10. Approach to Problem Solution

Research Problem 1: Our poor understanding of the factors regulating C allocation to root systems limits our ability to successfully apply new management systems designed to enhance or sustain ecosystem productivity, while maintaining biodiversity and ecosystem function.

Accomplishments planned for the next 5 years include:

1.1 Determine if fine roots are modular in the same sense that leaves and needles are modular organs with known points of abscission. Although it is well known that needles and leaves are modular organs and that their life expectancy is related to resource capture and nitrogen content, we have no knowledge of where on the branching root system "fine roots" die. Recent evidence suggests that the longevity and function of an individual fine root is determined by the position of that root on the branching fine root system. Individual roots also apparently have defined points of "abscission." These results may apply to all temperate and boreal trees and results should greatly improve our ability to understand how tree root systems grow and function. (Pregitzer, Eissenstat).

1.2 Quantify the role of coarse woody roots in forest carbon budgets. Most C inventories and models of ecosystem productivity assume that coarse roots are a constant proportion of aboveground biomass. There is, however, little, if any, evidence to support this simplistic assumption. We hypothesize that C allocation to coarse roots is higher in young even-aged stands during the first decade of stand development as the soil is being fully exploited by the rapidly growing trees. Initial studies will be conducted in a typical chronosequence of red pine plantations. We will also initiate studies of coarse root decomposition and explore ways to link reliable estimates of coarse root biomass to standard forest inventories and carbon accounting models. (King, Pregitzer, Johnson, Birdsey, Heath)

1.3 Test the effects of elevated CO_2 and ozone on soil respiration, root production, and root mortality in the FACTS-II Experiment. Studies over the first three years have documented a significant increase in soil respiration and root growth under elevated atmospheric CO_2 and these results have important regional and perhaps global ramifications for understanding the growth and yield of future forests and the ability of forests to store C. The results of ozone treatment are unclear and require additional study. An important unanswered question is whether or not the treatments effects are transient. (Pregitzer, King, Zak, Kubiske, Hom, Isebrands)

1.4 Understand the contributions of roots to soil organic matter pools in managed forested wetlands. Management of forested wetlands has been controversial. These forests dominate much of the upper North Central Region,

provide critical natural functions, and forested wetlands are an important potential source of softwood fiber. The pressure to extract existing stocks of softwood fiber from these forests is growing. On-going experimental studies suggest ecosystem structure and function recover rapidly following management. There also appears to be a rapid capacity of these forests to store soil C following disturbance. The role of roots in these rapidly aggrading belowground C pools is poorly understood. Studies will provide insight into how wetlands function following management. (Trettin, Jurgensen, Gale, Pregitzer)

1.5 Develop an improved understanding of the genetic and environmental controls on whole-tree carbon allocation, and the extent to which we can manage the potential plasticity of below-ground systems for improved soil productivity and C storage. The research challenge lies in a better understanding of whole-tree C allocation, the biomass and vertical distribution of roots, how long roots of various sizes live, rates of root decomposition, and how environmental conditions and management practices alter C allocation to root systems. (Wullschleger, King, Kubiske, Isebrands, Chen, Pregitzer)

Expected Products: (1) Studies will result in a better fundamental understanding of how tree root system grow and an improved ability to inventory C stocks, predict forest growth, and model the behavior of future forests. (2) Policy makers and managers will be able to more accurately evaluate the ability to forests to store C. (3) New information and silvicultural guidelines will be developed for the sustainable management of forested wetlands. (4) Research will provide improved methodologies for evaluating the cumulative impacts of human activities on forest ecosystems as required by the National Environmental Policy Act (NEPA). (5) New management techniques will be developed to promote the accumulation of belowground biomass and soil C.

<u>Research Problem 2: We do not understand how human activities alter the function and biodiversity of soil organisms, organisms that regulate carbon and nutrient cycling and the formation of stable soil organic matter.</u>

2.1 Determine how forest management alters the composition and function of soil microbial communities. Is microbial community composition and function driven by changes in plant community composition and ecosystem net primary productivity? Alternatively, are patterns of microbial biodiversity and C and N cycling driven primarily by environmental differences among ecosystems? Studies will be initiated in a variety of experimentally manipulated forests (LTSP plots in Michigan), managed stands along chronosequences, and old-growth forests. Results will provide important insights into how forest management practices alter microbial biodiversity and ecosystem function. (Zak, Pregitzer)

2.2 Understand the role of root tissue quality in regulating the biodiversity and function of soil microbial communities. Although it is well known that leaf tissue quality plays an important role in microbial function, there is almost no

information on how root tissue quality influences microbial biodiversity and function. Fine roots must be an important substrate for microbial metabolism simply because they account for a majority of the forest C budget in many northern forests. Our hypotheses center on understanding how specific organic substrates favor certain functional groups of microbes because of their competitive abilities to process different types of litter. Results will help us understand how the management of dominant vegetation regulates the processing of organic matter and the formation of soil C. (King, Zak, Ashby, Pregitzer)

2.3 Determine how simulated N deposition alters microbial diversity and the processing of soil C. Experimental additions of nitrate simulating chronic atmospheric N deposition have resulted in a significant increase in the production and export of dissolved organic C and N from northern hardwood forests. The processing of soil C must be altered as these forests approach N saturation. We hypothesize that changes in microbial diversity and function are driving observed changes in soil C and N cycling. Results will have important regional implications for forest health and potential linkages between terrestrial and aquatic ecosystems. (Zak, Burton, Ashby, Pregitzer)

2.4 Understand how soil fauna respond to forest management, elevated atmospheric CO_2, O_3, and atmospheric N deposition. Soil animals play key roles in the belowground foodweb and biogeochemical cycling, yet their biodiversity and function in forests remains poorly understood. Sampling and description of soil fauna will occur in a series of existing experiments to provide initial information about how soil biodiversity responds to the experimental manipulation of vegetation and essential soil resources. (Loranger, Mattson, Pregitzer)

Expected Products: (1) New fundamental information of the effects of forest management on soil biodiversity and ecosystem function. (2) New silvicultural systems designed to maximize C storage, while maintaining fiber yield and ecosystem integrity. (3) Information which can be used to access the regional impacts of air pollution on forest health. (4) Improved methodologies for evaluating the cumulative impacts of human activities on ecosystem function as required by the National Environmental Policy Act (NEPA).

<u>Research Problem 3: Another major research problem is to further our understanding of belowground biogeochemical cycles, evaluate how they are being altered by human activities and design management systems that maintain or enhance ecosystem function and maintain biodiversity.</u>

3.1 Understand how elevated atmospheric CO_2 and ozone influence soil C and N cycling. Nitrogen often controls productivity in forests and it has been hypothesized that increased growth in response to elevated atmospheric CO_2 will depend on soil N availability. Because the C and N cycles in soil are soil

interdependent, it is important to understand how soil C and N cycling respond to increasing atmospheric CO_2. Results will provide an important window into the future growth of the region's most important commercial pulp species. (Zak, Pregitzer, King, Kubiske, Isebrands)

3.2 Develop a more comprehensive understanding of the mechanisms regulating the seasonal and inter-annual flux of dissolved organic carbon and nutrients in a benchmark old-growth northern hardwood watershed. Lake Superior is the largest freshwater lake on earth. There are very few (<5) intact old-growth watersheds on the south shore of Lake Superior that can serve as a benchmark in terms of understanding the factors that regulate the flux of energy and nutrients from terrestrial to aquatic ecosystems. We will continue recently initiated watershed studies in the Porcupine Wilderness State Park in cooperation with RWU-NC-4351 (Grand Rapids, MN). Our goal is to develop a more fundamental understanding of baseline biogeochemical cycling in old-growth watersheds, specifically the mechanisms that control the flux of DOC and DON and related nutrients from terrestrial to aquatic ecosystems. Results will provide a baseline that can be compared and contrasted to managed watersheds in the region. (Goebel, Palik, Pregitzer)

3.3 Improve methods of forest inventory and monitoring to include ecological factors essential for determining if forest practices are sustainable at the landscape level. Sustainable forest management and monitoring and managing biodiversity requires information about habitat, information completely missing or insufficient in current standard forest inventory and monitoring programs. Understanding ecosystem processes at the stand and landscape level will require new approaches to standard inventory programs that include more sophisticated tools for understanding the relationships among terrain, soils and plant and animal diversity. We will experiment with new approaches to standard forest inventory that include more information on relationships between understory vegetation, soils and terrain and develop new software tools that enable forest managers and planners to quickly and easily understand the impacts of various management regimes on stands and landscapes. The development of these new indicators, metrics and tools will represent the unique contribution of RWU 4159 (O'Neill, Schmidt, Reed, Palik, Pregitzer)

3.4 Develop new methods and approaches for measuring belowground processes. Carbon and nutrient transformations in the soil form the basis for productivity and sustainability and yet these key ecological processes are relatively poorly understood. Work will be initiated in cooperation with our partners to develop a state of the science belowground observatory as a foundational part of our ecosystem process research capability. The facility will serve as a test bed for new devices and advances in the measurement of belowground processes. Effort will also focus on the construction of innovative, cost effective, rugged, small, remotely read instruments that measure key

processes such respiration and soil solution chemistry on relevant time steps. In many ways, our understanding of belowground processes is currently limited by cost-effective, reliable instrumentation. (Pregitzer, Wullschleger, Zak, Isebrands, O'Neill, Mattson, Trettin)

Expected Products: (1) A better fundamental understanding of the biogeochemical cycles that regulate forest productivity and more realistic predictions and models of future forest growth and yield. (2) New baseline information on linkages between terrestrial and aquatic ecosystems, which can be used to evaluate the cumulative impacts of management at the watershed level. (3) Improved methodologies for evaluating the cumulative impacts of human activities on ecosystem function as required by the National Environmental Policy Act (NEPA). (4) New methods of ecological inventory that will enable landscape evaluations of the impacts of forest management on sustainable forest management. (5) New software tools that will allow simple and rapid technical transfer of ecological information from inventory and monitoring programs across the landscape. (6) Internet based technical transfer products to help land managers and planners on National Forests. (7) A new belowground research facility and new approaches to ecosystem instrumentation.

Environmental Considerations: The research conducted within the framework of the Research Work Unit Description will be evaluated relative to the policies and procedures for environmental analysis and documentation enumerated in FSH 1909.15 of the Environmental Policy Procedures Handbook. We anticipate that some research activities will meet criteria for categorical exclusion. When they do not, an environmental assessment will be prepared. This determination will be made at the time of developing the study plan.

Research Work Unit Staff and Support: The goal of RWU 4159 is to have three permanent full-time scientists, one permanent technician, two permanent support positions (system administrator and administrative assistant), and two-three term technicians. Two permanent scientists will be added in FY 2001 and these two position descriptions have recently been written and approved. The project leader (K. Pregitzer) will focus primarily on Research Problem 1 in terms of his individual research. The new Microbial Ecologist position will be filled late in FY 2001 and this scientist will focus primarly on Research Problem 2. The new Biogeochemistry Position will be filled late in FY 2001 and this scientist will focus primarly on Research Problem 3. All three permanent scientists in RWU 4159 will work together as a team to help accomplish the entire plan of work outlined above over the next 5 years in collaboration with internal and external partners.

Base funding to the RWU begins at approximately $800,000 in the first year. This level of funding will support the three permanent scientists and two exisitng permanent staff positions, provide operating for the physical facilities, and a minimal amount of operating for science. Exisitng grants from DOE, other USFS

programs, industry and other agencies will supplement base operating for the RWU in the first three years, providing at least $150,000 of aditional operating immediately. Permanent RWU scientists will seek additional extramural support in collaboration with our partners, and we anticipate that supplemental competitive funding will become an important part of the total RWU budget. Hopefully, the base RWU budget will also grow modestly over the 5 year plan of work to reach $900,000 to $1,000,000. An increase in base funding to this level would enable joint venture agreements to be sustained at a total level of $75,000 - $100,000 per year, allow for some flexibility in operating, and result in the addition of one permanent technician. Post-doctoral scientists, graduate and undergraduate students, term, and temporary positions will be frequently used to achieve our research goals. All of the planned accomplishments outlined in the three problem areas above have enough exisitng funding through the base budget and/or exisitng extramural grants to make significant progress, except planned accomplishments 1.1, 1.4, 1.5 and 3.3. The Project Leader, working collaboratively with the new RWU scientists and external cooperators, will seek support to implement studies in these four areas in the second and third years of the 5 year plan.

Research Problem	**Project Year**	**1**	**2**	**3**	**4**	**5**
		Scientist Years per Project Year				
1		1.0	1.0	1.0	1.0	1.0
2		0.25	1.0	1.0	1.0	1.0
3		0.25	1.0	1.0	1.0	1.0
Total Scientist Years		1.5	3.0	3.0	3.0	3.0

This research will require an average of 3.0 scientists per year. Distribution of SY's through the 5-year RWU term is as follows: