		1. Number SRS-4351	**2. Station** Southern Research Station
(8/76)	FS-4000-1	**3. Unit Location** Otto, North Carolina	

USDA-Forest Service

RESEARCH WORK UNIT DESCRIPTION
Ref: FSM 4070

4. Research Work Unit Title
Evaluation of Watershed Ecosystem Responses to Natural, Management, and other Human Disturbances of Southeastern Forests.

5. Project Leader (Name and address)
James M. Vose, Project Leader, RWU FS-SRS-4351, Coweeta Hydrologic Laboratory, 3160 Coweeta Lab Road, Otto, North Carolina 28763

6. Area of Research Applicability
Southern Appalachian and Piedmont Regions, National, International

7. Estimated Duration
5 Years

8. Mission
To evaluate, explain, and predict how water, soil, and forest resources respond to ecosystem management practices, natural disturbances, and the atmospheric environment; and to identify practices which mitigate impacts on these watershed resources.

9. Justifications and Problem Selection
The southeastern United States encompasses a diverse array of forest ecosystems and environments from the subtropical coastal zone of Florida to the perhumid slopes of the Appalachian Mountains. The 85 million acres of forest land provide valuable resources, including timber, water, wildlife, fish, and recreation, for a rapidly expanding population. Upland hardwoods occupy one-third of the forested area while natural stands and plantations of pine occupy 40 percent of the area.

Southeastern forests are among the most intensively managed forested landscapes in the United States. Furthermore, the magnitude and diversity of human needs and expectations from this forested landscape have increased sharply in recent years and are expected to accelerate even more in the future. As forest management activities intensify and public needs from forest lands expand, there is a critical need to evaluate the environmental consequences of alternative practices from an ecosystem perspective and at large spatial scales (Swank and Van Lear 1994). However, information, methods, and guidelines are lacking to implement and evaluate ecosystem management concepts, practices, and effects on water, soil, and forest resources (Problem 1). Research will build on results from past RWU studies to synthesize environmental responses to a variety of management practices and develop appropriate guidelines and evaluation tools to assess effects on water quality, soil nutrients, and site productivity. The RWU will continue to lead and conduct research on the Wine Spring Creek Ecosystem Management project with an emphasis on

synthesis and technology transfer of interdisciplinary findings from Phase I of the project. New studies will address criteria for characterizing old-growth forests; expand analysis to a regional scale of impacts of land use practices on terrestrial and aquatic resources; and initiate efforts to evaluate the effectiveness of ecosystem restoration practices on ecosystem sustainability.

10. Approach to Problem Solution (Start at conclusion of item 9.)

Signature	**Title**	**Date**
Recommended: /s/ Nancy G. Herbert	**Assistant Director for Research**	01/12/98
/s/ Douglas F Ryan	**Assistant to Staff Director**	01/23/98
/s/ Richard V. Smythe	**Staff Director**	01/26/98
Approved Station Director /s/ Pete J. Roussopoulos	**Station Director**	02/04/98
Concurred /s/ Robert Lewis, Jr.	**Deputy Chief for Research**	02/25/98

A critical environmental problem emerging at regional national, and global scales concerns the effects of human activities on the atmosphere and, in turn, the impacts of a physically and chemically altered atmosphere on watershed resources and forest productivity. The consequences are of particular importance in the Southeast as related to carbon, water, and nutrient cycles of forest ecosystems; alteration of stream chemistry and initial acidification of Southern Appalachian streams; and patterns and trends in tree growth and forest health. Cause and effect relationships are complex and it is apparent that improved knowledge, baseline data, and predictive models are required to evaluate effects of the atmospheric environment on forested watersheds in the southeastern United States (Problem 2). During the past 5 years the RWU has focused process and modeling research on effects of a changing chemical and physical atmosphere on water, soil, and forest resources. Much of this research has been facilitated by participation in national cooperative programs. Completion and synthesis of these studies are planned in the next 5 years along with initiation of new research to develop regional scale models of carbon, nitrogen, and sulfur cycles; develop species specific models to evaluate effects of climate change on hardwood forest productivity; and evaluate evapotranspiration and runoff processes as related to management and environmental issues. The RWU is a leader in the NSF sponsored Long-Term Ecological Research Program and cooperative efforts will continue to support research in this problem.

The research work unit is an established center for ecosystem studies with an emphasis on establishing principles and guidelines for assessing man's impact on natural and managed hardwood and pine ecosystems. The approach to this mission is to meld theory development, experimental testing, modeling, and applications, usually on a landscape scale, where the watershed is the unit of both hydrologic and ecosystem investigation. Streamflow and stream chemistry responses after natural and man-caused disturbances are measured in terms of decades. Thus, studies of watershed responses due to meteorologic events, climatic changes, and management activities necessarily require long-term data sets and extend beyond the 5-year planning period. These activities (listed below) are carried forward in a Mission Problem to provide data essential to the formulation, development, and testing of shorter-term research.

Study No.	Title	Estbl.	Term.
SE-4351-3	Structural descriptions of plant communities as related to water yield. Addendum I. The dynamics of changes in water yield as related to white pine plantation development	1967	2015
SE-4351-5	Structural descriptions of plant communities as related to water yield. Addendum II. Successional trends of forest stands following the death of American chestnut	1969	2020
SE-4351-6	Structural descriptions of plant communities as related to water yield. Addendum III. Changes in streamflow associated with hardwood coppice development	1969	2010
SE-4351-15	Evaluation of environmental effects of cable logging on steep mountain watersheds	1975	2020
SE-4351-11	The hydrology of mountain watersheds under several cover types	1966	2020
SE-4351-4	Productivity and mineral cycling on natural and manipulated watersheds at Coweeta	1968	2020
SE-4351-13	Changes in stream chemistry associated with forest manipulations	1972	2015

Research findings from these RWU problem selections are directly related to needs specified in several enacted laws, including the National Forest Management Act of 1976 (NFMA); PL 92-500, the

Federal Water Pollution Amendment of 1972; Forest and Rangeland Renewable Resources Planning Act; Clean Water Act; Clean Air Act; and Acid Precipitation Act. Moreover, topics contained within the problems address issues that are entirely consistent with needs and topics identified in the draft Strategic Plan for Forest Service Research and Development; the Strategic Plan for SRS research and associated cross-cutting themes; Forestry Research: A Mandate for Change; Land Resource Management Plans for national forests in the Southern Region, and other research planning documents.

Previous results from the RWU have been utilized and/or adopted by public land managers, industries, states, environmental groups, and regulatory agencies. The same users groups will benefit from solutions derived in both problems. Information obtained in Problem 1 is critical to managers at local and regional levels in the development and implementation of Best Management Practices. Tools and methods generated by this research will provide improved guidelines for forest planning activities. The public will benefit from the maintenance and/or improvement of site productivity and water quality; the likelihood of successful problem solution is very high based on past RWU accomplishments and technology transfer in this problem area. Solution to Problem 2 will have regional, national, and international significance to scientists in the forestry and ecological research communities, to forest land managers, and to policy and decision-makers. This problem seeks enhanced understanding of interactions between the physical and chemical atmospheric environment and forested watershed ecosystems. Information gained from this research will be of immediate interest to research scientists, and will ultimately provide information required to design alternative approaches for managing forest watersheds under the influence of a chemically and physically altered atmospheric environment. The general public and policy and decision makers will also benefit from the availability of improved scientific information on which to base future national policy decisions. Results and databases are integral to efforts such as the Geosphere/Biosphere Program. There is a moderate likelihood of achieving partial solution to this problem in 5 years due to its inherent complexity and long-term nature.

10. APPROACH TO PROBLEM SOLUTION

Problem 1. Information, methods, and guidelines are lacking to implement and evaluate ecosystem management concepts, practices, and effects on water, soil and forest resources.

Research during the past 5 years has concentrated on quantifying the impacts of several alternative forest practices on soil and water resources. A body of knowledge, largely published, has emerged to assess practices such as cable logging, forest roads, herbicides, mechanical site preparation and cut/burn stand restoration. In many cases, results were translated into management guidelines and some studies were terminated. Remaining results will be published and appropriate guidelines and evaluation tools developed with an emphasis on responses of soil nutrients and site productivity. The RWU will continue to provide leadership in the Wine Spring Creek Ecosystem Management Project for both direction and conduct of research. New studies will address gaps in knowledge on the structure and function of ecosystems that must be filled to evaluate ecosystem sustainability.

Element 1. Analyze and publish results from studies of previous RWUD and/or direct extensions of previous RWUD.

Accomplishments planned for the next five years include:

Topic 1. Nutrient cycling/productivity studies

Study 1. Effects of whole-tree harvesting on site nutrient removals, soil carbon and nutrients, and productivity in hardwood forests.

Study 2. Long-term responses in site nutrients and productivity of slash pine plantations to four different rotation prescriptions.

Topic 2. Evaluate ecosystem impacts of site preparation burns in mixed pine-hardwood stands.

Study 1. Assess changes in area of exposed soil and erosion responses following burn.

Study 2. Effects of site preparation burn on soil N mineralization and soil nutrient content.

Study 3. Determine changes in aboveground C and N pools and evaluate potential changes in long-term site productivity.

Study 4. Assess the effects of burning on forest succession and vegetation diversity.

Element 2. New and Continuing Studies

Topic 1. Ecosystem Management Project on Wine Spring Creek

Study 1. Develop and validate a GIS-based erosion model which will allow decision makers to compare potential impacts of proposed land management activities.

Study 2. Monitor and characterize sediment movement in second to fourth order mountain streams before and after management activities such as prescribed fire, road reconstruction and logging, and riparian zone large woody debris addition.

Study 3. Development of a decision support nutrient cycling model to assist forest managers in assessing the impacts of management alternatives on long-term site productivity.

Study 4. Assess effects of various management prescriptions (stand replacement fire, regeneration harvest methods) on vegetation composition and diversity.

Study 5. Characterize baseline precipitation and stream chemistry and evaluate effects of management on stream solutes.

Study 6. Develop climate history utilizing on site measurements and correlations with long-term data sets and measure climatic driving variables.

Study 7. Evaluate the effects of alternative management prescriptions on

soil physical and chemical properties.

Topic 2. Characterize structural and functional attributes of old-growth mixed hardwood forest.

Study 1. Assess carbon pools and flux rates by major ecosystem components (i.e., soils, vegetation, coarse woody debris).

Study 2. Quantify amounts of coarse woody debris and standing biomass for three major forest types.

Study 3. Comparison of base cation pools and cycles in mixed hardwood old growth and aggrading forests.

Topic 3. Evaluate the functional significance (productivity, nutrient cycling, water cycling, resistance and resilience to disturbance) of a diverse forest stand.

Study 1. Develop a framework and test methods to define ecosystem diversity from a functional viewpoint.

Study 2. Remove major structural components (shrub layer, herb layer, shrub + herb layer) from mesic, mixed-oak communities and measure changes in whole system net primary production, and nutrient and water cycles.

Topic 4. Assess impacts of land-use change (forest cutting, pasture, old-growth) on regional C cycling as part of LTER regional analysis.

Study 1. Carbon pools and flux rates (respiration and NPP) will be determined for a range of land-cover types in the southern Appalachians. Models will be developed which relate flux rates to driving variables.

a. Develop species-specific respiration functions for early, mid, and late successional forest ecosystems.

b. Quantify and compare ecosystem C balance (carbon gain - carbon loss) among varying land-use types.

c. Develop and apply a landscape scale C balance model to the southern Appalachian region to assess the impacts of varying land use.

Topic 5. Role of evergreen understory in regulating ecosystem function.

Study 1. Effects of evergreen understory on above- and belowground resource availability.

Study 2. Effects of competition and allelopathy on carbon allocation (root: shoot) in two hardwood and one needle-leaf species.

Topic 6. Nutrient cycling and availability in forested southern Appalachian ecosystems.

Study 1. Changes in hardwood litter decomposition rates over 20 years in southern Appalachian mixed hardwood forests.

Study 2. Reconstruction of soil chemical history using dendrochemical analysis.

Study 3. Effects of soil nutrient availability on dogwood anthracnose infection.

Topic 7. Ecosystem restoration practices and system sustainability.

Study 1. Effectiveness of riparian restoration practices on water, soil, and air quality.

Study 2. Environmental and vegetation responses to prescribed burning in mixed-oak forests.

Environmental consideration: Most of the studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." For research involving the use of herbicides, environmental considerations will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs.

Problem 2. Improved knowledge, baseline data, and predictive methods are required to evaluate effects of the atmospheric environment on forested watersheds in the southeastern U.S.

Research over the past five years has focused on developing a mechanistic understanding of the interactions among the atmospheric environment (chemical and physical) and watershed resources and biological processes at multiple scales. Particular emphasis has been placed on quantifying the atmospheric environment's regulation of carbon, water, and nutrient cycles, as well as potential climate change impacts on productivity and hydrology. Modeling has been a large component of these activities for integrating, synthesizing, and scaling processes across space and time. In the upcoming five years, past studies will be concluded and results published. New research to develop regional scale models of carbon, nitrogen, and sulfur cycles will be conducted along with synthesis of trends in atmospheric deposition and watershed level stream chemistry responses. Other new studies will focus on evapotranspiration and runoff processes as related to management and environmental issues.

Element 1. Analyze, conclude, and publish results from the previous RWUD.

Topic 1. Forest Carbon, Water, and Nutrient Cycling Processes and Models

Study 1. Model of the sulfur (S) cycle in hardwood forest ecosystems. Utilize existing data on soil sulfur and soil horizons of hardwood forest ecosystems. Publish the following paper:

a. A soil sulfur model for disturbed and manipulated forest ecosystems.

Study 2. Quantify respiration, photosynthesis, and carbon allocation patterns in mature white pine and hardwood ecosystems. Develop models, which predict C gain changes in response to environmental stress. Publish results in the following papers:

a. Develop and validate a mechanistic stand growth model for eastern white pine.

b. Respiration of above- and below-ground components in a mature white pine ecosystem.

c. Landscape-scale variation in productivity and hydrology in hardwood forest ecosystems.

Study 3. Synthesis of wet and dry deposition to white pine (WS1) and hardwood (WS2) forest canopies with respect to impacts on nutrient cycling processes.

Study 4. Summarize patterns of atmospheric gases and particulates for base stations in the Coweeta Basin.

Topic 2. Impacts of climate change on hardwood forest ecosystems in the southern Appalachians.

Study 1. Parameterize and evaluate species-specific models predicting productivity response to climatic change.

Element 2. New and Expanded Studies

Topic 1. Forest Carbon, Water, and Nutrient Cycling Processes and Models.

Study 1. Landscape scale variation in soil respiration will be assessed with a combined measurement and modeling approach. Measurements include quantification of diurnal variation and the regulating abiotic and biotic factors.

a. As part of Study 1, improved models of soil temperature will be developed using biophysical measurements and landscape level scaling techniques.

Study 2. Interactions of CH_4 and CO_2 fluxes and nitrogen transformation rates across a soil and vegetation gradient. Identification of the regulating factors, spatial variability, and relationships between soil gas fluxes and soil nitrogen transformation rates at sites representative of the vegetation gradient within the Coweeta Basin.

Study 3. Revise the N cycling model for mature mixed hardwoods by synthesizing process level data obtained from Coweeta studies in the past two decades.

Study 4. Comparison of long-term soil carbon cycling in upper and lower elevation watersheds in the southern Appalachians using the CENTURY model.

Study 5. Linkages between transpiration and stem respiration will be assessed by measuring diurnal patterns in both processes.

Study 6. Carbon and nitrogen isotope variation through the soil profile in three southern Appalachian forest stands (early and late successional hardwood and mixed pine/hardwood). Examine the changes in ^{13}C and ^{15}N that occur during organic matter formation and decomposition through measurement of carbon and nitrogen isotope ratios in litter, forest floor, and within the soil profile.

Topic 2. Physical Interactions

Study 1. Directly measure transpiration in mature trees using heat pulse techniques. Compare results with estimates from models and direct transpiration rates with porometer.

Study 2. Evaluate the use of cottonwood trees to remediate ground water pollution by quantifying transpiration using heat pulse techniques.

Study 3. Forest ecosystem responses to episodic atmospheric induced disturbances (droughts, floods, hurricanes, ozone, deposition).

Environmental consideration: The studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in an EIS or EA." Where environmental concerns exist regarding particular studies, these will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs.

Mission Problem. Long-Term Hydrologic and Ecological Research on Forested Watersheds

Long-term hydrologic and ecological research on forested watersheds is required to describe the stability and change in ecosystem function and structure over extended spatial and temporal scales. Maintaining the continuity of existing long-term data bases, their synthesis, and associated interpretations is a unique and essential part of the RWU mission. These data bases extend back in time 25 to 60+ years and provide direct support for the short-term studies in Problems 1 and 2.

Element 1. Develop data bases to define trends and cycles of forest ecosystem vegetation, hydrology, and chemistry for time scales similar to the life spans of forest species.

Topic 1. Synthesis of vegetation, nutrient budget, and hydrologic responses to forest management.

Study 1. Long-term Forest Succession.

a. Forest succession following the death of American chestnut in the southern Appalachians.

b. Vegetation dynamics in large-scale blow-downs (Hurricane Opal) after salvage logging.

Study 2. Hydrologic Response to Disturbance.

a. Long-term changes in hydrologic processes, primary production, and nutrient recycling following hardwood to pine conversion.

b. Long-term changes in storm hydrographs and flow frequency distribution following conversion from hardwood to pine forest.

Study 3. Elevational and seasonal variation in hardwood LAI.

Study 4. Coweeta Book. Deciduous forest ecosystem recovery from cutting disturbance in the southern Appalachians. This book will be comprised of about 12 chapters and synthesizes 20 years of research with a focus on Coweeta WS7. All RWU scientists will be authors and/or co-authors of chapters.

Topic 2. Long-term forest, hydrometeorological, and biogeochemical monitoring (maintain existing sampling networks for climate, precipitation, streamflow, and soil moisture at 5 climatic stations, 10 precipitation sites, and 16 weirs).

Study 1. Climatology of a mountain watershed. Summary of precipitation and climatic data collected throughout the Coweeta basin since 1934, showing spatial and temporal variability related to topography, season, and regional climate events.

Study 2. Long-term changes in hydrology, precipitation, and stream water chemistry for reference and manipulated watersheds.

Study 3. Long-term forest monitoring. Periodic resampling of permanent vegetation plot network and remeasurement of nutrient pools and productivity of select ecosystems.

a. Long-term soil carbon dynamics in relation to alternative management practices.

Study 4. Stream temperature of second and third order mountain streams on north and south-facing slopes.

Element 2. Assessment of long-term forest ecosystem response to changing environmental conditions.

Topic 1. Ecosystem structure and function across environmental gradients.

Study 1. Canopy Gap Dynamics.

a. Microenvironmental response to artificially created forest openings with and without *Rhododendron maximum*.

b. Growth response of gap perimeter trees and rates of canopy closure.

c. Comparative physiology of seedlings vs. advance regeneration following gap creation from Hurricane Opal blow-down.

d. Characteristics of pit and mound topography in wind-induced forest openings.

e. Vegetation recovery in large blowdowns as remeasured through periodic plot reinventory.

f. Decadal vegetation responses in drought-induced forest openings.

g. Response of hardwood species to forest gaps. Comparative physiology of four co-occurring hardwood species at two elevations in the Coweeta basin.

Study 2. Coarse Woody Debris.

a. Determine the relative importance of species on long-term log decomposition and nutrient dynamics using large logs from Hurricane Opal.

b. Determine the relative importance of species vs. environment on long-term log decomposition along environmental gradients.

c. Quantify the functional attributes of coarse woody debris along environmental gradients from water and nutrient perspectives.

Study 3. Analysis of understory climate across an elevation gradient in relation to different forest types.

Study 4. Gradient analysis of NPP using dendrometer bands and a landscape scale physiologically based NPP model.

Study 5. Analysis of nitrogen transformation rates and soil chemistry changes across environmental and vegetation gradients.

Study 6. Community classification: Canonical correspondence analysis (CCA) will be used to understand plant species compositional changes in response to environmental gradients in the Coweeta basin. Permanent plots initially measured in 1934 and subsequently remeasured three times will be used in the analysis to determine the temporal and spatial distribution of species.

Study 7. Long-Term Intersite Decomposition Experiment (Team) - LIDET. Leaf litter, fine root, and wood decomposition study replicated 4 times at 28 sites in North and Central America.

Topic 2. Development of methods to measure ecosystem structure and function at variable temporal and spatial scales using remote sensing, GIS, and modeling.

Study 1. Develop and validate a basin scale ecosystem productivity model using a GIS database of projected climate and soils data.

Environmental consideration: The studies in this problem area are expected to have little or no potential for soil movement, water quality degradation, or impact on sensitive resource values and are therefore covered under FSH 1909.15, Chapter 30, "Categorical Exclusion from Documentation in as EIS or EA." Where environmental concerns exist regarding particular studies, these will be evaluated within individual study plans, or by Environmental Assessments or Environmental Impact Statements prepared with and approved by cooperating District or Forest staffs.

STAFFING

Conduct of this research will require an average of 6.0 scientists per year, with an average annual cost of $850,000 at the RWU allocation level (appropriated funding), $150,000 currently allocated for ecosystem management, and supplementation through grants of $300,000 per year. This capability excludes resources needed for Study 2 of Topic 7 in Problem 1. The scheduling of SY's over the 5-year span of the RWU is:

Problem Area	Scientist Years for Each Year of RWU				
	1	2	3	4	5
1	2.5	2.5	2.5	2.5	2.5
2	1.0	1.0	1.5	1.5	1.0
Mission	2.5	2.5	2.0	2.0	2.5
	6.0	6.0	6.0	6.0	6.0

The scientific staff will consist of six permanent full-time scientists, including the Project Leader. There are currently 4 permanent and 2 temporary full-time technicians; permanent support services specialist, computer specialist, computer assistant; temporary clerk; maintenance mechanic; and two Older Americans

positions within the RWU. Two additional temporary technician positions will be added in year 1. The University of Georgia supports four full-time positions at the RWU including an LTER site manager/scientist and these positions will be retained with continuance of the LTER Program. Other universities support an average of two positions each year at Coweeta.

The RWU has a long and productive record of cooperative research with 20 formal agreements currently active involving 57 graduate students and 50 senior investigators. Current and anticipated cooperative activities are summarized in the following table with cooperators and the nature of cooperative resources identified at the problem level.

Nature of Cooperation

PROBLEM	COOPERATOR	SOURCE OF FUNDS	RECIPIENT OF FUNDS	OPERATING SUPPORT	SCIENTIFIC SUPPORT	TECHNICIAN SUPPORT
Problem 1	**DOD**	**X**		**X**	**X**	**X**
	EPA	**X**		**X**	**X**	**X**
	SRS- 4202,4101 4901,4852, 4851	**X**	**X**		**X**	**X**

	U. FLORDIA		**X**		**X**	
	NCSU		**X**	**X**	**X**	
	CLEMSON		**X**		**X**	
Problem 2	**UGA**		**X**	**X**	**X**	**X**
	EPA	**X**		**X**	**X**	**X**
	USGS				**X**	
	NSF*	**X**		**X**	**X**	**X**
	SYRACUSE	**X**			**X**	
Mission Problem	**CLEMSON**			**X**	**X**	
	NASA	**X**		**X**	**X**	**X**
	U. MINN				**X**	**X**
	EPA	**X**		**X**	**X**	
	NSF*	**X**		**X**	**X**	**X**
	NF'S			**X**	**X**	
	DUKE U.			**X**	**X**	
	FURMAN U.	**X**	**X**		**X**	
	UGA	**X**		**X**	**X**	
	VA.TECH&SU				**X**	
	HIGHLANDS BIOLOGICAL STATION				**X**	
	U. WISCONSIN				**X**	
	MARS HILL				**X**	

* Includes LTER Institutions (UGA, VPI&SU, Duke U., U. Minnesota, U. Wisconsin, Mars Hill College).