the WEPP stochastic approach developed and present in Chapter 3 better illustrates the degree of variability and level of uncertainty in sediment delivery estimates. This study used GeoWEPP and the stochastic climate generator CLIGEN to develop a valid stochastic method for quantifying sediment load prediction uncertainty. The stochastic method allows an improved analysis of uncertainty compared to the deterministic approach of MUSLE. The stochastic approach provides sufficient output for the generation of sediment yield and exceedance frequency distributions. The deterministic MUSLE approach, on the other hand, gives a single sediment yield data point. While both approaches give sediment yield estimates, statistically, they are different.

The focus group component of Chapter 3 provided valuable data regarding the usefulness of resource management models for informing field decisions and setting conservation policy. The study suggests that communicating uncertainty may better help the general public understand the difficulties of controlling soil erosion and sedimentation. Rigorous statistical analyses using stochastic models can help stakeholders better understand uncertainty. However, the value of very specific and detailed statistical information must be balanced with the value of the resources required to generate it, and the ultimate influence it has on land stewardship and erosion control.

Complexity of the soil erosion process, rather than uncertainty quantification, was the primary concern for the technical professional and production focus groups. A concern that environmentalists lack an understanding of the complex problem was expressed by these two groups. The environmental interest group, however, expressed understanding of the complexities of soil erosion and sediment delivery, but encouraged a continued effort for improvements.

More knowledge and better understanding of social attitudes and behaviors are key to maintaining sustainable food production systems that limit soil and nutrient losses to our waters. It is time for a new look at the National Research Council report on TMDL needs (USEPA 2002) with greater consideration of the social obstacles to TMDL program success. Physical scientist cannot do it alone. Interdisciplinary collaboration is vital for successfully addressing soil erosion, sedimentation and NPS pol

Next Generation of Conservation

The approach to solving the difficult problem of soil erosion and sedimentation continues to evolve as we better understand and accept the complexities of the physical and social science aspects of natural resource management. Social obstacles are perhaps greater than the technical challenges for controlling non–point–source (NPS) pol

US national policy since the inception of the soil conservation movement has been one of top–down push for nationwide coverage of SCD and Resource Conservation and Development Areas (RC&D). Equal support for all has been the goal; an NRCS District Conservationist for each SCD and an RC&D Coordinator for each RC&D Area. Now, national SCD and RC&D Area coverage is essentially complete while funding for top-down administration and financial support is drying up. The USEPA TMDL program faces similar difficulties at the state level. SCDs, RC&D Areas and state TMDL programs are children of the federal government and have all fallen victim to the well intentioned but failed policy of "No Child Left Behind".

Nationally mandated measures of success pressure field conservationists to "teach to the test", to develop plans on paper only, to compute soil savings, to report practices poorly or perhaps never implemented, to do those things that support the continuation of their employment whether federal, state or county.

The old model created a civic structure for conservation. Now the stage is set for the next generation of conservation policy; a policy based on independent science and grass-roots initiatives for cooperative projects and agreements between conflicting interest groups, between the winners and losers of unsustainable soil management. Just as the "Race to the Top" policy for national education reform gives hope and encouragement to failing school districts across the United States, so too could competitive financial support for watersheds make soil and water quality improvements a reality. Goals set locally or within the boundaries of the affected areas, funded by beneficiaries of success, and supported by federal funds presently wasted on obsolete national conservation programs may prove to be a better policy. NRCS should stay true to its primary mission of providing excellent technical support for conservation. No longer can our nation's most valued technical conservation agency spend resources to prop up inactive or floundering SCDs and RC&D Areas. No longer can we afford developing TMDL plans without clear implementation support. Watershed based, grassed roots organizations and programs must be given the opportunity to compete on a level playing field with SCDs, RC&D Areas and state TMDL programs for support of measurably effective projects.

References

Morton, L.W. 2008. The role of civic structure in achieving performance–based watershed management. *Society and Natural Resources. 21*:751-766.

Newman, J.K., A.L. Kaleita, and L.W. Morton. 2010. Chapter 3. Uncertainty of sediment load estimates and stakeholder perspectives. In: Soil erosion prediction for shaping conservation policy and practice. Unpublished dissertation Iowa State University. Ames, Iowa.

USEPA. 2002. The Twenty Needs Report: How Research Can Improve the TMDL Program. EPA841-B-02-002, US Environmental Protection Agency Office of Water, Washington DC. pp. 43.

ADDITIONAL MATERIAL

C++ Code for Universal Change in Rotation Scenario

```
// Reads NRI prj files from prjfipsnullregfixed.txt and changes rotation
//scenario (rot file path/name)
#include <fstream>
#include <iostream>
#include <string.h>
#include <conio.h>
#include <iomanip>
using namespace std;

int main(int nNumberofArgs, char* pszArgs[])
{
char prjfipsnullregfixed[20];
char prj[15];
char fips[6];
char region[3];
//char fixedline[11];

ifstream openFile("prjfipsnullregfixed");
string fixedline;
```

```
if(openFile!=NULL)

   {
   if(!openFile)
   {
   cout << endl << "Fail to open file " << "prjfipsnullregfixed" << endl;
   return 1;
   }

while (!openFile.eof())
   {
   ofstream outFile("tempFile");
   getline (openFile,fixedline);
   //cout << "Got line from openFile" << endl;
   //system("PAUSE");
   cout << fixedline << endl;
   //system("PAUSE");
   if(!openFile.eof())
   {
   prj[0] = fixedline[0];
   prj[1] = fixedline[1];
   prj[2] = fixedline[2];
   prj[3] = fixedline[3];
   prj[4] = fixedline[4];
   prj[5] = fixedline[5];
   prj[6] = fixedline[6];
   prj[7] = fixedline[7];
   prj[8] = fixedline[8];
   prj[9] = fixedline[9];
```

```
 prj[10] = fixedline[10];
 prj[11] = '.';
 prj[12] = 'p';
 prj[13] = 'r';
 prj[14] = 'j';
 prj[15] = '\0';

 fips[0] = fixedline[12];
 fips[1] = fixedline[13];
 fips[2] = fixedline[14];
 fips[3] = fixedline[15];
 fips[4] = fixedline[16];
 fips[5] = '\0';

 region[0] = fixedline[18];
 region[1] = fixedline[19];
 region[2] = '\0';

 //cout << prj << fips << region << "Did it print .prj extension?" << endl;
 //system("PAUSE");

ifstream openprjFile(prj);
//cout << openprjFile << endl;
string prjline;

 if(!openprjFile)
 {
 cout << endl << "Fail to open file " << prj << endl;
 system("PAUSE");
```

```
 return 1;
 }

while (!openprjFile.eof())
{
getline (openprjFile,prjline);
if(!openprjFile.eof())
{
//cout << prjline << endl;
outFile << prjline << endl;
//system("PAUSE");
}
//Find the rot file string and replace it with new scenario rot file
//according to the correct region if "Management {" found

string::size_type loc = prjline.find( "Management {" );
if( loc != string::npos )
{
getline (openprjFile,prjline);
//cout << prjline << endl;
outFile << prjline << endl;
//system("PAUSE");
//cout << "   " << region << "-CGRER-CC-CT-NR.rot {" << endl;
outFile << "   " << region << "-CGRER-CC-CT-N.rot {" << endl;
//system("PAUSE");
getline (openprjFile,prjline);
getline (openprjFile,prjline);
//cout << prjline << endl;
outFile << prjline << endl;
```

```
//system("PAUSE");
//cout << "    File = \"nri\\CGRER-CC-CT-NR\\" << region << \
"-CGRER-CC-CT-NR.rot\"" << endl;
outFile << "    File = \"nri\\CGRER-CC-CT-N\\Silage\\" << region << \
"-CGRER-CC-CT-NRS.rot\"" << endl;
getline (openprjFile,prjline);
}
}
getline (openprjFile,prjline);
if(!openprjFile.eof())
{
//cout << prjline << endl;
outFile << prjline << endl;
}


//system("PAUSE");

 //Rename tempfile to prj
 ifstream openRevised("tempFile");
 string revline;
 if(!openRevised)
 {
 cout << endl << "Fail to open file " <<"tempfile";
 return 1;
 }
 //recreate file filename for output
 ofstream outRev(prj);
```

```
    while (!openRevised.eof())
    {
    getline (openRevised,revline);

    //print lines to the screen
    //cout <<fileName;
    if(!openRevised.eof())
    {
    //cout << revline << endl;

    //print lines to the file prj
    outRev << revline << endl;
    //system("PAUSE");
    }
    }
    //outFile.close();
    openRevised.close();
    //system("PAUSE");
}
}
openFile.close();
}
system("PAUSE");
return 0;
}
```

Batch Code for Stochastic Generation of Climate Files

```
@Echo off
echo Enter total number of climate files to be generated: > con
set /P total=Enter total number of climate files to be generated:
echo+
echo+
echo+ > con
echo+ > con
set /a "count=0"
:Here
set /a "count+=1"
set seed=%random%
echo Random seed for outfile%count% is %seed%

:Failedloop
cligenc -iiowa\ia\ia133487.par -oiowa\outfile%count%.cli -b1 -y100
:CONTINUE ABOVE LINE CODE WITH -r%seed% -t5 -F >iowa\cligenlog%count%.txt
:Flag "Failed" in the log and goto :Failedloop if "Failed" found
echo %count% climate files generated. > con
IF %count%==%total% GOTO END
Goto Here
:END
echo+
echo+ > con
echo %count% climate files generated.
echo %count% climate files generated. > con
:PAUSE
echo+
```

```
echo+ >con

set /a "count=0"

ECHO END OF CLIMATE FILE GENERATION BATCH

ECHO END OF CLIMATE FILE GENERATION BATCH > con
```

Batch Code for Stochastic Generation of Sediment Yield Output

```
@Echo off
:Copy all p*.man .cli .slp .sol file from runs directory to wepp directory
: BEFORE CLOSING WINWEPP WINDOW!!
copy ..\runs\p*.* *.*
echo:
echo Verify number of hillslopes above
echo:
set /P hillslopes=Enter number of hillslopes generated by GeoWEPP:
set /P climatesets=Enter number of climate sets generated by gencli.bat:
set /a "countcli=0"
set /a "countrun=0"
:CliHere
set /a "countcli+=1"
copy ..\data\climates\cligen\iowa\outfile%countcli%.cli common.cli > nul
:CALL Replace_Common_Climate.exe > nul
:RunHere
set /a "countrun+=1"
IF %countcli%==1 copy ..\runs\H%countrun%_slp.txt p%countrun%.slp > nul
copy common.cli p%countrun%.cli > nul
CALL wepp < p%countrun%.run > nul
copy ..\output\pass_%countrun%.txt H%countrun%_pass.txt
echo H%countrun%_pass.txt successfully created for .cli file %countcli%
IF %countrun%==%hillslopes% GOTO pwa
Goto RunHere
:pwa
copy common.cli pw0.cli >nul
CALL wepp < pwa0.run > nul
```

```
copy ..\Output\ebe_pw0.txt ..\Output\ebe_pw%countcli%.txt > nul
echo %countcli% climate sets completed
set /a "countrun=0"
IF %countcli%==%climatesets% GOTO End
GOTO CliHere
:End
ECHO END OF Watershed BATCH
```

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

DATE: September 14, 2009

TO: James K. Newman
126 Davidson Hall

CC: Dr. Amy Kaleita
205 Davidson Hall

FROM: Roxanne Bappe, IRB Coordinator
Office for Responsible Research

TITLE: **Soil Erosion and Sediment Load Prediction Focus Group Study**

IRB ID: **09-429** **Study Review Date:** 14 September 2009

The Institutional Review Board (IRB) Chair has reviewed this project and has declared the study exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b). The IRB determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as proposed in the IRB application**, including obtaining and documenting (signed) informed consent if you have stated in your application that you will do so or if required by the IRB.
- **Any modification of this research should be submitted to the IRB on a Continuing Review and/or Modification form, prior to making <u>any</u> changes**, to determine if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB proposal will need to be submitted and approved before proceeding with data collection.

Please be sure to **use the documents with the IRB approval stamp** in your research.

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB may make the determination of exemption,** even if you conduct a study in the future that is exactly like this study.

For IRB Use Only	Review Date: 14 September 2009 Approval Date: ____ Approval Expiration Date: ____ EXEMPT per 45 CFR 46.101(b): 2 Date: 9/14/09 EXPEDITED per 45 CFR 46.110(b) Category ____, Letter ____	IRB ID: 09-429 Length of Approval: ____ FULL Committee Review: ____ Minimal Risk: ✓ More than Minimal Risks: ____ Project Closed Date: ____

INSTITUTIONAL REVIEW BOARD (IRB)
Application for Approval of Research Involving Humans

IRB
SEP 09 2009

SECTION I: GENERAL INFORMATION

Principal Investigator (PI): James K. Newman	Phone: 515-294-7350	Fax:
Degrees: PhD	Correspondence Address: 126 Davidson Hall, Ames, Iowa 50011	
Department: ABE	Email Address: jknewman@iastate.edu	
Center/Institute:	College: Engineering and Ag. & Life Sciences	
PI Level: ☐ Faculty ☐ Staff ☐ Postdoctoral ☒ Graduate Student ☐ Undergraduate Student		
Alternate Contact Person: Dr. Amy Kaleita	Email Address: kaleita@iastate.edu	
Correspondence Address: 205 Davidson Hall, Ames 50011	Phone: 515-294-5167	
Title of Project: Soil Erosion and Sediment Load Prediction Focus Group Study		
Project Period (Include Start and End Date): [*mm/dd/yy*][*09/25/09*] to [*mm/yy/dd*][*11/25/09*]		

FOR STUDENT PROJECTS	
Name of Major Professor/Supervising Faculty: Dr. Amy Kaleita	Signature of Major Professor/Supervising Faculty: [signature]
Phone: 515-294-5167	Campus Address: 205 Davidson Hall
Department: ABE	Email Address: kaleita@iastate.edu
Type of Project: (check all that apply) ☐ Research ☐ Thesis ☒ Dissertation ☐ Class project ☐ Independent Study (490, 590, Honors project) ☐ Other. Please specify: ____	

KEY PERSONNEL

List all members and relevant experience of the project personnel. This information is intended to inform the committee of the training and background related to the specific procedures that each person will perform on the project.

NAME & DEGREE(S)	SPECIFIC DUTIES ON PROJECT	TRAINING & EXPERIENCE RELATED TO PROCEDURES PERFORMED, DATE OF TRAINING
✓ J.K. Newman PhD Candidate	Invite participants, develop focus group questions, prepare final report	Completed IRB training on protection of human research participants Certificate #280106 (9/3/09)
✓ Dr. Amy Kaleita	Advise PI, moderate focus group session	Tenured faculty, experienced academic advisor and instructor. 09/18/09

To list additional personnel please attach separate sheet.

FUNDING INFORMATION

☐	Internally funded, please provide account number:
☐	Externally funded, please provide funding source and account number:
☐	Funding is pending, please provide OSPA Record ID on GoldSheet:
	Title on GoldSheet if different from above:
☐	Other: *(e.g., funding will be applied for later)*
☒	Student Project—no funding or funding provided by student

SCIENTIFIC REVIEW

Although the assurance committees are not intended to conduct peer review of research proposals, the federal regulations include language such as "consistent with sound research design," "rationale for involving animals or humans" and "scientifically valuable research," which requires that the committees consider in their review the general scientific relevance of a research study. Proposals that do not meet these basic tests are not justifiable and cannot be approved. If an assurance review committee(s) has concerns about the scientific merit of a project and the project was not competitively funded by peer review or was funded by corporate sponsors, the project may be referred to a scientific review committee. The scientific review committee will be an ad hoc and will consist of your ISU peers and outside experts as needed. If this situation arises, the PI will be contacted and given the option of agreeing that a consultant may be contacted or withdrawing the proposal from consideration.

☒ Yes ☐ No Has or will this project receive peer review?

If the answer is "yes," please indicate who did or will conduct the review:
Yes. A paper reporting the insights from the focus group will be submitted to a peer-reviewed journal for potential publication.
If a review was conducted, please indicate the outcome of the review: N/A

COLLECTION OR RECEIPT OF SAMPLES

Will you be: (Please check all that apply.)

☐ Yes ☒ No Receiving samples from outside of ISU? See examples below.
☐ Yes ☒ No Sending samples outside of ISU? See examples below.

Examples include: genetically modified organisms, body fluids, tissue samples, blood samples, pathogens.

If you will be receiving samples from or sending samples outside of ISU, please identify the name of the outside organization(s) and the identity of the samples you will be sending or receiving outside of ISU. If the outside organizations have not been identified, please check no for both questions above.

N/A

Please note that **some samples may require a** USDA Animal Plant Health Inspection Service (APHIS) **permit**, a USPHS Centers for Disease Control and Prevention (CDC) Import Permit for Etiologic Agents, a Registration for Select Agents, High Consequence Livestock Pathogens and Toxins or Listed Plant Pathogens, or a Material Transfer Agreement (MTA) EH&S Website

ASSURANCE

- I certify that the information provided in this application is complete and accurate and consistent with any proposal(s) submitted to external funding agencies.
- I agree to provide proper surveillance of this project to ensure that the rights and welfare of the human subject or welfare of animal subjects are protected. I will report any problems to the appropriate assurance review committee(s).
- I agree that I will not begin this project until receipt of official approval from all appropriate committee(s).
- I agree that modifications to the originally approved project will not take place without prior review and approval by the appropriate committee(s), and that all activities will be performed in accordance with all applicable federal, state, local and Iowa State University policies.

CONFLICT OF INTEREST

A conflict of interest can be defined as a set of conditions in which an investigator's or key personnel's judgment regarding a project (including human or animal subject welfare, integrity of the research) may be influenced by a secondary interest (e.g., the proposed project and/or a relationship with the sponsor). ISU's Conflict of Interest Policy requires that investigators and key personnel disclose any significant financial interests or relationships that may present an actual or potential conflict of interest. By signing this form below, you are certifying that all members of the research team, including yourself, have read and understand ISU's Conflict of Interest policy as addressed by the ISU Faculty Handbook (http://www.provost.iastate.edu/faculty) and have made all required disclosures.

☐ Yes ☒ No Do you or any member of your research team have an actual or potential conflict of interest?
☐ Yes ☐ No If yes, have the appropriate disclosure form(s) been completed? **N/A**

SIGNATURES

9/9/09

Signature of Principal Investigator — Date

9/9/09

Signature of Department Chair — Date

The Major Professor/Supervising Faculty member must sign the cover page in the section entitled "For Student Projects".

PLEASE NOTE: Any changes to an approved protocol must be submitted to the appropriate committee(s) before the changes may be implemented.

Please proceed to SECTION II.

SECTION II: IRB SECTION - STUDY SPECIFIC INFORMATION

Please complete all of the following questions.

STUDY OBJECTIVES

Briefly explain in **language understandable to a layperson** the specific aim(s) of the study.

The goal of the focus group is to gain insight into how participants perceive the influence that better science and technology has or will have on land management for meeting soil erosion goals from agricultural lands. The discussion will begin with this general theme and focus in on discussion of two statistical methods for expressing risk and uncertainty, and the impact that the methods might have on actual implementation of pollution control efforts.

BENEFITS TO SOCIETY AND PARTICIPANTS

Explain in **language understandable to a layperson** how the information gained in this study will advance knowledge, and/or serve the good of society. Please also describe the direct benefits to research participants; if there are no direct benefits to participants, indicate that. **Note**: monetary compensation cannot be considered a benefit to participants.

This study will help guide future science and public policy for soil erosion control.

PART A: PROJECT INVOLVEMENT

1) ☐ Yes ☒ No Is this project part of a Training, Center, Program Project Grant?
Director Name: Overall IRB ID:
2) ☐ Yes ☒ No Is the purpose of this project to develop survey instruments?
3) ☐ Yes ☒ No Does this project involve an investigational new drug (IND)? Number:
4) ☐ Yes ☒ No Does this project involve an investigational device exemption (IDE)? Number:
5) ☐ Yes ☒ No Does this project involve existing data or records?
6) ☐ Yes ☒ No Does this project involve secondary analysis?
7) ☐ Yes ☒ No Does this project involve pathology or diagnostic specimens?
8) ☐ Yes ☒ No Does this project require approval from another institution? Please attach letters of approval.
9) ☐ Yes ☒ No Does this project involve DEXA/CT scans or X-rays?

PART B: MEDICAL HEALTH INFORMATION OR RECORDS

10) ☐ Yes ☒ No Does your project require the use of a health care provider's records concerning past, present, or future physical, dental, or mental health information about a subject? The Health Insurance Portability and Accountability Act established the conditions under which protected health information may be used or disclosed for research purposes. If your project will involve the use of any past or present clinical information about someone, or if you will add clinical information to someone's treatment record (electronic or paper) during the study, you must complete and submit the Application for Use of Protected Health Information.

PART C: ANTICIPATED ENROLLMENT

Estimated number of participants to be enrolled in the study Total: 12 Males: 11 Females: 1	
Check if any enrolled participants are: ☐ Minors (Under 18) Age Range of Minors: ☐ Pregnant Women/Fetuses ☐ Cognitively Impaired ☐ Prisoners	Check below if this project involves either: ☒ Adults, non-students ☐ Minor ISU students ☐ ISU students 18 and older ☐ Other (explain)
List estimated percent of the anticipated enrollment that will be minorities *if known*:	
American Indian: 0	Alaskan Native: 0
Asian or Pacific Islander: 0	Black or African American: 0
Latino or Hispanic: 0	

PART D: PARTICIPANT SELECTION

Please use additional space as necessary to adequately answer each question.

11. Explain the procedures and rationale for selecting participants, including the inclusion and exclusion criteria (e.g., where will names come from, what persons will be included or excluded and why, etc.).

> Convenient sampling of individuals with an interest in soil erosion control from agricultural lands. Invitations will be extended to 4 Story County farmers, 4 individuals from academia, and 4 individuals from government.

12. Describe the procedures for contacting participants (e.g., letter, email, flyer, advertisements, phone call, etc.). Attach copies of any letters, scripts, flyers, or advertisements that will be used. Recruitment materials should include a statement of the voluntary and confidential nature of the research.

> All participants were initially contacted by phone and email. Farmer contacts were obtained through ISU extension specialists that work frequently with outreach demonstration and education projects with farmers. One farmer's contact information was obtained through publically available information online. Academic contacts are professional acquaintances of the PI that have expertise in the science and practice of soil conservation. Government contacts were made by email addresses available through public websites.

PART E: RESEARCH PLAN

Include sufficient detail for IRB review of this project independent of the grant, protocol, or other documents.

13. The information needed here is similar to that in the "methods" or "procedures" sections of a research proposal—it should describe the flow of events that will occur during your interactions with subjects. Please describe in detail your plans for collecting data from participants, including all procedures, tasks, or interventions participants will be asked to complete during the research (e.g., random assignment, any conditions or treatment groups into which participants will be divided, mail survey or interview procedures, sensors to be worn, amount of blood drawn, etc.). This information is intended to inform the committee of the procedures used in the study and their potential risk. Please do not respond with "see attached" or "not applicable."

> One 2-hour meeting for open discussion of soil erosion prediction technology. Discussion will be recorded with audio tape and transcribed. Accepted focus group procedures will be followed.

14. For studies involving pathology/diagnostic specimens, indicate whether specimens will be collected prospectively and/or already exist "on the shelf" at the time of submission of this review form. If prospective, describe specimen procurement procedures; indicate whether any additional medical information about the subject is being gathered, and

whether specimens are linked at any time by code number to the participant's identity. If this question is not applicable, please type N/A in the response cell.

N/A

15. For studies involving deception or where information is intentionally withheld from participants, such as the full purpose of the study, please explain how persons will be deceived or what information will be withheld. Additionally, a waiver of the applicable elements of consent will be needed. Please complete the "Waiver of Elements of Consent" form (available at the IRB website). If this question is not applicable, please type N/A in the response cell.

N/A

PART F: CONSENT PROCESS

A copy of any translated informed consent documents and an English version should be submitted with the application. Provide the name of the individual who translated the consent documents, their qualifications for translating documents, and in particular informed consent documents, below.

If the consent process does not include documented consent, a waiver of documentation of consent must be requested. If any information about the study is intentionally withheld or misleading (i.e., deception is used), a waiver of the elements of consent must be requested. Forms for requesting waivers are available at the IRB website.

16. Describe the consent process for adult participants (those who are age 18 and older).

Participants will receive the written invitation (copy is submitted with this application) which states that their presence at the meeting will be considered as informed consent.

17. If your study involves minor children, please explain how parental consent will be obtained prior to enrollment of the minor(s).

N/A

18. Please explain how assent will be obtained from minors (younger than 18 years of age), prior to their enrollment. Also, please explain if the assent process will be documented *(e.g., a simplified version of the consent form, combined with the parental informed consent document).* According to the federal regulations assent "...means a child's affirmative agreement to participate in research. Mere failure to object should not, absent affirmative agreement, be construed as assent."

N/A

PART G: DATA ANALYSIS

19. Describe how the data will be analyzed (*e.g. statistical methodology, statistical evaluation, statistical measures used to evaluate results*).

Data will be subjectively analyzed for insight into collective perspectives of participants.

PART H: RISKS

The concept of risk goes beyond physical risk and includes risks to participants' dignity and self-respect as well as psychological, emotional, legal, social or financial risk.

20. ☐ Yes ☒ No Is the ***probability*** of the harm or discomfort anticipated in the proposed research greater than that encountered ordinarily in daily life or during the performance of routine physical or psychological examinations or tests?

21. ☐ Yes ☒ No Is the ***magnitude*** of the harm or discomfort greater than that encountered ordinarily in daily life, or during the performance of routine physical or psychological examinations or tests?

22. Describe any risks or discomforts to the participants and how they will be minimized and precautions taken. Do ***not*** respond with N/A. If you believe that there will not be risk or discomfort to participants, you must explain why.

No risk or discomfort beyond those encountered in normal daily life will be experienced.

23. If this study involves vulnerable populations, including minors, pregnant women, prisoners, the cognitively impaired, or those educationally or economically disadvantaged, what additional protections will be provided to minimize risks?

N\A

PART I: COMPENSATION

24. ☐ Yes ☒ No Will participants receive compensation for their participation? If yes, please explain.

Do not make the payment an inducement, only a compensation for expenses and inconvenience. If a person is to receive money or another token of appreciation for their participation, explain when it will be given and any conditions of full or partial payment. (E.g., volunteers will receive $5.00 for each of the five visits in the study or a total of $25.00 if he/she completes the study. If a participant withdraws from participation, they will receive $5.00 for each of the visits completed.) It is considered undue influence to make completion of the study the basis for compensation.

N/A

PART J: CONFIDENTIALITY

25. Describe below the methods that will be used to ensure the confidentiality of data obtained. (For example, who has access to the data, where the data will be stored, security measures for web-based surveys and computer storage, how long data or specimens will be retained, anticipated date that identifiers will be removed from completed survey instruments and/or audio or visual tapes will be erased, etc.)

Only collective opinions and perspectives to be reported. Records will not include names of individual participants.

PART K: REGISTRY PROJECTS

26. To be considered a registry: (1) the individuals must have a common condition or demonstrate common responses to questions; (2) the individuals in the registry might be contacted in the future; and (3) the names/data of the individuals in the registry might be used by investigators other than the one maintaining the registry.

☐ Yes ☒ No Does this project establish a registry?

If "yes," please provide the registry name below.

N/A

Checklist for Attachments

Listed below are the types of documents that should be submitted for IRB review. Please check <u>and attach</u> the documents that are applicable for your study:

☐ A copy of the informed consent document **OR** ☐ Letter of introduction containing the elements of consent
☐ A copy of the assent form if minors will be enrolled
☐ Letter of approval from cooperating organizations or institutions allowing you to conduct research at their facility
☐ Data-gathering instruments (including surveys)
☐ Recruitment fliers, phone scripts, or any other documents or materials participants will see or hear

The original signed copy of the application form and one set of accompanying materials should be submitted for review. **Federal regulations require that one copy of the grant application or proposal be submitted for comparison with the application for approval.**

FOR IRB USE ONLY:

Action by the Institutional Review Board (IRB):

☐ Project approved. Date: ____________
☒ Project is exempt. Date: 14 September 2009
☐ Project not approved. Date: ____________
☐ IRB approval is not required. Date: ____________
  ☐ Project is not research according to the federal definition.
  ☐ Project does not include human subjects as defined by the federal regulations.

Claire K. Ament
IRB Approval Signature

14 September 2009
Date

SECTION III: ENVIRONMENTAL HEALTH AND SAFETY INFORMATION

☐ Yes ☒ No Does this project involve human cell or tissue cultures (primary OR immortalized), or human blood components, body fluids or tissues?

PART A: HUMAN CELL LINES

☐ Yes ☒ No Does this project involve human cell or tissue cultures (primary OR immortalized cell lines/strains) that have been documented to be free of bloodborne pathogens? If the answer is "yes," please answer question 1 below and attach copies of the documentation.

1) Please list the specific cell lines/strains to be used, their source and description of use.

CELL LINE	SOURCE	DESCRIPTION OF USE

Add New Row

2) Please refer to the ISU "Bloodborne Pathogens Manual," which contains the requirements of the OSHA Bloodborne Pathogens Standard. Please list the specific precautions to be followed for this project below (e.g., retractable needles used for blood draws):

N/A

Anyone working with human cell lines/strains that have not been documented to be free of bloodborne pathogens is required to have Bloodborne Pathogen Training annually. Current Bloodborne Pathogen Training dates must be listed in Section I for all Key Personnel. Please contact Environmental Health and Safety (294-5359) if you need to sign up for training and/or to get a copy of the Bloodborne Pathogens Manual
(http://www.ehs.iastate.edu/cms/default.asp?action=article&ID=214)

PART B: HUMAN BLOOD COMPONENTS, BODY FLUIDS OR TISSUES

☐ Yes ☒ No Does this project involve human blood components, body fluids or tissues? If "yes," please answer all of the questions in the "Human Blood Components, Body Fluids or Tissues" section.

1) Please list the specific human substances used, their source, amount and description of use.

SUBSTANCE	SOURCE	AMOUNT	DESCRIPTION OF USE
E.g., Blood	*Normal healthy volunteers*	*2 ml*	*Approximate quantity, assays to be done.*

Add New Row

2) Please refer to the ISU "Bloodborne Pathogens Manual," which contains the requirements of the OSHA Bloodborne Pathogens Standard. Specific sections to be followed for this project are:

N/A

Anyone working with human blood components, body fluids or tissues is required to have Bloodborne Pathogen Training annually. Current Bloodborne Pathogen Training dates must be listed in Section I for all Key Personnel. Please contact Environmental Health and Safety (294-5359) if you need to sign up for training and/or to get a copy of the Bloodborne Pathogens Manual (http://www.ehs.iastate.edu/cms/default.asp?action=article&ID=214).

ISU IRB # 1 09-429
EXEMPT DATE: 14 September 2009

Soil Erosion and Sediment Load Prediction Focus Group Study

PURPOSE:

The purpose of this focus group is to explore how soil erosion and sediment load prediction science can reduce soil loss and improve water quality.

PROTOCOL:

Group Size	6-10 people, 1 moderator
Duration	One 2 hour meeting
Location	Neutral and convenient
Form of data	Conversation, silences, body language
Data Collection	Audio tape and transcript
Report Outlet	PhD dissertation

DISCUSSION QUESTIONS:

1. What practices best control soil erosion and sediment loss under agricultural land uses?
2. What is meant by "the probability of an erosion event?" How does it differ from the probability of a precipitation event?
3. What do you use erosion prediction models for? What methods of erosion prediction are you familiar with? What are their strengths and weaknesses?
4. How important is it that prediction of future soil erosion be accurate (that what really happens matches what was predicted) when you install or recommend the best practices mentioned before?
5. How useful is it to know the probability that the soil erosion goal will be met?
6. (Display and explain plots of stochastic and 2yr-24 hour event outputs) What questions come to your mind as you compare these two? How much do the differences matter to you?
7. When you evaluate soil erosion and sedimentation what other kind of information would be useful to you?

ISU IRB # 1 09-429
EXEMPT DATE: 14 September 2009

Consent Form For: Soil Erosion and Sediment Load Prediction Focus Group Study

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Please discuss any questions you have about the study or about this form with the project staff before deciding to participate.

Who is conducting this study?

This study is being conducted by James Newman under the supervision of Dr. Amy Kaleita. This study has received no funding from outside sources.

Why am I invited to participate in this study?

You are being asked to participate in this study because you are a farmer or landowner in Iowa; or a scientist with knowledge of soil erosion processes; or a natural resource professional that works to reduce soil erosion and sedimentation.

What will I be asked to do?

If you agree to participate, you will be asked to brainstorm with other participant to list the best practices for controlling soil erosion in central Iowa. You will then be asked to share your understanding of soil loss prediction methods, their strengths and weakness, and information that would be helpful for you to reduce soil losses and sedimentation. The discussion is estimated to take about 45 minutes.

What are the possible risks and benefits of my participation?

Risks – There are no risks to participants.

Benefits – Direct benefits to farmers and landowners from this project will be the development of soil erosion prediction techniques and information useful to these stakeholders. Scientists and natural resource professionals will gain insight into the landowner's perceptions of risk and how best to present statistically complex information about soil erosion potential. Participants may receive a copy of the report from this study if they request.

How will the information I provide be used?

The information you provide will be used for the following purposes: Data will be analyzed by the research team and used to prepare a study paper to compliment previous work by Mr. Newman during his PhD study program. The analysis will be included in the student's PhD dissertation and may be submitted for publication in peer-review and public media.

What measures will be taken to ensure the confidentiality of the data or to protect my privacy?

Records identifying participants will be kept confidential to the extent allowed by applicable laws and regulations. Records will not be made publicly available. However, auditing departments of Iowa State University and the ISU Institutional Review Board (a committee that reviews and approves research studies with human subjects) may inspect and/or copy your records for quality assurance analysis.

To ensure confidentiality to the extent allowed by law, the following measures will be taken: Participants will be assigned a unique code and letter that will be used on forms instead of their name. If the results are published, your identity will remain confidential. The data will be kept in Dr. Kaleita's password protected computer files. Original data will be retained for four years before erasure.

Will I incur any costs from participating or will I be compensated?

You will not have any costs from participating in this study.

What are my rights as a human research participant?

Participating in this study is completely voluntary. You may choose not to take part in the study or stop participating at any time, for any reason, without penalty or negative consequences. You can skip any questions that you do not wish to answer.

Whom can I call if I have questions or problems?

You are encouraged to ask any questions at any time during this study.

- For further information about the study contact Mr. James Newman, principal investigator, Department of Agricultural and Biosystems Engineering, 126 Davidson Hall, Ames, Iowa 50011, Iowa State University (515)294-7350. jknewman@iastate.edu
- If you have any questions about the rights of research subject or research-related injury, please contact the IRB Administrator,(515)294-4566, IRB@iastate.edu, or Director,

ISU IRB # 1 09-429
EXEMPT DATE: 14 September 2009

(515)294-3115, Office for Responsible Research, 1138 Pearson Hall, Iowa State University, Ames, Iowa 50011.

Consent and Authorization Provisions

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to you participation in the study.

Participant's Name (printed)______________________________________

______________________________ _______________________
(Participant's Signature) (Date)

Investigator Statement

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed i this study and has voluntarily agreed to participate.

______________________________ _______________________
(Signature of Person Obtaining Consent) (Date)

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

DATE: October 23, 2009

TO: James K. Newman
126 Davidson Hall

CC: Dr. Amy Kaleita
205 Davidson Hall

FROM: Roxanne Bappe, IRB Coordinator
Office for Responsible Research

TITLE: **Soil Erosion and Sediment Load Prediction Focus Group Study**

IRB ID: **09-429** **Study Review Date:** 23 October 2009

The Institutional Review Board (IRB) Chair has reviewed the modification of this project and has declared the study remains exempt from the requirements of the human subject protections regulations as described in 45 CFR 46.101(b). The IRB determination of exemption means that:

- **You do not need to submit an application for annual continuing review.**
- **You must carry out the research as proposed in the IRB application**, including obtaining and documenting (signed) informed consent if you have stated in your application that you will do so or if required by the IRB.
- **Any modification of this research should be submitted to the IRB on a Continuing Review and/or Modification form, prior to making <u>any</u> changes**, to determine if the project still meets the Federal criteria for exemption. If it is determined that exemption is no longer warranted, then an IRB proposal will need to be submitted and approved before proceeding with data collection.

Please be sure to **use the documents with the IRB approval stamp** in your research.

Please note that you must submit all research involving human participants for review by the IRB. **Only the IRB may make the determination of exemption**, even if you conduct a study in the future that is exactly like this study.

For IRB Use Only	Modification Approval Date October 23, 2009 Continuing Review Approval Date Approval Expiration Date: n/a – exempt

ISU HUMAN SUBJECTS CONTINUING REVIEW AND/OR MODIFICATION FORM

IRB

TYPE OF SUBMISSION: ☐ Continuing Review ☒ Modification ☐ Continuing Review and Modification

OCT 09 2009

Principal Investigator: James K. Newman	Phone: 515-294-7350
Degree: PhD	Correspondence Address: 126 Davidson Hall, Ames, Iowa 50011
Department: ABE	E-mail Address: jknewman@iastate.edu
Project Title: Soil Erosion and Sediment Load Prediction Focus Group Study	
IRB ID: 09-429	Date of Last Continuing Review: 09/14/09
IF STUDENT PROJECT	
Name of Major Professor: Dr. Amy Kaleita	Phone: 515-294-5167
Department: ABE	Campus Address: 205 Davidson Hall
	E-mail Address: kaleita@iastate.edu

FUNDING INFORMATION:

☐ External Grant/Contract ☐ Internal Support (no specific funding source) or Internal Grant (indicate name below)	
Name of Funding Source:	OSPA Record ID on Gold Sheet:
☐ Part of Training, Center, Program Project Grant – Director:	Overall IRB ID No:
☒ Student Project—No funding or funding provided by student	

CONFLICT OF INTEREST

The proposed project or relationship with the sponsor require the disclosure of significant financial interests that present an actual or potential conflict of interest for investigators involved with this project. By signing this form, all investigators certify that they have read and understand ISU's Conflict of Interest policy as addressed by the ISU Faculty Handbook and made all disclosures required by it. (http://www.provost.iastate.edu/faculty)

Do you or any member of your research team have a conflict of interest? ☐ Yes ☒ No
If yes, has the appropriate disclosure form been completed? ☐ Yes ☐ No

ASSURANCE

I certify that the information provided in this application is complete and accurate and consistent with proposal(s) submitted to external funding agencies. I agree to provide proper surveillance of this project to insure that the rights and welfare of the human subjects are protected. I will report any adverse reactions to the IRB for review. I agree that modifications to the originally approved project will not take place without prior review and approval by the Institutional Review Board, and that all activities will be performed in accordance with state and federal regulations and the Iowa State University Federal Wide Assurance.

Signature of Principal Investigator 10/9/09 Date

Student Projects: Faculty signature indicates that this application has been reviewed and is recommended for IRB review.

Signature of Supervising Faculty 10/9/09 Date   IRB Approval Signature Kerry A Agnitsch   October 23, 2009 Date

For IRB Use Only	EXPEDITED per 45 CFR 46.110(b) _____, Category _____, Letter _____ STUDY REMAINS EXEMPT per 45 CFR 46.101(b) 2 WAIVER of SIGNED CONSENT per 45 CFR 46.117(c) _____ WAIVER of ELEMENTS of Consent per 45 CFR 46.116 _____ VULNERABLE POPULATION per 45 CFR 46._____

Please answer each question. If the question does not pertain to this study, please type not applicable (N/A).

SECTION I: KEY PERSONNEL

☐ Yes ☒ No Have there been any personnel/staff changes since the last IRB approval was granted?
If yes, complete the following sections (Additions/Deletions) as appropriate.

Add	Delete	Last Name	First Name
N/A			

Add New Row

List all current members and relevant experiences of the project personnel. This information is intended to inform the committee of the training and background of the investigators and key personnel.

NAME & DEGREE(S)	POSITION AT ISU & ROLE ON PROJECT	TRAINING & DATE OF TRAINING
✓ James K. Newman PhD Cand.	Research Assistant, invite participants, develop focus group questions, prepare final report	Completed IRB training on protection of human research participants Certification #280106 9/3/09
✓ Dr. Amy Kaleita	Advise PI, moderate focus group sessions	Tenured faculty, experienced academic advisor and instructor. 9/9/09

Add New Row

SECTION II: CONTINUING REVIEW

In addition to completing Section I: Key Personnel, please complete Section II if this is an application for Continuing Review. If this is an application for continuing review and you will be modifying your project in the future, please complete all sections of the form. **If this application is only to request approval for a modification or change to your study, please complete Section I: Key Personnel and Section III: Proposed Modifications or Changes.**

Part A: Enrollment Status

1. ☐ Yes ☐ No Is the research **permanently** closed to the enrollment of new participants?
2. ☐ Yes ☐ No Have **all** participants completed all research-related interventions?
3. ☐ Yes ☐ No Does research remain active only for long-term follow-up of participants?
4. ☐ Yes ☐ No Are the remaining research activities limited to data analysis? OR
5. ☐ Yes ☐ No Participant enrollment has not begun and no additional risks have been identified.

Number of Participants Approved by IRB:	Number of Participants Consented to Date:
Number of Participants Consented Since Last Continuing Review: Total: Males: Females:	
Number of Participants Screened:	Number of Participants Lost to Follow-up:
Check if any enrolled participants are: ☐ Minors (under 18). Age Range of Minors: _ ☐ Pregnant Women/Fetuses ☐ Cognitively Impaired ☐ Prisoners	Check below if this project involves either: ☐ Existing Data/Records ☐ Secondary Analysis ☐ Pathology/Diagnostic Specimens
List Estimated Percent of the Total Enrolled That Are Minorities Below	
American Indians:	Alaskan Native:
Asian or Pacific Islander:	African American:

Black (Not of Hispanic Origin):	Hispanic:

1. ☐ Yes ☐ No Have any participants withdrawn or have you asked any participants to withdraw from the study?

List number for each and reason for withdrawal:

Part B: Protocol Summary – Please use the amount of space needed to adequately address the questions.

1. Please provide a concise summary of the purpose and main procedures of the study.

2. Please provide a summary of how the study is progressing (e.g., progress to date in terms of the overall study plan, success or problems encountered, reasons enrollment has not begun, etc.)

3. Is there any new information (positive or negative) from this study (e.g., interim analysis) or elsewhere (e.g., current literature) that might affect someone's willingness to enroll or continue in the study? It is especially important for the investigator to notify the IRB of literature or information that's relevant to the risks to participants in the study.

4. Please provide a summary of amendments or modifications since last IRB review.

Part C: Adverse Events and Unforeseen Problems

1. ☐ Yes ☐ No Have there been any adverse events or unanticipated problems involving risks to participants or other people?

   If yes, please give them numbers and describe.

   If yes, was it reported to the IRB? Date reported
   If report was not submitted, please explain why.

2. ☐ Yes ☐ No Have there been any participant complaints?

   If yes, please describe.

   Attach any reports submitted to NIH or a Data and Safety Monitoring Board. ☐ Attached ☐ N/A

Part D: Informed Consent

1. ☐ Yes ☐ No If a signed Informed Consent Form was required, was Informed Consent obtained from all participants?

If no, please explain.

2. ☐ Yes ☐ No Are all signed Informed Consent Forms on file with the PI?

If no, please explain.

3.

☐ Attached ☐ N/A	Submit copy of the currently approved Informed Consent Form and an original unstamped copy (if stamped). If changes have been made, please submit the original, a copy with the changes highlighted, and a copy to be stamped with IRB approval
☐ Attached ☐ N/A	Submit currently approved informational letter
☐ Attached ☐ N/A	Submit an unstamped copy of all survey instruments, interview questions, recruitment materials, instructions, and all other material participants will see or hear during their participation so that a current IRB approval stamp can be added. If changes have been made, please submit the original, a copy with the changes highlighted, and a copy to be stamped with IRB approval.

SECTION III: PROPOSED MODIFICATIONS OR CHANGES

If this application is to request approval for modification or changes to your project, please complete Section I: Key Personnel and Section III.

The submission of a modification form is required whenever changes are made to an approved project. This includes but is not limited to a title change, changes in investigators, resubmission of a grant proposal involving changes to the original proposal, changes in the funding source, changes of an instrument, advertisements, reports from a data safety and monitoring board, addition of a test instrument, etc. **NOTE: All changes must be submitted and approved by the IRB prior to their implementation, unless the change is necessary to protect the safety of participants.**

1. Does your project require approval from another institution, please attach letters of approval?

☐ Yes ☒ No

2. The following modification(s) are being made (check all that apply):

☐ Change in protocol.
☒ Change in type or total number of participants. New anticipated total: 20
☒ Change in informed consent document.
☐ Change in co-investigator(s). New co-PI name:

Signature of new Co-PI: ______________________

☐ Change in funding source/sponsor. Please attach copy of grant proposal sent to new funding agency.
☐ Other (e.g., change in project title, adding new materials, adding advertisement, etc.)

NOTE: If the change involves a new Principal Investigator, a new Human Subjects Review form must be submitted.

3. Describe the modification(s) indicated above in sufficient detail for evaluation independent of any other documents. When submitting revised documents please submit one clean copy of the new document and a copy with the changes highlighted.

Two additional focus group meeting will be held. One of the additional groups will consist of 4 to 6 farmers/producers and 3 to 4 individuals from producer associations. The other additional group will consist of 6 to 10 individuals with environmental interests either personally or through association with an environmental organization. Discussion questions for each focus group will be the same as originally approved in IRB 09-429. The first focus group session was conducted on September 29, 2009 with the participation of 1 individual from academia and 4 individuals from the natural resources profession. The two additional focus group meetings will be conducted in November and December of 2009.

The consent form is revised as follows:

Replace: "You are being asked to participate in this study because you are a farmer or landowner in Iowa; or a scientist with knowledge of soil erosion processes; or a natural resource professional that works to reduce soil erosion and sedimentation."

With: "You are being asked to participate in this study because you are a farmer/producer or represent a producer association in Iowa or because you have environmental interests or are associated with an environmental organization in Iowa."

ISU IRB # 1 09-429
EXEMPT DATE: 23 October 2009

Consent Form For: Soil Erosion and Sediment Load Prediction Focus Group Study

This form describes a research project. It has information to help you decide whether or not you wish to participate. Research studies include only people who choose to take part—your participation is completely voluntary. Please discuss any questions you have about the study or about this form with the project staff before deciding to participate.

Who is conducting this study?

This study is being conducted by James Newman under the supervision of Dr. Amy Kaleita. This study has received no funding from outside sources.

Why am I invited to participate in this study?

You are being asked to participate in this study because you are a farmer/producer or represent a producer association in Iowa or because you have environmental interests or are associated with an environmental organization in Iowa.

What will I be asked to do?

If you agree to participate, you will be asked to brainstorm with other participant to list the best practices for controlling soil erosion in central Iowa. You will then be asked to share your understanding of soil loss prediction methods, their strengths and weakness, and information that would be helpful for you to reduce soil losses and sedimentation. The discussion is estimated to take about 45 minutes.

What are the possible risks and benefits of my participation?

Risks – There are no risks to participants.

Benefits – Direct benefits to farmers and landowners from this project will be the development of soil erosion prediction techniques and information useful to these stakeholders. Scientists and natural resource professionals will gain insight into the landowner's perceptions of risk and how best to present statistically complex information about soil erosion potential. Participants may receive a copy of the report from this study if they request.

ISU IRB # 1 09-429
EXEMPT DATE: 23 October 2009

How will the information I provide be used?

The information you provide will be used for the following purposes: Data will be analyzed by the research team and used to prepare a study paper to compliment previous work by Mr. Newman during his PhD study program. The analysis will be included in the student's PhD dissertation and may be submitted for publication in peer-review and public media.

What measures will be taken to ensure the confidentiality of the data or to protect my privacy?

Records identifying participants will be kept confidential to the extent allowed by applicable laws and regulations. Records will not be made publicly available. However, auditing departments of Iowa State University and the ISU Institutional Review Board (a committee that reviews and approves research studies with human subjects) may inspect and/or copy your records for quality assurance analysis.

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Will I incur any costs from participating or will I be compensated?

You will not have any costs from participating in this study.

What are my rights as a human research participant?

Participating in this study is completely voluntary. You may choose not to take part in the study or stop participating at any time, for any reason, without penalty or negative consequences. You can skip any questions that you do not wish to answer.

Whom can I call if I have questions or problems?

You are encouraged to ask any questions at any time during this study.

- For further information about the study contact Mr. James Newman, principal investigator, Department of Agricultural and Biosystems Engineering, 126 Davidson Hall, Ames, Iowa 50011, Iowa State University (515)294-7350. jknewman@iastate.edu
- If you have any questions about the rights of research subject or research-related injury, please contact the IRB Administrator,(515)294-4566, IRB@iastate.edu, or Director,

(515)294-3115, Office for Responsible Research, 1138 Pearson Hall, Iowa State University, Ames, Iowa 50011.

Consent and Authorization Provisions

Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant's Name (printed)____

________________________________ ________________________
(Participant's Signature) (Date)

Investigator Statement

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.

________________________________ ________________________
(Signature of Person Obtaining Consent) (Date)