Project Number: NC-1017/(formerly NC-174)
Project Title: Carbon sequestration and distribution in soils of eroded landscapes
Requested Project Duration: October 1, 2004 through September 30, 2009.

Statement of Issues and Justification: Soil erosion results in a considerable economic loss to landowners because of reduced productivity of eroded soil, and to society at large because of degradation of surface water by sediment and sediment deposition, and emission of greenhouse gases into the atmosphere. Crosson (1984) estimated a monetary loss in the U.S. from soil erosion effects on reduced cropland productivity to be 40 million dollars in a given year. In 2001, den Biggelaar et al. (2001) estimated the loss at $55.6 million. Others Crosson (1986) and Pimentel et al. (1995) have estimated the loss to be over $100 million. The results vary depending on the erosion rates and crop prices for the years covered in the study. For many soils, continued erosion results in degraded topsoil and continuing declines in crop yields as root restrictive layers, such as fragipans, subsoil horizons high in clay content, or coarse sand, become closer to the soil surface (Langdale et al., 1985).

Offsite damages to the environment caused by soil erosion and subsequent deposition of sediments in the U.S. are considerable (Pimentel, 1992). Deposition of eroded soil materials in surface water bodies such as reservoirs, lakes, rivers and streams cause a decline in water quality, and decrease the functional life expectancy of reservoirs. Eroded sediments often contain not only soil materials from the organic surface soil which are enriched in nutrients and C, but often include commercial and/or organic (animal waste) fertilizers, pesticides and agricultural pharmaceuticals.

In addition to water quality problems associated with soil erosion, the loss of organic-rich surface soil also impacts the global C balance. While there has been limited research on the impact of soil erosion on soil C balance, the soil is a major C sink and it is not always managed in a manner to take advantage of this potential. Previous work by members of NC-174 has demonstrated the importance of storing soil C (through increasing organic matter) for improving soil quality, including soil physical properties such as improved water holding capacity (Lal, 1999). However, a strong connection between soil erosion and the global C balance has not been well established. There is also a need for developing a good method for obtaining a quantitative estimate of the actual distribution of C on various eroded and noneroded landscapes in the Midwest. It was recognized during Kyoto Protocol that net emissions of greenhouse gases, such as CO_2 and CH_4 could be decreased by either reducing emissions or by increasing the rate of C sequestration in soils. Agricultural soils are one of the largest reservoirs of C, and thus have a great potential to mitigate the increasing concentration of CO_2 in the atmosphere (FAO, 2001). Evaluation of the C pool in soils is difficult because of its heterogeneity in time and space (FAO, 2001). The global loss of C because of erosion is estimated to be in the range of 150 to 1500 million tons per year (Lal, 1995; Gregorich et al., 1998; Lal, 2003) but the processes are not well understood and we note that these values are only estimates. Erosion is a selective process involving detachment and transport of the light soil fraction consisting of soil organic carbon (SOC) and clay. The fate of eroded soil particles is complex depending on many parameters including soil properties, landscape elements and properties, and drainage net and soil management. Many of the soil particles eroded are moved downslope and may remain in the same field or watershed for a considerable length of time. However, this movement results in increased spatial variability of the landscape soil properties, especially soil organic matter and those elements of environmental concern that are associated with it - carbon and nitrogen (Schumacher et al., 1999).

Federal agencies, such as the Natural Resources Conservation Service (NRCS), state agencies involved in natural resource conservation and management, certified crop advisors, farm managers, experiment station research units, farmers, and many others have a mutual interest in better understanding the relationships among soils and landscapes as related to erosion and the effects of erosion on the amount and distribution of C in soils under different management systems. Better understanding of these relationships will improve environmental protection, soil, air, and water quality, and global warming. In addition, the research will lead to improved efficiency in use of farmer dollars in nutrients applied to the land.

This proposal outlines a project designed to help better understand C losses including soil degradation resulting from accelerated erosion and the effects of erosion on quantitative distribution of C on soil landscape. It will provide needed data on the changes in the C reservoir related to intensive land use for some of the major soils in the NC region. This study will contribute to our understanding of soil-landscape processes and has the potential to provide data that will contribute to improved management of our soil and water resources. We view this approach as a natural progression related to the past research efforts of NC-174.

Knowledge gained from the proposed research will contribute to a more quantitative understanding of agroecosystems on global C balance and increase to our understanding of the effects of erosional processes on the amounts and landscape distribution of C and organic matter. It will contribute to our knowledge leading to sustainable management of natural resources in different ecosystems.

The North Central Regional Association of Agricultural Experiment Stations has a current list of research priorities for seven cross-cutting research areas and objectives. The proposed Regional Project addresses four of these objectives for the Natural Resources and the Environment. These include: (1) Understand the ecological processes operating in human, plant and animal communities, (2) Define sustainable principles for resource management, utilization and land use, (3) Identify and apply ecosystem management principles and practices for the utilization and protection of resources, restoration of natural systems and management of rural landscapes, and (4) Assess the relationships of agricultural/forestry practices (primary production) upon soil and water systems and bio-diversity. Our project will contribute to these research priorities.

Related Current and Previous Work: The following regional research projects have similar focus and/or directions as those of the proposed project.
North-Central Region
NC-218 Assessing nitrogen mineralization and other diagnostic criteria to refine nitrogen rates for crops and minimize losses
Start date: 10/01/95
Revised date: 10/01/01
Termination date: 09/30/06
NCR-59 Soil organic matter

Start date: 09/01/80
Revised date: 10/01/01
Termination date: 09/30/06
NC-94 Impact of climate and soils on crop selection and management
Start date: 07/01/70
Revised date: 07/74, 10/79, 10/84, 10/89, 10/94, and 10/99
termination date: 9/30/04
NCR-103 Specialized soil amendments, products, growth stimulants and soil fertility management programs
Start Date: 09/01/80
Revised Date: 10/98
Termination Date: 09/30/02
NCR-180 Site Specific Management
Start date: 09/01/93
Revised date: 09/97
Termination date: 09/30/06
West
W-188 Characterization of flow and transport processes in soils at different scales
Start Date: 10/01/94
Revised Date: 10/99
Termination Date: 09/30/04
W-190 Agricultural water management technologies, institutions and policies affecting economic viability and environmental quality
Start date: 12/01/94
Revised date: 10/99
Termination date: 9/30/04
Northeast
NEC-1001 Land use management
Start date: 10/01/00
Termination date: 09/31/05
NEREC-5 Environmental enhancement through farm and woodland management
Start date: 02/01/97
Termination date: 09/30/02
South
S-283 Develop and assess precision farming technology and its economic and environmental impacts
Start date: 01/01/98
Termination date: 09/30/02

The two existing Regional Projects which most relate to our proposal are NCR-59 (Soil Organic Matter and Soil Quality) and NC-218 (Assessing N Mineralization And Other Diagnostic Criteria To Refine N Rates For Crops And Minimize Losses). The objectives of NCR-59 (an approved but non-funded regional project) include: (1) Quantify and characterize the biological, chemical and physical soil processes affecting the genesis, composition and reactivity of soil humic substances and other soil organic matter pools, (2) Identify mechanisms and driving variables linking soil organic matter properties to soil function, (3) Increase participation of or interaction with individuals with extension and outreach agencies, and (4) Interact with other regional committees including NC-174/NCT-199 as appropriate. The second objective of NC-218 is to: Conduct fundamental work to enhance current understanding of the role of active C and N pools in cropping systems and to predict net N mineralization as influenced by C sequestration management. There is little overlap of other projects with NCT-199/(NC-174) which has focused more on the chemical and physical properties of soil with the biological component limited primarily to total C or total N. The new proposed NCT-199/(NC-174) project emphasis relates to the effects of management on eroded soil productivity, differential distribution of C related to erosion and landscape position, and quality of soil, air and water resources. Total soil C is used as only one indicator of the impact of erosional impacts on soil processes and properties, but is an important indicator of soil quality and change in its pool has impact on enrichment of atmospheric concentration of CO_2. NC-174 and NCR-59 committees have developed a close working relationship which has resulted in two joint meetings to share information and contribute to joint efforts such as a Methods book. Aside from this, the two projects complement each other since the work will be conducted in the same region of the U.S. with similar soils, physiographic regions, and weather patterns.

Based on a CRIS survey of projects there were none listed under erosion or eroded landscapes. For soil erosion-productivity there are 35 projects listed. However, none of these were studies of paired soil landscape-land use-C distribution-erosion effects with an objective similar to the proposed study.

Past and future NC-174/NCT-199 research efforts are summarized in Figure 1. The objective sequence represents a natural progression from studying soil productivity-erosion relationships to determining C distributions, dynamics and sequestration in eroded landscapes. During the first 5-year phase of the NC-174 project (1983-1988) we identified and documented the effects of erosion on soil properties and corn or small grain yield for research sites located in 11 states (Figure 1). Five years of data were collected to better document the effects of weather on the interaction between soil properties and corn yield in the north central United States. First phase achievements included 13 refereed journal articles and chapters in books. Once the database was enlarged, emphasis was placed on selection of management and restoration alternatives at either the initial or a new research site (Figure 1). The NTRM (Nitrogen, Tillage, Residue and Management) and EPIC (Erosion-Productivity Impact Calculator) models were used in conjunction with the existing data base collected during the initial phase of the NC-174 project to identify factors limiting crop productivity of each soil series investigated. The models were used to evaluate long-term effect of management and restoration alternatives prior to field testing. The second phase (Figure 1) of the project (1988-1993) was to field test the practices selected to maintain or enhance current productivity and to determine the extent to which productivity of eroded soils can be restored. Phase 2 outputs included 25 journal articles and chapters in books. The third phase (Figure 1) of the project (1993-1998) determined threshold soil property values for the restoration of productivity and quality of eroded soils to initial levels. Third phase accomplishments included 74 refereed journal articles and chapters in books. During the fourth phase (Figure 1) of the project, from 1998 to 2003, we examined the erosional and landscape impacts on soil processes and properties as well as assessed the management effects on eroded soil productivity and the quality of soil, air, and water resources. Achievements during phase 4 of the project included 70 refereed journal articles and chapters in books. In this proposal several states intend to continue assessing the management and erosion effects on C distribution and sequestration, productivity and soil quality. The first objective of the planned fifth phase of the project (Figure 1) is to: Determine spatial C distribution and dynamics in soils of eroded landscapes including 3-dimensional model assessments for better quantification. All states will participate in the 1st objective.

Phase 1 of NC-174 — Years 1983 to 1988

1. Identify and document the effects of erosion on soil properties and crop yields using field plots and models.

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Phase 2 of NC-174 — Years 1988 to 1993

1. Continue assessing the effects of erosion on soil properties and crop yields using field plots and models.
2. Evaluate methods for the maintenance and/or restoration of soils productivity of previously eroded soils as evidenced by the field studies and /or model prediction.

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Phase 3 of NC-174 — Years 1993 to 1998

1. Continue to evaluate methods for the maintenance and/or restoration of soils productivity of previously eroded soils as evidenced by the field studies and /or model prediction.
2. Develop soil quality standards for agricultural soils being degraded by tillage and erosion which utilized soil property and productivity parameters and threshold values.

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Phase 4 of NC-174 — Years 1998 to 2003

1. Determine erosional and landscape impacts on soil processes and properties.
2. Assess management effects on eroded soil productivity and quality of soil, air and water.

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Phase 5 of NC-174/NCT-199 — Years 2004 to 2009

1. Determine spatial C distribution and dynamics in soils of eroded landscapes including 3-dimensional model assessments for better quantification.
2. Assess management (cropping systems, amendments and tillage) effects on C sequestration, productivity and soil quality including the importance of no-tillage on increasing C sequestration in eroded soils.

Figure 1. The progression of objectives during the 5 phases of NC-174/NCT-199 projects.

Researchers have compared uncultivated and undisturbed sites with eroded sites to determine the intensity of erosion. These techniques include the comparison of soil properties (Olson et al., 1994) and geomorphologic effects (Kreznor et al., 1989; 1992). In Southern Illinois, Olson et al. (1994) found the removal of a 7.5 cm layer of the surface soil from a cultivated site, with slopes in the range of 5-10%, during 80 years was due to accelerated erosion on a backslope position. They arrived at these results by comparing soil properties of the cultivated site with a nearby-forested site with similar soil, slope, and landscape characteristics. Kreznor et al. (1989) compared accelerated erosion effect on a cultivated site with an uncultivated and uneroded cemetery site in Northwestern Illinois having similar slopes in the range of 6-10%. They found a decrease in A horizon thickness and organic C contents, and an increase in clay contents because of cultivation and erosion. While there is a good understanding of C decreases with increased erosion the quantitative distribution is not known.

Numerous researchers have found decrease in yield with erosion. In Kentucky, Frye et al. (1982) observed that corn grain yields for eroded soils decreased 12-21% when compared to uneroded soils. Spomer and Piest (1982) compared yields from 16 years for summit, backslope, and footslope positions; and found that footslope positions, where eroded soil materials tend to be deposited and accumulate, produced greater yields.

Similar to yield, soil C is also influenced by management practices. Soil organic matter content can be increased by mulch tillage (Beale et al. 1955) and increasing the rate of residue return (Larson et al., 1972; Duiker and Lal, 1999). Over a 10-year period in South Carolina, corn grown by no-tillage in a vetch and rye mulch system increased the soil organic matter, degree of soil aggregation, and stability of the soil structure in the Ap horizon. Frye et al. (1982) found that restoring the organic matter of an eroded soil has greater impact on increasing the available water-holding capacity than restoring the fertility of the soil. However, loss of organic matter can affect the use and effectiveness of herbicides (Frye et al., 1985). In Illinois, during a 14-year study the no-till (NT) treatment sequestered or maintained more soil organic C (SOC) than the chisel plow (CP) and moldboard plow (MP) treatments. For land coming out of the Conservation Reserve Program and returning to row crop production, NT system maintained more SOC than CP and MP systems. The maintenance of SOC with NT system, compared to MP and CP systems, can reduce CO_2 emissions to the atmosphere. The NT system maintained or improved nutrient retention and aggregate stability in the surface layer compared with MP and CP. The NT system performed better than the MP system for soil water storage but failed to maintain macroporosity and resulted in greater bulk density in the surface layer. Based on 14-years of crop yield measurements (7 years corn and 7 years soybean), the NT system appears to result in improved long-term productivity compared to MP and CP systems as a result of reduced soil erosion. The NT system, when compared to CP and MP, performed better in dry years by conserving moisture and the NT crop yields improved over time (K.R. Olson, personal communication).

The second objective of the planned fifth phase of the project (Figure 1) is to: Assess management (cropping systems, amendments and tillage) effects on C sequestration, productivity and soil quality including the importance of no-tillage on increasing C sequestration in eroded soils. Most states (Illinois, Michigan, Minnesota, Missouri, North Dakota, Ohio and Wisconsin) will participate in the 2nd objective.

Erosion can impact the soil as a source or sink of CO_2, CH_4, and other greenhouse gases, depending on soil quality and the predominant pedospheric processes (Bouwman, 1990; Lal et al., 1995a; b; Lal, 2003). Whereas some of the C transported into the aquatic ecosystems and depressional sites may be buried and sequestered, as much as 15 TgC/y in the U.S. (Lal, 2003) and 1 PgC/y in the world (Lal, 2003) may be emitted into the atmosphere because of the erosional processes. Adopting conservation-effective measures for erosion control can minimize risks of erosion-induced emissions. Further, increases in SOC and soil inorganic C (SIC) contents, by using best management practices (BMPs) and soil restorative measures, can make soil a net sink for atmospheric C and reduce or mitigate the greenhouse effect (FAO, 2001). Decreases in SOC and SIC contents, because of accelerated soil erosion and attendant soil degradation leading to decline in biomass productivity, can exacerbate the greenhouse effect due to emissions of CO_2 and CH_4 from soil to the atmosphere. Soil erosion leads to on-site depletion of SOC content because of transport of dissolved organic C (DOC) and particulate organic carbon (POC) in runoff and eroded sediments. Accelerated erosion also enhances the rate of mineralization by breaking down aggregates and exposing the hitherto protected or encapsulated carbon to microbial processes and enzymatic action.

Bajracharya et al. (2000a;b) reported significant variations in CO_2 flux among seasons in Ohio but found no direct effect of erosion phase on C flux from the soil. In contrast, Parkin and Kaspar (2003) reported that an eroded Clarion soil (Typic Hapludoll) had greater CO_2 flux than an adjacent Endoaquoll. Similarly, the same investigators (Parkin and Kaspar, 2003) reported greater respiration/flux on eroded sites and diurnal patterns of CO_2 flux.

Objectives:
(1). Determine spatial C distribution and dynamics in soils of eroded landscapes including 3-dimensional model assessments for better quantification.
(2). Assess management (cropping systems, amendments and tillage) effects on C sequestration, productivity and soil quality including the importance of no-tillage on increasing C sequestration in eroded soils.
(3). Coordinate research efforts, work and interpretations with NCR-59.

Methods:
Objective 1. Determine spatial C distribution and dynamics in soils of eroded landscapes including 3-dimensional model assessments for better quantification. All states will participate in Objective 1. A model will be used that includes the elements of a hillslope. Hillslopes may be subdivided by position into summit, shoulder, backslope, footslope and toeslope (Ruhe, 1975). These landscape positions are greatly influence by both hydrological, and pedological processes (Hall, 1983). Walker et al. (1968) reported that soils on backslope were those most affected by erosion and soils on footslopes had greater clay and organic matter contents. Malo et al. (1974), and Ovalles and Collins (1986) reported significant relationships between landscape positions and soil properties. Riecken and Poetsch (1960) showed that finer particles moved from upslope and were redeposited on the footslope and toeslopes along a hillslope in western Iowa.

In each participating state, a minimum of two sites with contrasting ecosystems but similar soil-landscape relationships will be sampled. For most states the least disturbed ecosystem will be native grass or timber, depending on the location in the NC region. The other site will be an intensively managed agroecosystem used for continuous row crop or wheat production. The following sampling protocol will be used by all states:

Three soil cores should be collected from center of each hillslope element (treatment) with a 120-cm long, 6-cm diameter solid steel sampling tube containing a 5.7-cm acetate contamination liner to a recommended minimum depth of 1 meter (sampling depth may depend on thickness of soil root zone and presence or absence of carbonates). In the laboratory, the cores will be cut into 5-cm, 15-cm, or 30-cm sections and core bulk density will be determined on each section. Each core section will constitute one soil sample. The soils will then be air-dried and crushed to pass a 2-mm screen. The soil profiles will be described using standard procedures and sampled as described above. Particle-size analysis, pH, bulk density, total C and SIC (if carbonates are present) or SOC (if carbonates are not present), and moisture at time of sampling will be completed for each sample. A minimum of three cores will be collected per treatment to compensate for soil variability within the local study area. No less than two cores will be collected per treatment to account for variability, which will allow for some simple statistics to be calculated. We prefer to section the cores by defined depth increments rather than by horizon because it is simpler to later compile the data to calculate C mass in the soil. Horizons are not the same thickness from plot to plot or treatment-to-treatment! The depth increments will not be less than 5-cm and will be selected based on the soils and treatments being studied. Ideally, the first one or two increments from the surface should be 5-cm because of rapidly changing differences due to management practices. Deeper in the profile, the depth increments will be at least 15-cm. All the cores collected from a given study will have the same depth increments for ease of comparing treatment effects. Approximately 10-15 g subsamples will be further ground to pass 100 mesh screen for C analysis. Total C analysis will be performed by high temperature combustion. If soil carbonates are present, SIC will be determined by an accepted method, e.g. titrimetric, volumetric or pressure transducer, and the qualities will be subtracted from total C values. Quantities of SIC will be subtracted from the total C values to obtain SOC values. If soil carbonates are absent, SOC will be determined by an accepted method (Nelson and Sommers, 1982). The C content of soils will be adjusted for soil bulk density and reported as kg C /m^3 or Mg C/ha/m if sampled to 1 meter and as kg C /m^2/ root zone depth or Mg C/ha/root zone depth if carbonates are present. A procedure manual will be developed to accommodate regional soil (such as presence or absence of carbonates) and weather differences to insure as much uniformity in sampling procedure and laboratory analyses as possible.

To assess soil C distributions we will develop 3-D models for the research sites using a technique developed by Grunwald et al. (2001). This method requires soil profile penetration data for several soil horizons. Rooney and Lowery (2000) developed a profile cone penetrometer (PCP) for collecting such data. The PCP consists of a 30^o cone with a 2.0 cm base diameter, threaded to a 1.25 cm in diameter by 1.5 m long stainless steel rod (ASAE, 2000). Penetration force will be measured with a 1360-kg load cell, while depth will be measured using a string potentiometer. The PCP will be pushed into the soil profile at a rate of 5 cm sec^{-1} with a hydraulic soil probe mounted on a truck. An electronic data logger will be used to collect load cell and string potentiometer data every 0.05 sec. A digital elevation model (DEM) will be created from data collected with a differentially corrected global positioning system (GPS) unit attached to an all-terrain vehicle. Profile cone penetrometer sampling points will be geo-referenced with a GPS unit.

Penetration force data will be transformed into cone index (CI) using $CI = F_p / A_c$, where F_p is the penetration force, and A_c is the basal area of the cone. At each recorded depth, there will be an associated CI value, thus creating a continuous curve for the entire profile at each sampling point. These data will then be analyzed using the Cluster Observation procedure in Minitab (Minitab, 2000), with the standardized variables option selected, and using the Squared Pearson and Ward method for distance measure and linkage method, respectively. The cluster procedure creates clusters, or groups, of observations that are similar. Thus, each erosion level will be delineated as a unique group of CI values. Profile CI values will then be clustered into three clusters which represented slight, moderate, and severe erosion. These data combined with GPS data and integrated with the output of soil erosion models will be used to create a 3-D soil map displaying soil variability as a function of soil erosion. erosion.

Soil erosion 3-D models (TEP and WATEM) (Lindstrom et al., 2000) will be used to estimate changes in the pattern of soil and C translocation in study sites. DEM developed by survey grade differential GPS data as described previously will be used as primary input into the models. Additional inputs will include rainfall erosivity (R), soil erodibility (K), and crop management factors (C) determined from local NRCS data. Soil bulk density will be obtained from core samples as described previously. Tillage translocation coefficients (k) will be assigned based on past tillage practices at the study sites. Patterns of soil translocation will be evaluated using current 3-D erosion models. The resulting pattern will be compared with the measured distribution of C and profile cone penetrometer soil variability within the field (Schumacher et al., 2003, Grunwald et al., 2001). We will combine the 3-D spatial values and erosion estimates with soil C data to obtain a 3-D soil carbon variability map. The contributions of water and tillage erosion in C movement within the study landscape will be estimated and compared with the pattern of C in the non-cultivated landscape (Schumacher et al., 2003).

Objective 2. Assess management (cropping systems, amendments and tillage) effects on C sequestration, productivity and soil quality including the importance of no-tillage on increasing C sequestration in eroded soils. The following states will participate in Objective 2 - Illinois, Michigan, Minnesota, Missouri, North Dakota, Ohio, and Wisconsin. Soil and crop management methods investigated for the maintenance and/or restoration of soil productivity on eroded soils were based on evaluation of the literature, assessment of current research, simulation modeling using the existing data base (2^{nd} phase of project) to identify limiting factors of a specific soil, and field testing of promising management alternatives (All participating states). Long-term data were necessary to adequately evaluate management-climate interactions on yields. Prior to the initiation of this project, most yield and management system studies were conducted on uneroded soils and soils not subject to significant erosion. Various cropping systems, amendments, and soil management systems were used by each state. The contributions from each state allowed a comparison of yields obtained from the 1st phase of the project to be used in an evaluation of the cropping systems, amendments, and soil and water management among a range of soil and climatic conditions in the region.

Lindstrom et al. (1992), Schumacher et al. (1994), and Shaffer et al. (1994) have demonstrated the sensitivity of crop productivity in many of the soils studied in the North Central Region to available water holding capacity as well as growing season precipitation. The model outputs were evaluated statistically when inputs are replicated. All participating states have received outputs from the model to be used as a tool in the interpretation of mechanisms acting on soil productivity. Sensitivity analysis was conducted on selected soil properties to determine if erosion induced variation accounts for observed productivity effects. The model simulation outputs have been combined with conventional data analysis and interpretation. Results have been used in the selection of an appropriate restoration or management strategy for field testing. Management factors have been changed in the simulation models to evaluate the optimum potential for the maintenance and restoration of soil productivity on eroded soils and to quantify the management factors contributing to production. Methods included: (1) cropping systems (Illinois, Ohio, Missouri, and North Dakota), (2) amendments (Wisconsin, North Dakota, Minnesota and Michigan), and (3) tillage and water management (Illinois, Ohio, Missouri, and Minnesota).

States opting to evaluate the effects of no-tillage and cropping systems on C sequestration have or will have to establish an experiment with 3 treatments (NT, chisel plow, and moldboard plow) with and without cover crops in a split pot design. Soil samples will be collected before and after the application of tillage and cover crops. The soil samples will be collected from 0-5 cm, 5-15 cm, 15-30 cm, 30-50 cm, 50 to 70 cm and 70-100 cm. Five soil cores, one from near each of the four corners and one in the center of the subplot, will be collected and composited by crumbling and mixing. The sample will be air-dried and pulverized to pass through a 2-mm sieve prior to either SOC or total C and SIC analysis. If soil carbonates are present the soils will be analyzed for SIC and total C using a carbon analyzer and if carbonates are not present the SOC will be determined by using an accepted method (Nelson and Sommers, 1982). Field moist core bulk density will be determined (Soil Survey Staff, 1984) using a Model 2000 soil core sampler manufactured by Soil Moisture Equipment Corp or a sampler of similar design.

The threshold soil values and productivity parameters serve as an early warning signal of reduced productive capacity of soils common to the north central United States. Specific soil parameters and threshold values were suggested for both surface and subsoil layers. All participating states will use data previously collected as part of the NC-174 project to evaluate the soil parameters and to determine threshold values for degraded productive capacity. Changes in the surface layer properties that appear to affect productivity under a high level of management included: erosion phase, porosity, bulk density, aggregation, SOC, infiltration, texture, and coarse fragments. Changes in the subsoil properties that affected soil productivity included mechanical strength, structure, aeration porosity, water storage, porosity, residual porosity, bulk density, hydraulic conductivity, pH, and rooting depth. Minor (1-15%) and major (>15%) reductions in inherent soil productivity (Olson, 1992) were considered as a basis for setting threshold values for measurable and observable soil properties or conditions based on current methods of technology and research. Threshold values were determined by correlating soil properties with yields obtained from research fields as well as from simulation models. The threshold values served as an indicator of reduced productive capacity. These soil parameters and specific threshold values were based on erosion-productivity relationships shown by previous NC-174 research as affected by soil conditions in the north central United States which can vary with location, crop, soil, management, and climate (all participating states).

Because of the complex response of soil properties and crop yield to different tillage systems and amendments, a soil quality index approach (Harris et al., 1996) was evaluated. The hypothesis was tested by quantifying soil properties into a soil quality index with the objective of the evaluation of different tillage systems and amendments effect on soil quality within a state (Illinois) or region. In the process of soil quality assessment, the selection of appropriate soil quality indicators, standardized scoring function, and threshold limits for soil quality indicators are important for the sensitivity of the model to the management practices and local conditions could change the soil quality index. Measurements will be made on existing eroded and non-eroded sites corresponding to inputs for a soil quality index designed to include soil properties that are critical for sustaining productivity while maintaining or improving off-site environmental quality (Doran and Jones, 1996). Restorative effects of BMPs on enhancement in soil quality and C sequestration will be monitored through periodic measurement of SOC contents of soil. Gaseous emissions of CO_2 will be measured using the static chamber technique (Iowa, Minnesota, and Ohio) (Rolston, 1986).

Objective 3. Coordinate research efforts, work and interpretations with NCR-59. NCT-199/(NC-174) and NCR-59 committees have developed a close working relationship which has resulted in two joint meetings to share information and contribute to joint efforts such as a Methods book. If this proposal is approved we anticipate additional joint meetings and efforts. Aside from this, the two projects complement each other since the work will be conducted in the same region of the U.S. with similar soils, physiographic regions, and weather patterns.

Measurement of Progress and Results:

Outputs: This project is designed to better understand C losses including soil degradation resulting from accelerated erosion and the effects of erosion on quantitative distribution of C at the landscape level. It will provide needed data on the changes in the C reservoir related to intensive land use for some of the major soils in the NC region. This study will contribute to our understanding of soil-landscape processes and has the potential to provide data that will contribute to improved management of our soil and water resources. Knowledge gained from the proposed research will contribute to a more quantitative understanding of processes operating in agroecosystems that influence global C balance. The knowledge will also expand understanding of the effects of erosional processes on the amounts and landscape distribution of C and organic matter. The research will contribute to our knowledge leading to sustainable management of natural resources in different ecosystems improving soil C sequestration.

This project will contribute mainly with scientific publications, guidebooks, fact sheets and organizing workshops and meetings with land managers and policy makers. These publications will address the specific benefits of various innovative and beneficial management practices for enhanced productivity and environmental quality. The knowledge communicated through these publications and workshops will benefit producers, federal and state agencies, and the general public by maintaining and improving environmental quality. The sustainable agricultural and C sequestration components of this research will require on-research center demonstrations, outreach and education and integrated farming systems. The knowledge will allow for better management decisions to ensure environmental quality into the future. The utilization of information from previous studies and established study sites will provide better understanding of long-term effects of specific soil management practices on soil C sequestration.

Outcomes or Projected Impacts: We will have a better understanding of changes in soil properties resulting from intensive cropping and erosional processes among agroecosystems. The effect of different management practices used to restore productivity of eroded soils will be evaluated and changes in soil properties resulting from these practices will be quantified. The effect of different management systems and the effect of erosion on the landscape distribution of C will be elucidated by this study. This information will contribute to improved management of our resources and enhanced environmental quality. Results from the study will provide for documenting economic incentives for voluntary adoption of no-till systems with cover crops which could be significant to policymakers who develop tillage and soil loss guidelines requiring conservation tillage. In addition to sequestering of soil organic C, these soil-improving practices also increase soil productivity, improve soil quality, enhance the quality of water draining from agricultural land. The sequestration of C will reduce the net greenhouse gas emissions. These before mentioned principles promote good land stewardship and sound environmental policy.

Milestones: A Web site (South Dakota) will be developed and a manual of methods and procedures will be completed by December 30, 2004. Site selection will be completed by September 30, 2005. Sampling and laboratory analyses will be completed by December 30, 2008. The project will be completed by September 30, 2009.

Project Participation:

Project: NCT-199/(NC-174)
Title: Carbon sequestration and distribution in soils of eroded landscapes.
Administrative Advisor: Dr. Kevin McSweeney

Participant Name and e-mail address	Institution and Department	Research CRIS Codes RPA SOI FOS	Personnel SY	PY	TY	Objective 1	2
Kenneth R. Olson krolson@uiuc.edu	University of Illinois	102 0199 2000 102 0199 2030 102 0199 2061	0.1	0	0.1	X	X
Gary Steinhardt gsteinhardt@purdue.edu	Purdue University	“	0.1	0	0	X	
Mahdi Al-Kaisi malkaisi@iastate.edu	Iowa State University	“	0.2	0.5	0.2	X	
Delbert L. Mokma mokma@msu.edu	Michigan State Univ.	“	0.1	0.5	0	X	X
John Moncrief moncrief@soils.umn.edu	Univ. of Minnesota	“	0.1	0	0	X	X
Randy Miles milesR@missouri.edu	Univ. of Missouri	“	0.1	0	0	X	X
Larry J. Cihacek Larry.Cihacek@ndsu.nodak.edu	North Dakota State	“	0.3	0	0	X	X
Rattan Lal lal.1@osu.edu	The Ohio State Univ	“	0.1	0.25	0.25	X	X
Thomas Schumacher Thomas.Schumacher@sdstate.edu	South Dakota State	“	0.2	0.2	0	X	
Birl Lowery blowery@facstaff.wisc.edu	Univ. of Wisconsin	“	0.1	0.5	0	X	X

Thomas C. Kaspar kaspar@nstl.gov	ARS, NSTL	“	0.2	0	0.2	X

Outreach Plan:
Results will be presented in refereed publications and in posters and symposia at National Meetings of the American Society of Agronomy, Soil Science Society of America, and the Soil and Water Conservation Society. We will also provide the information to collaborating agencies such as the NRCS and various state and local agencies. Additionally, some of the committee members will extend this information at local field days and workshops and through preparation of fact sheets.

Organization and Governance:
The Regional Technical Committee will follow the operational procedures listed on pages 19-22 and 34-36 of the CSRS "Manual for Cooperative Regional Research" revised and dated October 1992. The voting membership of the Regional Technical Committee includes one representative from each cooperating agricultural experiment station or institution appointed by the director and a representative of each cooperating USDA-ARS research unit or location. The administrative advisor and the CSRS representative are non-voting members. All voting members of the Technical Committee are eligible for office. The offices of the Regional Technical Committee include the Chair, the Vice-Chair and the Secretary. These officers will be elected annually at the Technical Committee meeting, and they may succeed themselves.

The duties of the Technical Committee are to coordinate work activities related to the project. The Chair, in accord with the Administrative Advisor, will notify the Technical Committee of the time and place of the meeting, will prepare the agenda and preside at meetings of the Technical Committee and Executive Committee. He or she is responsible for preparing the annual progress report and coordinating the preparation of regional reports. The Vice-Chair assists the Chair in all functions and the Secretary records the minutes and performs other duties assigned by the Technical Committee or Administrative Advisor. The Chair appoints subcommittees as needed. Annual meetings will be held by the Technical Committee, as authorized by the Administrative Advisor, for the purpose of conducting business related to the project.

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