USDA Forest Service **RESEARCH WORK UNIT DESCRIPTION** REF: FSM 4051	**1. Number** FS-SRS-4551	**2. Station** Southern Research Station
	3. Unit Location Lincoln	

4. Research Work Unit Title
Tree-based Buffer Technologies for Sustainable Land Use

5. Project Leader (Name and Address)
Michele M. Schoeneberger
Southern Research Station
USDA National Agroforestry Center
East Campus-UNL
Lincoln, NE 68583-0822

6. **Area of Research Applicability**	**7. Estimated Duration**
U.S. agroecosystems nationwide	5 years (2000-2005)

8. Mission
To understand the functions and processes of riparian and upland tree-based buffer technologies and to utilize this information to integrate trees into land use systems to restore ecological functions, and provide environmental services and economic opportunities.

Signature	Title	Date
Recommended	ASSISTANT DIRECTOR for RESEARCH	
	ASSISTANT to STAFF DIRECTOR	
	STAFF DIRECTOR	
Approved	STATION DIRECTOR	
Concurred	DEPUTY CHIEF for RESEARCH	

9. Justification and Problem Selection
In the U.S., conversion of natural upland grasslands and forested riparian areas to intensive cultivation and grazing has occurred to such an extent that public concerns for environmental health and sustainability have now become prominent land management issues. The goal of these conversions has

been to maximize net primary and secondary production from these systems to directly benefit humans. In the short term, this goal has been met and a massive increase in food production has been achieved upon which society is very dependent. However, the impacts of this conversion and land use intensity are less benign. In these highly disturbed, intensively managed, and predominantly privately owned landscapes, the stabilizing ecological processes have become decoupled, resulting in declining soil and water quality that threaten the public and ecological health of the region. The sustainability of these extensively cultivated and grazed landscapes is in doubt as soil erosion continues at rates much faster than what is considered sustainable. Altered hydrology of watersheds is causing more frequent damaging floods and extensive erosion of channels, banks, and flood plains. Sediments are filling the regions' flood control and recreational reservoirs at unacceptably high rates, and municipal drinking water supplies are becoming contaminated with nitrate and pesticides. Much farther from these sources, additional impacts are being recognized, such as the 7,000 square mile hypoxia-created "Dead Zone" in the Gulf of Mexico which has been linked to nutrient runoff from agricultural lands in the central U.S. Agricultural sources now account for over 70% of the non-point source pollution in the U.S., with soil erosion alone causing around $44 billion in direct and indirect damage to waterways, fisheries, and health in the U.S. With over 40% of the US waters not meeting today's water quality goals, agencies are shifting their emphasis on 'cleaning up the messes' to developing programs that repair the systems and enable them to accommodate a number of our activities.

Additional sustainability concerns are centered on the rising levels of CO_2 and its effects on climate. This concern spawned the International Convention on Climate Change, which the U.S. government signed and ratified. As a result the U.S. is legally bound by international law to lower its net emission of CO_2. It can do this by either reducing CO_2 emissions or by finding ways to offset emission levels with mitigation techniques that sequester carbon.

The incorporation of "buffer zones", consisting of permanent vegetation within landscapes, is a key strategy that has tremendous potential for mitigating water quality problems, sequestering carbon, and providing valuable links for wildlife on private lands. If properly managed, natural and planted tree-based buffers on private lands are an ecological and aesthetic resource that can provide significant environmental, social and economic benefits to the landowner and society and, by fulfilling these multiple objectives, serve as an appealing *private land* stewardship option. In the 907 million acres of cropland, pastureland and rangeland where tree-based practices could be applied, placing as little as 5% in tree-based buffers could have enormous beneficial impacts.

In the agriculturally-dominated Midwest and Great Plains region, native "forest islands and biological corridors" (e.g. woody draws, riparian forests, and forest galleries) historically provided vital ecological services through the structural and functional diversity they contributed to the landscape. These services include: nutrient cycling, microclimate modification, habitat, refugia and corridors for organisms ranging from microorganisms to large ungulates, and numerous environmental services, such as, reduced flooding, erosion control, enhanced water quality and quantity, streambank stabilization and improved air quality. The agricultural paradigm that has dominated the land use management decisions and practices of this region over the decades has led to a massive biological simplification at all scales, making the value of these contributions much greater than the small land area they occupy. Unfortunately, the presence and function of these woody features have been severely reduced through time and now consist of fragmented riparian pieces, shelterbelts and woodlots that are continuing to rapidly disappear as the trend for larger field size and urban sprawl continues.

The agriculture-induced disaster of the 1930s Dust Bowl prompted the first massive tree-based buffer planting program in the United States, the Prairie States Forestry Program. Conservation leadership provided by the U.S. Forest Service from 1934-1942 resulted in the planting of millions of tree seedlings into linear structures called shelterbelts or windbreaks for the purpose of conserving soil. Since then, conservation efforts by State Foresters, NRCS and others have continued to promote shelterbelts and a suite of other tree-based buffer practices for use in snow management; microclimate modification for crops, livestock and homesteads; wildlife habitat enhancement; diversification of rural economies; and water quality protection. These linear, fragmented forests can dramatically alter air, soil and water quality, impact water and nutrient cycles, and alter plant and animal species and community compositions within the larger agrolandscape. They will also have a myriad of additional ecological ramifications that must be taken into account in the planning process if benefits are to accrue to the land and land manager. Although we have decades of research on forests and agricultural systems to draw from, this information has little bearing in understanding the mixed *agricultural + forest* private lands system that dominates the nation's landscape. **To design effective management options for privately owned lands, there is a need for process-level research to better understand how riparian and upland tree buffers protect water quality and aquatic and terrestrial environments, and sequester carbon. (Problem 1.)**

Increasing public demand for solutions to the environmental problems facing agriculture-dominated areas have converged on riparian areas to provide the critical ecological functions to help sustain landscape integrity in these ecosystems. Properly functioning riparian buffers are able to mitigate nonpoint-source pollution problems by trapping and processing runoff, stabilizing bank and channel formations, and providing highly critical habitat to numerous wildlife and aquatic species. Unfortunately, riparian areas themselves are stressed and damaged by landscape changes produced by agricultural activities (e.g. riparian land clearing, herbicide drift, altered hydrology, nutrient enrichment, sediment deposition, riparian erosion, and exotic species). Restoration of riparian zones must be strategically combined with upland buffers if key ecological services are to be successfully restored within these systems.

In contrast to public lands, an agency does not make land stewardship decisions on private lands; rather the individual landowner does. The health of agroecosystems ultimately hinges on what millions of individual landowners do to make their land healthy. Numerous USDA incentive programs (e.g. SIP, CRP, EQIP, WHIP) and focused initiatives being implemented or developed, such as the National Conservation Buffer Initiative, the Stewards of our Lakes and Streams Initiative, and the Vice-President's Clean Water Initiative, promote tree-based buffer practices, especially riparian buffers. By providing additional social and economic returns to the private landowner (e.g. short rotation woody crops, nontraditional forest products, such as medicinals, edible fungi, and floral products, and recreational opportunities from hunting and hiking to birdwatching), along with ecological services, tree-based buffer systems are an excellent approach to assist private landowners in balancing productivity and profitability with environmental stewardship. Such a win-win situation is critical in getting adoption of conservation practices on private lands.

The placement, arrangement, and species composition, along with management, will influence the biological processes which determine the amount and type of ecological and economic services these tree-based buffer practices provide. The design and management of these systems are therefore dependent on reliably predicting which processes will be changed, to what level, and how they can be manipulated within our design and management capabilities. Inputs of water, soil, chemicals, energy etc. into these systems will come from adjacent lands and must be taken into account when studying these biological processes. Modifications of the design to incorporate additional landowner objectives will also influence the biological processes upon which the ecological functions are dependent. Given the multiple objectives and wide range of environmental factors that need to be considered, adoption of these practices will depend on having *flexible* design criteria to accommodate both. Performance of these practices will change over time and therefore will also depend on good maintenance management. Present research in this area is minimal and poorly integrated among disciplines. **Site-based flexible design management and criteria research is needed to assist in guidelines development for establishing functioning upland and riparian buffer systems. (Problem 2.)**

Many ecological processes that contribute to the sustainability of the land, such as water quality, and wildlife habitat, only become fully expressed at the landscape level. Each landowner's actions determine not only the health of his/her own land, but also of the adjacent lands, the larger ecosystems, and the watershed in which they live. Although conservation practices on private lands are practiced in a piece-meal fashion, it is really the cumulative functions of the activities of all the "neighbors" living in the landscape that determines the ultimate ecological health of that system and which therefore demands an "All Lands" approach to land management. Ecosystem management, managing for ecosystem integrity, means expanding the scope of management decisions from the individual practice and the landholding (i.e. farm) to larger scales, such as, area-wide planning which looks at landscapes from the subwatershed and beyond. Tree-based buffers are not isolated systems but rather working parts within this larger matrix. The value of tree-based buffers to the ecosystem and society will depend on the strategic placement of buffers within the larger matrix.

Buffer designs are normally based on site-focused assessments at the individual property level. However, many of the conservation problems that buffers can address are unrecognizable, or are otherwise inadequately accounted for using a site-scale assessment since many of the ecological functions of tree-based buffers that contribute to sustainability operate at much larger scales. A watershed context is necessary for proper evaluation of water quality and stream health problems, and region and landscape evaluations are required for proper consideration of habitat for many species of wildlife (i.e., deer, birds). To realize the full range of conservation benefits from buffers, they must be designed to account for both site and landscape-level issues. Effective and efficient environmental planning is attained when a watershed approach is taken that addresses the multiple objectives in a uniform manner rather than individually. How tree-based systems are arranged and connected within the larger landscape will determine the quantity and quality of benefits obtained. A linked system of upland and riparian tree-based buffers, designed in regards to other landscape features (i.e. grassed waterways, terraces), will optimize soil and water conservation in the watershed by increasing efficiencies and integrating other ecological functions. Benefits include longer concentrations times for overland flow, increased infiltration, and increased retention times which facilitate assimilation of agrichemicals. Systems of upland and riparian buffers can make significant contributions in reducing flood water volume and damage from sedimentation and pollution.

Designing tree-based buffer systems that restore or enhance targeted ecological functions will therefore be a task of creating strategic configurations *across ownerships* that attain societal goals as well as the goals and objectives of the individual landowner on whose land the conservation planting is being placed. Scale, pattern or dispersion, and patch dynamics of the landscape must be taken into account. Natural resource professionals need tools that will provide guidance in altering spatial configurations in a landscape to achieve a particular level or mixture of ecological responses. Further, tools to assist in the optimization of multiple goals within a landscape are needed to show that it is possible to balance productivity, environmental stewardship, and socio-economic needs.

Because widespread buffer installation can be a substantial economic cost, we need to explore ways to derive the most value from each acre of buffer. Current methods for application of riparian and upland buffer practices in this region are ad hoc, i.e., practices are designed and applied to sites to solve individual resource problems. Tools do not exist for balancing site-specific applications of practices and watershed level considerations. Successful use of riparian restoration technologies and upland buffer creation for mitigating the region's pressing conservation problems will require approaches that facilitate effective planning and design, and assure successful installations, predictable impacts, and efficient use of public resources. Examples of new and useful tools and methodologies include:

i) Assessment methodologies to evaluate existing resource problems and functioning of riparian and upland buffer systems.
ii) Models which utilize assessment information to predict the potential for restoration to improve ecological functions and mitigate resource problems at both site and watershed scales. Such models are critical for targeting and prioritizing projects for investment of public resources.
iii) Guidelines to assist land managers with planning, design, and placement of multi-purpose riparian and upland buffer systems to maximize their effectiveness and efficiency. To facilitate acceptance and application of riparian restoration and upland buffer creation, these guidelines must also be capable of accommodating landowner objectives, as well.

These efforts must include tackling the issue of long term maintenance of the buffer systems: how do we keep them on the landscape once they are established. New tools/techniques/methodologies will facilitate planning and management of riparian restoration and buffer creation to efficiently and effectively meet ecological needs and public demands in agroecosystems. **Greater information on landscape-level ecological patterns and processes, as well as special tools to effectively integrate buffer technologies into landscape management strategies, is needed to optimize riparian and upland tree buffer placement in watersheds. (Problem 3.)**

The RWU at Lincoln, an integral part of the USDA National Agroforestry Center (NAC), is ideally positioned to provide FS leadership in tree-based buffers research. This research addresses the problem of nutrient-loading in the Mississippi River Basin, and supports the USDA National Conservation Buffers Initiative (that the FS, and specifically NAC, are a partner in), the new "Stewards of our Lakes and Streams" and Vice-President's Clean Water initiatives (if funded) and the new "Missouri Agroforestry Floodplain Project" (funded by EPA). This research focus is also an outstanding opportunity to generate partnerships, public support, leverage resources, and enhance credibility of FS R&D programs. It directly addresses a high priority research need of State Foresters, the Natural Resources Conservation Service, and many other stakeholders for private land stewardship throughout the Mississippi River Basin (41% of the land area of the continental U.S.). It has direct relevance to public forest land management in mixed ownership/land use watersheds. This research specifically addresses the Department of Agriculture's commitment to building a sustainable America: #13 *Increase awareness of agroforestry technology to reduce water pollution from agricultural activities.* The authority for this research is contained within the Forest and Rangeland Renewable Resources Research Act of 1978, Section 2 (2) and Section 3 (a) (1) and (d) (3). This research supports all RPA mission elements, in particular it will "increase emphasis on ecological research, expand cooperation with our partners in both the public and private sectors, increase public participation in decision-making processes, and continually learn, convey and apply conservation principles".

10. Approach to Problem Solution

Problem 1: <u>To design effective management options for privately owned lands, there is a need for process-level research to better understand how riparian and upland tree buffers protect water quality and aquatic and terrestrial environments, and sequester carbon.</u>

Much of our understanding of riparian buffers is based on years of data collected from sites in the Pacific Northwest and the East Coast, where critical environmental issues associated with fisheries and estuary quality have made riparian research a top priority. Riparian ecosystems in the southwest have also received attention over the last decade and a foundation of scientific information is now available for these three regions with which to conduct wise management of this critical, linear landscape feature. Despite the mounting water quality problems of the agriculturally dominated Midwest and Great Plains and the potential for riparian and upland buffers to mitigate these water quality problems and help restore other key ecological functions, scientific information relevant to this region is lacking.

Research accomplishments proposed in this RWUD will provide an ecological framework from which we can start to comprehend the roles and interactions tree-based buffers have with the surrounding landscape matrix. This information will allow us to explore the potential for management options at the field (Problem 2) and landscape (Problem 3) levels.

Efforts in Problem 1 will be focused in three key areas: Determining hydrological patterns in central U.S. landscapes that influence the ability of upland and riparian buffers to intercept and control water quality (Element 1); research on processes for mitigating nonpoint source pollution by tree-based buffers (Element 2), and carbon sequestering mechanisms and effectiveness in riparian buffer zones (Element 3).

<u>Element 1.</u> Determine hydrological patterns in central U.S. agricultural landscapes that influence ability of riparian buffers to intercept runoff and control water quality.

In order for water quality to be impacted by riparian buffer processes, the runoff must go through the buffer system; either as overland flow or subsurface flow. A first step in planning and designing buffer systems will therefore hinge on being able to predict the hydrological connections between the adjacent upland and riparian areas. The hydrologic processes will determine the loads delivered to the riparian buffer systems, and, by altering residence time in the buffer zone and pathways, will determine the quantity and quality of runoff processed by the buffer complex. Using established crop fields that are operated at a commercial scale (University of Nebraska), we will investigate the relationship between crop field area (as a source of non-point source (NPS) runoff) and riparian area (a potential sink for NPS runoff) toward estimating the potential effectiveness of filter/buffers, and identifying practices/landscape circumstances which may improve/decrease that potential benefit. By measuring the microtopography of fields, field margins, existing buffers; utilizing existing runoff equations and verifying with field collected data, we will estimate runoff area to buffer pathway area and the pattern of surface water runoff from agricultural fields into buffers as related to natural topography, land shaping, and tillage practices

Field studies will be initiated to investigate the patterns of stream flow generation in agricultural landscapes, particularly the partitioning between surface runoff and groundwater pathways in order to determine the relative contributions of surface runoff with associated pollutant loads, and groundwater runoff with its associated pollutant loads. The pattern of subsurface flow to streams (shallow vs deep) will be related to geomorphology, soils, topography, and watershed position. Using existing soils/geomorphology data and models to generate partitioning index (e.g., NRCS HUMUS Project data and models) for regions and watersheds and USGS-derived data bases and models, general patterns of regional differences in partitioning will be developed as was done for the Chesapeake Bay Program. Based on the partitioning index, we will then develop a simple model for estimating the potential impact of riparian buffer installation on stream water quality. This model will be used to classify regions, watersheds, and areas within watersheds for potential to improve stream water quality using riparian buffers

Accomplishments for the next 5 years include:

1. Provide a basis for predicting the hydrologic patterns that influence the ability of upland and riparian buffers to intercept and control water quality.
2. Develop and test a relatively simple field assessment tool for evaluating the water quality function of buffer systems in the central US.
3. Develop and/or modify computer simulation models which predict the impacts of buffer systems on the transport and fate of water, sediments, and other agriculture-related contaminants.

Element 2: Research on processes for mitigating nonpoint source pollution by tree-based buffers.

Riparian buffers can alter the water quality of our surface waters by trapping, filtering, and bio-processing sediments and chemicals contained in runoff from adjacent lands. These processes are both plant and microbial-mediated; the relative importance of each within this region being unknown. Precipitation in the Midwest and Great Plains is sporadic with significant inputs occurring as torrential spring frontal and summer convective storm episodes. These episodes produce runoff “flushing” events that provide the majority of contaminants in our surface waters, particularly in the spring when the soil has minimum cover, has recently been disturbed by various field practices, and is high in agricultural inputs (i.e. fertilizers and pesticides). Therefore, functions or processes that dissipate runoff energy to increase residence time of runoff within buffers, increase infiltration before the runoff enters surface waterways, or increase microbial or plant immobilization of runoff chemicals must be identified and quantified to determine their role in mitigating NPS-related problems. Field studies, located at the University of Nebraska Experimental Farms (Mead and Rogers) and other locations (i.e. Missouri Floodplain Agroforestry Project; NE Corn Growers Project), will be utilized to investigate relative contributions of short-term buffer processes important to NPS control and the variability in those processes as impacted by vegetation type, arrangement (e.g., width), and successional change. Runoff processes of key interest will be: infiltration, dilution, particulate settling, and the change in process performance for different runoff compositions and over time. Field components will include controlled experiments on large field plots utilizing woody-based buffers of varying widths and composition; and micro-simulation plots for application of simulated rainfall & runoff events. Data collected will be stratified by soil type, vegetation types (natural), tillage practices (fields), site history, and evaluated in terms of patterns and correlations.

Woody plant nutrient uptake studies will investigate the potential for plants to sequester infiltrated nutrients with subsequent export via harvesting, as processes contributing to long-term nutrient runoff control. Studies will involve sampling existing woody-based buffers and analyzing tissues for nutrient concentrations, developing algorithms for growth rates and nutrient accumulation, and calculating the harvestable portion of the nutrient pools for each vegetation type.

Although denitrification has been identified as a major process in NPS mitigation in more humid ecosystems, its potential to contribute to NPS abatement is unknown for the Midwest/ Great Plains regions. Investigations will look at the potential for denitrification within buffers and its relation to soil type, hydrology, vegetation type and buffer width. Potential denitrification rates (index of actual rates) on soil samples will be measured and correlated with soil, vegetation type, hydrology, and distance from crop edge.

Accomplishments planned for the next 5 years include:

1. Identify type and relative importance of key processes in riparian buffers that control NPS pollution in the central US.
2. Determine the development of these processes over time from establishment to maturity of the tree component.
3. Identify infiltration characteristics that influence riparian buffer function and their relationship to soil type, vegetation type, and site history.
4. Document the magnitude of infiltration in natural buffers vs agricultural fields.
5. Document the nutrient uptake capability of buffers, and its relation to vegetation type.
6. Identify plant attributes that can enhance the sink capability of riparian buffers in the central US.
7. Transfer information gathered above for use in educating private landowners and natural resource professionals on riparian buffer function in regards to water quality.
8. Participation in the USDA National Conservation Buffers Initiative Technical Team.

Element 3: Carbon sequestering mechanisms and effectiveness in riparian buffer zones.

The U.S. is examining the role of trees in helping the nation to sequester carbon. The biomass of both above- and below-ground tree components, as well as increases in soil carbon levels can be substantial at a national scale. In this regard, tree-based riparian and upland buffer systems can significantly contribute to carbon sequestration in terms of the more longer-termed sinks of wood products and soil carbon, while meeting additional landowner and societal objectives. Due to favorable moisture and nutrient conditions, trees grown in riparian areas have extremely high rates of biomass accretion. In addition, the cycling of carbon in the soil associated with riparian zones differs from that of drier sites and results in large and rapid accumulation of soil carbon. Therefore the contribution of tree-based riparian buffers to carbon sequestering can be shown to be several times greater than that of trees which otherwise occur in the other landscape positions. The performance of the riparian buffers to mitigate water quality problems is in turn enhanced by the accretion of soil carbon resulting in a multiplier effect on environmental services.

The RWU will investigate the potential of tree-based riparian buffer systems for carbon sequestering. The biomass accumulation of trees, shrubs, and other plants in the riparian system will be tracked. Research will examine the rate at which soil carbon is accumulated in riparian zone soils and the effectiveness of various plant species in building soil carbon levels. The major soil carbon pools will be fractionated and analyzed to determine the effect of tree-based riparian systems on short-, medium-, and long-term storage pools. Research data will be used to develop a model of soil carbon cycling in a tree-based riparian system.

Accomplishments for the next 5 years include:

1. Species specific growth rate information on the tree, shrub, and other plant components of a tree-based riparian system.
2. Information on the contribution of various plant species in tree-based riparian buffers to soil carbon storage.
3. A simulation model of soil carbon cycling with tree-based riparian buffer systems.

Problem 2: Site-based flexible design management and criteria research is needed to assist in guidelines development for establishing functioning upland and riparian buffer systems.

The type and amount of environmental services provided by riparian buffers will be determined by the *buffer design* (i.e. location, size, vegetation type, species composition, and arrangement), by *buffer management* (i.e. renovation, harvesting), and by the *adjacent land use* (i.e. vegetation and management practices). Across the U.S., buffer design will vary to meet the different environmental conditions and, more importantly, to tailor the buffers to specific conservation issues that dominate in each region. In the Northwest, buffers are employed primarily to restore and protect salmon and trout habitats. In the arid southwest, buffers improve habitat for more at-risk aquatic and terrestrial species. In the east, buffers emphasize reduction of nutrients and sediment that reach stream and estuaries. This variety of applications is testimony to the flexibility of riparian buffers to address numerous and varied conservation concerns. Design must also take into account the adjacent crop and management practices, with efforts being directed to minimize competition (i.e. water, light) and damage (i.e. from spray drift). Design considerations must also include the need for management considerations to maintain function of the tree-based buffers, such as vegetation removal and soil grading.

Design criteria for the Midwest and Great Plains are lacking. The need to meet the diverse array of ecological, economic and social objectives for these plantings on the predominantly private land base of this region necessitates that guidelines provide a flexible framework for the landowner and natural resource manager. However, we lack the scientific basis from which flexible, but ecologically-sound design and management guidelines can be developed for these agrolandscapes.

Element 1: Interactions with adjacent crops and management practices.

Given the dominant matrix of the Great Plains and Midwest landscapes is agriculture, competition for resources at the tree/crop interface can have impacts on crop yields that will determine its perceived value to the landowner. Research will focus on the nutrient/water/light interactions that take place at the tree/crop interface. Currently the RWU has access to an experimental site that has a commercially-sized, fully established and replicated shelterbelt system. Owned and cropped by the School of Natural Resources at the University of Nebraska, this site comes with a wealth of data regarding shelterbelt/crop interactions that has been collected over several years and on which the RWU has been a key collaborator. Root-pruning treatments will be applied at the tree/crop interface and soil moisture and crop development yields monitored in transects going from the tree buffer system into the crop for a 1 H (height of tree buffer) distance. This will be done on the E/N/S sides of the U-shaped shelterbelt systems in order to examine the influence of aspect and measurements will be taken through several growing seasons in which a corn/soybean rotation will be used. The information from this study will provide the basis for a more intense evaluation of water and light usage at this interface, at which time the pruning treatments will be reapplied and measurements taken to allow a more complete picture of water usage at the interface. Trenches will be dug at surrounding shelterbelt sites in order to determine how far tree roots grow into the adjacent crop.

Accomplishments planned for the next 5 years include:

1. Quantify impact of tree buffers on adjacent crops with regards to yield.

2. Determine the relative importance of above-versus belowground competition in the tree/ crop interface.
3. Estimate tree root distribution into the adjacent crop area.
4. Transfer information gathered above for use in educating private landowners and natural resource practioners on tree/crop interactions.

Element 2. Buffer design for efficient pollution abatement.

Data collected from Element 1 research efforts will be used to 1) identify best buffer designs (i.e. vegetation types/relative width) for controlling specific NPS pollutants; 2) predict how long it takes to convert cropland to full-functional filters; 3) estimate potential level of pollutant control using buffers in the short and long term; and 4) estimate potential impact of buffer installation on stream water quality. The effort will be two-phased, with the first phase being a synthesis of existing data to provide a best-guess framework and the second phase being additional directed field studies to verify or refine these best guess guidelines.

Additional riparian buffers using a variety spatial and plant arrangements will be established in the field and monitored from establishment through time for soil, plant, and water parameters identified as critical NPS abatement processes in Problem 1. These buffer designs will incorporate both best-guess function criteria and equipment/management constraints that land managers deal with. Flumes installed within the watersheds containing existing riparian research and demonstration efforts will be used to measure catchment level NPS runoff from agricultural fields and correlate loads to landscape characteristics and farming methods. These data will enable us to quantify, utilizing existing NPS models such as AGNPS, total NPS loads leaving small agricultural catchments where catchment histories are well-known and documented and then correlate loads for a variety of landscape characteristics, and farming practices.

Plant and soil data collected from efforts in Problem 1 and from established buffer plantings that utilize a variety of arrangements and plant composition, will be utilized to synthesize the sink capability of riparian buffers in the central US. Management scenarios, from no-management to sequential harvesting, will be examined using the data generated from the previous experiment, in order to identify management guidelines to maintain or enhance performance of these systems over time. Plant attributes that lend themselves to NPS mitigation, growth in the riparian zone and for providing other amenities (e.g. wildlife and aquatic habitats, aesthetics, products) will be compiled, along with a decision-making framework for riparian buffer plant selection for the Great Plains and western cornbelt region.

Accomplishments for the next 5 years include:
1. Characterize buffer performance over time as a function of spatial and plant compositions.
2. Development of a plant species selection guide for riparian buffer plantings in the Great Plains that incorporates attribute identification for NPS mitigation as well as for other potential benefits (i.e. wildlife habitat, streambank stabilization, aesthetics).
3. Development and transfer of scientifically sound guidelines for riparian buffer planting design for improving runoff water quality in the central US.
4. Participation on national and regional riparian technical teams (i.e. National Riparian Service Team, NRCS Buffer technical teams, North Central Regional Riparian Research Committee etc.)

Problem 3: <u>Greater information on landscape-level ecological patterns and processes, as well as special tools to effectively integrate buffer technologies into landscape management strategies, are needed to optimize riparian and upland tree buffer placement in watersheds</u>.

Currently, no comprehensive methodology exists for guiding the strategic placement of tree-based buffers to create landscape systems. Landscape tools have been developed for a few specific resources, such as water quality and wildlife. Site analysis tools have also been developed. However, these tools do not account for the broader range of benefits buffers can provide and no attempt has been made to synthesize landscape and site methodologies into a comprehensive package. A comprehensive approach is needed to assure adequate consideration of multiple scales and resource objectives so that buffers are designed to achieve optimum conservation value. Further, relatively simple, planner-friendly methodology is critical for such a comprehensive methodology to become widely used.

<u>Element 1.</u> Modeling to integrate tree-based buffers into landscape management strategies.

A decision-tree approach based on environmental planning principles, in contrast to explicit computer modeling methods, will provide a holistic framework ideally suited for integrating a wide range of ecological and social information. It is also important to recognize and acknowledge the roles of community norms, government programs, and biophysical characteristics of the farm and landscape in shaping these goals. The possible "futures" will be evaluated for their impacts on water quality and biodiversity using best available information, and ecological and hydrological effects models. Tools will be developed that link existing GIS technologies to photographic scanning and visual modification tools in order to provide a planning tool for rapid aesthetic and spatial evaluation of numerous buffer scenarios at farm and landscape scales. This in turn will be utilized as a research tool for evaluating aesthetic factors in acceptance of buffers by landowners and other segments of the public, as a training tool, to provide visual examples of various buffer designs and landscape placement strategies to managers and practitioners, and as a general education and promotion tool, by producing visual aids for incorporation into brochures, posters, presentations, etc. It will also be tested to determine its utility to provide basis for future link with economic models for evaluating cost/benefit of various buffer scenarios.

Integral to these activities will be the capability to model succession of these planted systems over time spans of 5 to several hundred years. The riparian forest growth model, developed by prior extramurally funded projects, will continue to be developed and modified to better predict succession of other tree-based buffers, most importantly shelterbelts, to incorporate crop yield and wildlife habitat relationships, and to examine the roles these linear, fragmented systems may have in mitigating hypothesized climate change impacts predicted for this region.

Accomplishments for the next 5 years include:

1. Development of a tool which can be used to target subwatersheds or locations within watersheds with greatest potential for impact on stream water quality.
2. Produce a series of Agroforestry Notes that provide the "How to..." guidelines for incorporating landscape-level (ecosystem management) considerations into site-level buffer designs and placement and which focuses on multi-purpose designs and watershed/landscape planning.
3. Develop a computer visualization tool which enables realistic simulation of visual and spatial characteristics of buffers on farms and landscapes.
4. Develop a model of riparian forest growth in the Great Plains, with special regard wildlife habitat quality, which can be used to assess current habitat value and predict consequences of buffer

forest aging, fragmentation and restoration, and impacts of hypothesized climate change scenarios for the Great Plains.

11. Mission Problem No. M1:

The RWU will have this mission problem "Advance the Use of Agroforestry Practices in Sustainable Land-use Systems" in which the development activities by the Technology Transfer and Applications (TT&A) Programs of NAC are accounted for. The mission of the TT&A Program is much broader than Research's encompassing all types of tree-based buffer practices and the full range of aspects that must be addressed in order to get the successful adoption of tree-based buffer practices (e.g. ecological to socio-economic). Work accomplished under this Program includes demonstrations, assessments, and information & education activities. The RWU will participate in this mission problem in an opportunistic fashion (i.e. availability of extramural funds) and where research input is needed.

The socio-economic considerations influencing adoption of tree-based buffer systems are recognized as key factors in designing a successful and stewardship program for private lands. Currently this work is strategically accomplished by partnering with other Centers established specifically to address these types of issues (i.e. North Central Regional Center for Rural Development; FAPRE), and where the RWU then provides the ecological/biological expertise and information necessary in designing more socially-acceptable land stewardship technologies and programs. Work funded through the Fund For America Center Planning Grant (FY98) initiated discussions with several key groups in the North Central Region, and work planned under the Missouri Agroforestry Floodplain Project will also entail addressing socioeconomic aspects of agroforestry adoption. We expect these efforts to further crystallize as the larger projects progress.

12. Cooperation

The Research Work Unit at Lincoln, NE capitalizes on the following linkages with other key natural resource institutions:
** USDA Forest Service, State & Private Forestry and International Forestry
** Technology Transfer and Applications Program at NAC
** USDA Natural Resources Conservation Service
** NRCS Institutes: Watershed, Grazing Lands, Social Sciences
** State Forestry agencies, Conservation Districts, other federal and state conservation agencies (i.e. NE Department of Environmental Quality), and conservation organizations (e.g. National Association of Conservation Districts, National Arbor Day Foundation, Trees Forever) that provide technical assistance on tree-based buffer technologies to landowners.
** EPA: Region 7 (Iowa, Nebraska, Missouri, and Kansas)
** Universities: existing collaborations on tree-based buffer technologies with University of Nebraska-Lincoln, University of Missouri, University of Minnesota, Iowa State University (NCT-179 Riparian Management in Midwestern Agricultural and Forest Landscapes).
** University-Based Centers: Center for Sustainable Agricultural Systems (UNL), North Central Regional Center for Rural Development (ISU)

Scientific collaboration is maintained with scientists within other Experiment Stations and USDA institutions (i.e. ARS units: Natl Soil Tilth Lab; Pastures Systems & Watershed Management Lab; Biomass Research Center; Southeast Watershed Lab; Appalachian Farming Systems Research Center) who are doing related research on tree-based buffer systems, especially riparian-related, soil and water quality, and wildlife/habitat relationships.

13. Staffing (2000-2005)

This research will require an average of 3.25 SY's per year (2.75 Research SY and 0.5 SY for Program Manager), at an average annual RWU funding level of approximately $0.7 million. Current funding is $0.6 million and current RWU staffing is 1.75 PFT scientists and 0.5 PFT Program Manager (the other 0.5 FTE is funded by S&PF). The RWU lost 4 PFT scientist and 2 PFT technician positions, along with several term positions in the FY96 budget cut. A research riparian ecologist (PFT) that will work in all 3 Problem Areas (predominantly in #1 & 2) was finally brought on in mid FY99 and a post-doctoral position in landscape ecology/watershed sciences will be filled in mid FY00 that will work predominantly in Problem Area #3. A post-doctoral position is being proposed given the entirely new area Problem #3 represents for the unit.

SYs per YEAR of RWUD

Problem Area	1	2	3	M1	Total
1	1	1	1	1	1
2	0.55	0.55	0.55	0.55	0.55
3	0.1	1.1	1.1	1.1	1.1
M1	0.6	0.6	0.6	0.6	0.6
TOTAL	2.25	3.25	3.25	3.25	3.25

The current professional PFT staff in the RWU at Lincoln consists of a Research Soil Scientist (0.75 SY, GM-13), who serves as Research Project Leader, a Research Riparian Ecologist (1 SY, GS-13), and a Program Manager (0.5 SY supported by RWU, GS-15). Technical support staff includes a Support Services Specialist (PFT, GS-7), a Biological Technician (PFT, GS-6), a clerk/editor (0.6 PPT, GS-5), and a clerk (TFT, GS-4). Half of both the clerk and clerk/editor salaries are covered by USDA-NRCS, and the other half of the clerk position is covered by S&PF funds coming to NAC. Temporary field and lab assistants are hired as needed. Priority staffing needs are to fill the research the landscape ecologist/watershed post-doctoral position (GS- 11/12), and to convert/hire the Biological Technician position to a PFT. An additional GS-5 technician will also be needed once these other new scientist positions are brought on board. An increase in RWU base funding is needed to adequately support current staff plus these new positions