

HJA LTER Renewal Proposal - 1996

Long-Term Ecological Research at the H.J. Andrews Experimental Forest (LTER4)

Project Summary

The central question guiding Andrews Forest LTER studies is: **How do land use, natural disturbances, and climate change affect three key ecosystem properties: carbon dynamics, biodiversity, and hydrology?** These three ecosystem properties are of high scientific and social interest and represent three rather different categories of ecological response to landscape patterns. The principle spatial scale for synthesizing results of these studies is the Andrews Forest landscape (6400 ha) and the adjacent upper Blue River watershed (9000 ha). The time scale of interest spans the past 500 yrs and extends several centuries into the future, based on model projections of alternative possible future conditions. LTER studies link closely with work at larger spatial scales and paleoecological time scales. This proposal represents a strategic plan to answer this question by continuing to use Andrews LTER as the core of the large, multi-faceted research program based at Andrews Forest.

Since its inception in 1980, the Andrews Forest LTER program has consisted of long-term experiments, measurement programs, short-term studies, and modeling analyses in a series of research Components: Climate; Hydrology; Disturbance Regimes/Landscape Dynamics; Vegetation Succession; Biological Diversity; Carbon and Nutrient Dynamics; and Forest-Stream Interactions. Most of the long-term studies in these research Components are proposed for continuation in LTER4 (1996-2002). The highly regarded information management systems of the Quantitative Sciences Group will continue to be a vital part of our science and data sharing. In addition, we propose four related Synthesis Areas: A. **Effects of species on ecosystem function** to assess how the abundance and distribution of species influence ecosystem functions; B. **Early succession** to examine how the rate of conifer establishment following clearcutting affects selected ecological properties; C. **Small watersheds** to examine the influence of post-clearcut vegetation succession on peak and low streamflows from small watersheds; and D. **Landscape dynamics** to determine how land use, natural disturbances, and climate variability affect carbon dynamics, biological diversity, and hydrology in forest patchworks and stream and riparian network systems. The effect of ecological and geophysical patterns on ecosystem function is a common theme through these research Components and Synthesis Areas. The ultimate objective of this work is to advance scientific understanding of controls on ecosystem structure and function in the forested landscapes of the Pacific Northwest.

In the period of LTER3 (1990-1996) Andrews Forest science and scientists have played prominent roles in the dramatic shift toward ecosystem-based management of natural resources in the Pacific Northwest. These roles, including communication with general public, policy makers, and land managers concerning management of forests and watersheds, will continue.

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Section 1. RESULTS OF PRIOR SUPPORT. BSR 90-11663. Title: Long-Term Ecological Research on the H.J. Andrews Experimental Forest. Jan. 1, 1991-Oct. 15, 1996.

Section 1.1. Over its 15-year history the Andrews LTER program has become a major center for analysis of forest and stream ecosystems in the Pacific Northwest. Today, several dozen university and Federal scientists use this LTER site as a common meeting ground, working together to gain basic understanding of ecosystems and to apply this new knowledge in management and policy (Franklin 1992, Swanson and Franklin 1992, Cissel et al. 1994). The Andrews LTER program has its roots in the establishment of the H. J. Andrews Experimental Forest by the US Forest Service in 1948 ([Fig. 1.1](#)). This began two decades of predominantly Forest Service research on the management of watersheds, soils, and vegetation. With the inception of the International Biological Programme-Coniferous Forest Biome (IBP-CFB) in 1969, university scientists began to play increasingly important roles in the Andrews program. The focus shifted from single disciplines to more integrated research on forest and stream ecosystems, especially old-growth forests. IBP-CFB ended in the late 1970s and LTER commenced in 1980. The first decade of LTER work developed a backbone of long-term field experiments ([Table 1.1](#)) as well as long-term measurement programs focused on climate ([Table 1.2](#)), streamflow and water quality ([Table 1.3](#)), and vegetation succession ([Table 1.4](#)). Development of data and information management systems as part of the science program has been a major accomplishment (Stafford et al. 1988). During LTER3 (1990-1996) we continued these long-term projects, but placed increasing emphasis on integration under the central theme: **Develop concepts and tools needed to predict effects of natural disturbance, land use, and climate change on ecosystem structure, function, and species composition.** The following paragraphs briefly describe our major accomplishments during LTER3, moving from largely abiotic factors to ecosystem properties and finishing with synthesis.

Observations and analysis of **climate** at the Andrews LTER have provided a strong basis for defining its temporal and geographic context. Greenland (1994a, b) found the Andrews climate to be representative of the Pacific Northwest, with drier and warmer conditions having a weak but significant positive correlation to El Nino. Analyses of effects of climate change on forests and disturbance regimes (Franklin et al. 1991, Urban et al. 1993) of the Oregon Cascades, while noting important uncertainties, suggested the possibility of a 500-1000 m elevation rise of forest zones under some global warming scenarios. Since climatic variation in time and space substantially affects species distributions, ecological function, and disturbance patterns, the climate measurements program ([Table 1.2](#)) was modified to provide better characterization of climate variables that support Andrews landscape studies. Modeling of climate variables at Andrews (an important aspect of integrating climate with ecosystem patterns and processes) has yielded maps of monthly temperature, precipitation, and potential short wave solar radiation.

This effort has also yielded new insights into the factors controlling spatial variation of climatic variables. For example, precipitation patterns differ dramatically in wet and dry seasons because orographic effects vary with seasonal differences in the direction of major air mass movements (Daly et al. 1994).

Hydrology and geomorphology studies produced new insights by linking upstream disturbance and vegetation effects to downstream responses. Changes in sediment yield (Grant and Wolff 1991) and peak streamflows (Jones and Grant in press) following timber harvest were highly contingent on the timing of harvest in relation to major storms, the effects of vegetation succession, and the influence of roads. Hydrologic studies, based on new statistical approaches, revealed surprisingly large increases in peak flows from both the effects of roads (which function as extensions of the stream network) and from effects of forest cutting on evaporation and snow accumulation and melt rate (Jones and Grant in press). Geomorphology studies revealed both the strong imprint of vegetation on stream morphology (Nakamura and Swanson 1993, 1994) and of geomorphology on stream and riparian habitats and disturbance regimes (Grant et al. 1990, Grant and Swanson 1995). Coupling hydrology, geomorphology and ecological models to evaluate alternative management and climate scenarios (Duan et al. 1995) has advanced our understanding of streamflow generation mechanisms and highlighted the range of trajectories that watersheds can follow in response to disturbances. The varying trajectories observed in long-term measurements of small basins suggest that hydrologic responses to land use treatments interact significantly with fluctuations in climate, successional trends in vegetation, and the spatial arrangement of vegetation (hillslopes vs. riparian zones).

Highly contrasting **disturbance regimes** of natural and human origins affect the Andrews and surrounding landscapes. We have examined disturbances, including wildfire (Morrison and Swanson 1990), valley floor geomorphic processes (Grant and Swanson 1995), land use (Li et al. 1993, Spies et al. 1994, Wallin et al. 1994, in press a, b), and insect outbreaks (Powers 1995), as well as their effects on landscape patterns. These studies revealed major differences in the frequency, severity, size distribution, and spatial pattern between wildfire and forest cutting on public and private lands. Results of these LTER3 studies have been instrumental in shifting public land management from a simple dispersed clear-cut patch system to one more closely reflecting landscape dynamics driven by wildfire, geomorphic, and other natural disturbances (Swanson et al. 1993, Cissel et al. 1994). Our work also indicates that interactions among disturbance processes and past patterns strongly influence the character of landscapes. Examples include the linkage of geomorphic processes on hillslopes to channels (Swanson et al. 1992a, b), the temporal interaction of windthrow and drought in controlling bark beetle outbreaks (Powers 1995), and the constraints of past landscape fragmentation on future landscape patterns, using forest cutting as an example (Wallin et al. 1994). This interactive nature of disturbances lead us to ask if certain combinations of disturbances tend to result in rapid, unpredictable changes in landscape patterns--a question relevant to both science and management of ecosystems.

Studies of **vegetation succession** have concerned resistance and resilience of communities to disturbance, temporal patterns of biodiversity, the role of gap-phase dynamics in our tall-stature stands, mortality rates of tree species in different climatic settings, and coarse debris dynamics (e.g., Halpern and Franklin 1990, Spies et al. 1990, Harmon and Chen 1991, Garman et al. 1992, Greene et al. 1992, Halpern and Spies 1995). A review of Andrews field studies by Halpern and

Spies (1995) revealed that the biological legacies of surviving plants play a prominent role in early successional response to even quite severe mechanical and burning disturbance. Results of succession studies support other topics as diverse as carbon budgets (Krankina and Harmon 1994), biogeochemistry (Binkley and Sollins 1990, Binkley et al. 1992), coarse debris loading in streams (Van Sickle and Gregory 1990, McDade et al. 1990, Gregory and Ashkenas 1990, McKee et al. in press), and canopy arthropod communities (Schowalter 1995). Further work is needed to understand causes and consequences of alternative successional pathways, especially where conifer establishment is protracted.

Studies of **biodiversity** on Andrews Forest have revealed a large variation in species richness among taxa, documented in part in species lists for over a dozen taxa (on line: <http://www.fsl.orst.edu/Lterhome.html>). Although a few tree species dominate biomass, there are about 500 vascular plant species occurring on the Andrews. Chronosequence studies in natural forests indicate increased diversity of vascular plant species and soil arthropods through succession to old growth, but most species are not restricted to particular stages of stand development (Richardson 1995, Torgerson et al. 1995, Schoonmaker and McKee 1988). Much of the biodiversity effort has focused on the strikingly rich arthropod fauna which represent over 86% of the species on the Andrews (Asquith et al. 1990, Lattin 1993). During LTER3 we compiled and published taxonomic, biological, and ecological information on over 3,400 species of arthropods (Parsons et al. 1991), with over 300 species added since this publication. Canopy arthropod community structure examined over a successional chronosequence revealed old-growth to have greatest arthropod biodiversity in these forests, although arthropod communities in Douglas-fir canopies had largely recovered by 150 years (Schowalter 1995). Species diversity and abundance of several taxa, especially predators and detritivores, were significantly lower in young plantations than in older forests, which may partially explain why defoliation was higher in younger stands. As a prelude to landscape analysis of arthropod distributions, we are currently examining potential controlling factors such as host plant specificity for a variety of arthropod taxa, such as Lepidoptera and Hemiptera.

Controls on **decomposition, soils, and nutrient cycling** have been investigated at several levels of spatial and temporal resolution during LTER3. Examination of long-term decomposition dynamics of woody detritus (Harmon 1991) has yielded significant new findings concerning its role in hydrologic and nutrient cycles. Changes in water balance indicate that 2-6% of canopy throughfall is absorbed and then evaporated from logs (Harmon and Sexton 1995). Over the first decade, decomposing logs lost more nutrients via leaching and fungal sporocarp formation than they absorbed from throughfall (Harmon et al. 1994, Harmon and Sexton 1995). The amount of nutrients exported is small, but the fact exports occur at all raises serious questions about past conceptual models of the nutrient dynamics of woody detritus which have predicted that logs would initially immobilize nutrients. Soil studies have provided conceptual and empirical bases for extrapolating the results of process studies to landscape and regional scales. Sollins et al. (in press) defined a conceptual model of mechanisms and controls on stability of soil organic matter. In a compilation of regional soil data, the soil C pool was positively correlated with temperature, in contrast with the general pattern found in the Great Plains grasslands (Homann et al. 1995). Our proposed work in LTER4 will be aided greatly by a spatial data base of all soil pit descriptions and associated chemical analyses recently compiled for Andrews Forest. Nutrient cycling studies have focused on effects of thinning, fertilization, and pruning on above ground

biomass increment, growth efficiency, and foliar nutrients (Velazquez-Martinez et al. 1992). Ectomycorrhizal mats appear to be a critical link between the dominant vascular plants and soil by influencing forest soil biodiversity (Cromack et al., 1988), increasing respiration and enzyme activities, acidity, and ionic content of pore water while decreasing denitrification rates and mineralizable nitrogen concentrations in soils (Griffiths et al. 1990, 1991). Organic acids produced by mats also weather mineral soils, thereby releasing plant nutrients (Griffiths and Caldwell 1992, Griffiths et al. 1994). Mat distribution varies with stand age, position relative to major overstory trees, the presence of understory trees, and stand successional stage (Griffiths et al. 1995, in press). Comparative studies of soil properties, including mats, in old and young forests and in sites where conifers have failed to regenerate for decades after clearcutting indicate that many soil properties change when conifer establishment is slow.

A major effort during LTER3 has been to examine the **carbon dynamics** of Pacific Northwest forests by integrating data on forest production, decomposition, and condition (i.e., functional groups, age). As a consequence of this effort, we have created important tools for analyzing carbon flux including models to predict the woody residue produced by timber harvest (Harmon et al. in press a), the carbon stored in forest products (Harmon et al. in press b), and ecosystem carbon dynamics at the landscape (Wallin et al. in press a) and stand level (Harmon et al. 1995a). Preliminary analysis indicated a substantial quantity of carbon was released by past timber harvest in the region (Harmon et al. 1990). A subsequent analysis, which coupled an ecosystem carbon model to remotely sensed data on forest age and disturbance history, confirmed the earlier finding and indicated that carbon flux varied greatly with location, wood use standards at the time of harvest, and stage of succession after harvest (Cohen et al. in press, Wallin et al. in press a). Location is important to carbon flux since production and decomposition rates are both highly dependent on location in our mountainous landscape. A major uncertainty uncovered by this work is the wide variation in successional trajectories following clear-cut harvest, indicating that our earlier simplifying assumption of uniform succession rates may have underestimated regional carbon fluxes.

Through LTER, we have developed a conceptual model of **forest-stream interactions** (Gregory et al. 1991) and experimentally examined mechanisms of aquatic response to natural disturbances and land use (Lamberti et al. 1991). Studies of wood dynamics (Harmon et al. 1986, Van Sickle and Gregory 1990) have contributed to basic ecosystem science and management of millions of acres of public forests (Gregory and Ashkenas 1990, FEMAT 1993, Gregory in press). Population studies of trout and salamanders have revealed long-term patterns of interannual variation that provide a quantitative foundation for interpreting regional declines in salmonids and amphibians (Bisson et al. 1992, Hawkins et al. 1993, Bisson et al. in press, Gregory et al. in press). Our long-term studies have created opportunity for measuring responses to episodic disturbances, such as the occasions when landslides and debris flows have occurred in study sites (Lamberti et al. 1991). Cooperative studies with land management agencies are testing basic ecological concepts in the context of ecosystem restoration (Sedell et al. 1991, Gregory and Wildman 1994). These studies include replicated manipulations of stream habitat where subsequent shifts in habitat structure, fish populations, and ecological processes are observed. Recent efforts coupling remote sensing interpretation of riparian landscape patterns, policy-related analyses (FEMAT 1993), and modeling to examine large basin response to land-use change (D'Angelo et al. 1995) have led us to consider the network properties of these

systems to complement past emphasis on longitudinal gradients (Vannote et al. 1980, Gregory et al. 1991).

Communication of findings from Andrews LTER takes many forms--as science articles from research Components described above, as input to land managers and policy makers concerning watershed and ecosystem management, and in communications with the public. Numerous publications, including book-level syntheses (e.g., Perry 1994), have been prepared for these varied audiences (Section 1.2). In addition to standard scientific publications, we have worked closely with journalists of the print and video media to get information to the public locally and at-large ([Table 6.1](#)). Five New York Times articles since 1989, for example, have been based substantially on Andrews Forest work and helped the public understand the science behind the changes in ecosystem management of forested landscapes. The 50+ field tours we conduct annually for science, public, land manager, media, and policy maker audiences provide good opportunity for dialogue with critical users of research results.

Our work has taken place in the midst of great turmoil and rapid change in land management and policy in the Pacific Northwest. Because of the 25-yr history of Andrews-based science on issues now on the political forefront (e.g., old growth, northern spotted owl, watershed effects of forestry), academic and federal scientists have provided crucial input to policy makers ([Table 6.1](#)). Credible, NSF-sponsored, peer-reviewed science has been the cornerstone of the resulting changes in forest and watershed management. For example, our landscape studies (Wallin et al. 1994, in press a) led to the development of a landscape management plan for a 7000-ha area designed to follow past disturbance regimes of wildfire and geomorphic processes (Cissel et al. 1994).

In summary, the Andrews LTER program has been productive scientifically and in service to society. We have made significant progress during LTER3 by developing and maintaining long-term experiments and measurement programs, information management systems, field facilities (including 19,000 sq. ft. of new buildings), and analysis tools required to examine how natural disturbance, land-use change, and climate change affect key ecosystem functions. Moreover, we are successfully integrating a wide range of processes and scales of spatial and temporal resolution to answer these questions. We believe strongly that LTER is more than site-based science. Accordingly, we encourage Andrews scientists to lead major inter-LTER and International LTER projects ([Table 1.5](#)). Andrews LTER has also been instrumental in the development of Memoranda of Understanding between USGS-USFS and USFS-NSF, furthering interagency involvement in LTER. Our high level of progress has been possible only by coupling LTER funding with other sources, such as USDA Forest Service, USDA-CSRS, NASA, BLM/NBS, EPA, and various NSF programs ([Fig. 1.2](#)). While the LTER program funds only a quarter of the overall Andrews-based science program, **LTER is the critical meeting ground for coordination of science, management of infrastructure, and application of results to management of ecosystems.** We seek to maintain this balance during LTER4, but this will be challenging, given the anticipated reduction of funding within and outside the LTER program.

The key findings from LTER3 have set the stage for LTER4 ([Fig. 1.1](#)) and helped guide our selection of new research areas. First, we know fire disturbance, climate, and land-use systems have co-varied over the recent 500-year history of the Andrews, producing vegetation patches of

various size distributions and juxtaposition. Second, rates of conifer canopy closure following forest harvest disturbance vary markedly from place to place within the Andrews. Third, key ecosystem properties respond dramatically to various scales of disturbance in ways that are not entirely predictable. For example, there have been large, persistent responses of streamflow, wood debris, and sediment in streams after forest harvest. The conceptual models we relied upon in LTER3 require further development to adequately explain these interactions, particularly for ecosystem processes in stream/riparian networks. We will continue the important areas of prior research as Components in LTER4 and have selected four Synthesis Areas, capitalizing on the 40+ years of long-term studies to develop new approaches to better understand the structure and function of the Andrews landscape ([Fig. 2.1](#)).

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Section 1.3. List of on-line data and metadata for Andrews Forest study data, spatial data (noted by study code 'GIS'), models, and software accessible on the World Wide Web

1. Climate

Study Code: MS01
Study Title: HJ Andrews benchmark meteorological station network
Lead PI: McKee
Core Areas: 1-5
Study dates: 1972-present
Status: All metadata and some or all data on-line

Study Code: MS01
Study Title: HJ Andrews secondary meteorological station network
Lead PI: McKee
Core Areas: 1-5
Study dates: 1951-present
Status: All metadata and some or all data on-line

Study Code: MS01
Study Title: HJ Andrews raingage network
Lead PI: McKee
Core Areas: 1-5
Study dates: 1963-present
Status: Metadata only on-line

Study Code: MS01
Study Title: HJ Andrews air, soil, and stream thermograph network
Lead PI: McKee
Core Areas: 1-5
Study dates: 1971-present
Status: All metadata and some or all data on-line

Study Code: MS01
Study Title: HJ Andrews snow course survey
Lead PI: McKee
Core Areas: 1-5
Study dates: 1978-present
Status: Metadata only on-line

Study Code: GIS
Study Title: Raingage network site locations
Lead PI: McKee
Core Areas: 1-5
Study dates: 1990
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: Thermograph network site locations
Lead PI: McKee

Core Areas: 1-5
Study dates: 1990
Status: Metadata only on-line with graphical displays of Arc/Info coverages

2. Hydrology/Watershed

Study Code: CF01
Study Title: HJ Andrews watershed grab samples: Long term stream chemistry patterns

Lead PI: McKee
Core Areas: 4
Study dates: 1973-1981
Status: Metadata only on-line

Study Code: CF02
Study Title: HJ Andrews proportional streamflow samples: Long-term stream chemistry patterns

Lead PI: McKee
Core Areas: 4
Study dates: 1968-present
Status: Metadata only on-line

Study Code: CP01
Study Title: HJ Andrews precipitation chemistry for NADP acid rain monitoring

Lead PI: McKee
Core Areas: 4
Study dates: 1980-present
Status: All metadata and some or all data on-line

Study Code: CP02
Study Title: HJ Andrews long-term precipitation chemistry patterns and dry deposition chemistry

Lead PI: McKee
Core Areas: 4
Study dates: 1968-present
Status: All metadata and some or all data on-line

Study Code: HF04
Study Title: HJ Andrews watershed streamflow summaries

Lead PI: Grant
Core Areas: 4,5
Study dates: 1953-present
Status: All metadata and some or all data on-line

Study Code: HF06
Study Title: HJ Andrews watershed storm histories with peak flows

Lead PI: Grant
Core Areas: 4,5
Study dates: 1955-1988
Status: Metadata only on-line

Study Code: HS03
Study Title: HJ Andrews suspended sediment grab samples

Lead PI: Grant
Core Areas: 4,5
Study dates: 1956-1988

Status: All metadata and some or all data on-line

Study Code: GIS
Study Title: HJ Andrews perennial streams
Lead PI: Grant
Core Areas: 4,5
Study dates: 1995
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: HJ Andrews gaging stations
Lead PI: Grant
Core Areas: 4
Study dates: 1990
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: HJ Andrews hydrologic response units
Lead PI: Grant
Core Areas: 4
Study dates: 1992
Status: Metadata only on-line with graphical displays of Arc/Info coverages

3. Vegetation

Study Code: TP41
Study Title: Post-logging community structure and biomass accumulation in HJ Andrews, Watershed 10
Lead PI: Halpern
Core Areas: 1,2,5
Study dates: 1973-present
Status: Metadata only on-line

Study Code: TP54
Study Title: HJ Andrews Forest management history
Lead PI: McKee
Core Areas: 1,5
Study dates: 1950-present
Status: In preparation; metadata and/or data will be coming on-line

Study Code: TP73
Study Title: Plant biomass dynamics following logging and burning in the HJ Andrews Watersheds 1 and 3
Lead PI: Halpern
Core Areas: 1,2,5
Study dates: 1962-present
Status: Metadata only on-line

Study Code: TP103
Study Title: Species interactions during succession
Lead PI: Halpern
Core Areas: 1,2
Study dates: 1990-1996
Status: Metadata only on-line

Study Code: TV009
Study Title: Dendrometer studies for stand volume and height
measurements
Lead PI: Harmon
Core Areas: 1,2,3
Study dates: 1978-present
Status: All metadata and some or all data on-line

Study Code: TV010
Study Title: LTER reference stand system
Lead PI: McKee
Core Areas: 1,2
Study dates: 1910-present
Status: Metadata only on-line

Study Code: GV09
Study Title: Riparian geomorphic surface - vegetation relationships in
the Blue Biver Basin
Lead PI: McKee
Core Areas: 2,4,5
Study dates: 1986-1986
Status: Metadata only on-line

Study Code: TP88
Study Title: Population dynamics of young forest stands as affected
by density and nutrient regime
Lead PI: Perry
Core Areas: 2
Study dates: 1981-present
Status: Metadata only on-line

Study Code: GIS
Study Title: HJ Andrews plant communities
Lead PI: McKee
Core Areas: 1,2
Study dates: 1990
Status: Metadata only on-line with graphical displays of Arc/Info
coverages

Study Code: GIS
Study Title: Willamette National Forest current vegetation
Example products: managed stands, size class, seral
stage, canopy layers & species, plant species
Lead PI: Lienkaemper
Core Areas: 1,2
Study dates: 1993
Status: Metadata only on-line with graphical displays of Arc/Info
coverages

Study Code: GIS
Study Title: HJ Andrews stand age image
Lead PI: Cohen
Core Areas: 2
Study dates: 1994
Status: Metadata only on-line with graphical displays of Arc/Info
coverages

Study Code: GIS
Study Title: HJ Andrews reference stand locations
Lead PI: McKee
Core Areas: 1,2
Study dates: 1991
Status: Metadata only on-line with graphical displays of Arc/Info coverages

4. Biodiversity/Species List

Study Code: SA001
Study Title: Invertebrates of the HJ Andrews Forest: An annotated list of insects and other arthropods
Lead PI: Lattin
Core Areas: 2
Study dates: 1971-1995
Status: All metadata and some or all data on-line

Study Code: SA002
Study Title: Vascular plants on the HJ Andrews Experimental Forest and nearby research natural areas
Lead PI: McKee
Core Areas: 2
Study dates: 1958-present
Status: All metadata and some or all data on-line

Study Code: SA003
Study Title: Bird species list for the HJ Andrews Experimental Forest and Upper McKenzie River Basin
Lead PI: McKee
Core Areas: 2
Study dates: 1975-present
Status: All metadata and some or all data on-line

Study Code: SA004
Study Title: Amphibians and reptiles of the HJ Andrews Experimental Forest
Lead PI: Beatty
Core Areas: 2
Study dates: 1975-1995
Status: All metadata and some or all data on-line

Study Code: SA005
Study Title: Mammals of the HJ Andrews Experimental Forest
Lead PI: Anthony
Core Areas: 2
Study dates: 1971-1995
Status: All metadata and some or all data on-line

Study Code: SA006
Study Title: Fish in the HJ Andrews Experimental Forest
Lead PI: Gregory
Core Areas: 2
Study dates: 1975-1995
Status: All metadata and some or all data on-line

Study Code: SA007
Study Title: Benthic algal species in the HJ Andrews Experimental

Forest

Lead PI: Gregory
Core Areas: 2
Study dates: 1991-1992
Status: All metadata and some or all data on-line

Study Code: SA008
Study Title: Mosses of the HJ Andrews Experimental Forest
Lead PI: Peck
Core Areas: 2
Study dates: 1991-1991
Status: All metadata and some or all data on-line

Study Code: SA009
Study Title: Riparian bryophyte list of the HJ Andrews Experimental Forest
Lead PI: Jonsson
Core Areas: 2
Study dates: 1994-1995
Status: All metadata and some or all data on-line

Study Code: SA010
Study Title: Epyphites of the HJ Andrews Experimental Forest, Watershed 10
Lead PI: Carroll
Core Areas: 2
Study dates: 1970-1972
Status: All metadata and some or all data on-line

Study Code: SA011
Study Title: Epiphitic macrolichens in and around the HJ Andrews Experimental Forest
Lead PI: Neitlich
Core Areas: 2
Study dates: 1993-1993
Status: All metadata and some or all data on-line

Study Code: SA012
Study Title: Aquatic macroinvertebrates of the HJ Andrews Forest
Lead PI: Gregory
Core Areas: 2
Study dates: 1992-1993
Status: All metadata and some or all data on-line

Study Code: SA013
Study Title: Aquatic invertebrates of Lookout Creek in the HJ Andrews Experimental Forest
Lead PI: Gregory
Core Areas: 2
Study dates: 1988-present
Status: All metadata and some or all data on-line

Study Code: GIS
Study Title: Bryophyte study sites
Lead PI: McKee
Core Areas: 2
Study dates: 1995

Status: Metadata only on-line with graphical displays of Arc/Info coverages

5. C-N/Soils/Decomposition

Study Code: TD12
Study Title: Log and snag dimensions
Lead PI: Harmon
Core Areas: 3
Study dates: 1984-present
Status: All metadata and some or all data on-line

Study Code: TD14
Study Title: Long-term log decay experiments at the HJ Andrews Experimental Forest
Lead PI: Harmon
Core Areas: 3
Study dates: 1985-2185
Status: Metadata only on-line

Study Code: TD17
Study Title: Stream - upland wood decay experiment
Lead PI: Harmon
Core Areas: 3
Study dates: 1985-present
Status: All metadata and some or all data on-line

Study Code: TD18
Study Title: Nitrogen fixation and respiration potential of conifer logs
Lead PI: Harmon
Core Areas: 3,4
Study dates: 1987-present
Status: Metadata only on-line

Study Code: TD20
Study Title: Respiration patterns of logs in the Pacific Northwest
Lead PI: Harmon
Core Areas: 3
Study dates: 1986-present
Status: Metadata only on-line

Study Code: TD21
Study Title: Fine wood decay studies
Lead PI: Harmon
Core Areas: 3
Study dates: 1989-1994
Status: Metadata only on-line

Study Code: TD22
Study Title: Coarse woody debris density and nutrient data
Lead PI: Harmon
Core Areas: 3
Study dates: 1982-present
Status: All metadata and some or all data on-line

Study Code: TD23
Study Title: Fine Litter Decomposition Experiment (LIDET)
Lead PI: Harmon

Core Areas: 3
Study dates: 1990-2002
Status: Metadata only on-line

Study Code: TD25
Study Title: Log leachates from the HJ Andrews Experimental Forest
Lead PI: Harmon
Core Areas: 3,4
Study dates: 1986-present
Status: Metadata only on-line

Study Code: TL01
Study Title: HJ Andrews reference stand component litterfall study
Lead PI: McKee
Core Areas: 1,3
Study dates: 1976-present
Status: Metadata only on-line

Study Code: MS08
Study Title: HJ Andrews log decomposition thermograph data
Lead PI: Harmon
Core Areas: 3
Study dates: 1985-1989
Status: Metadata only on-line

Study Code: SP01
Study Title: Soil descriptions and data for profiles in the HJ Andrews
and selected reference stands
Lead PI: Dyrness
Core Areas: 1,3,4
Study dates: 1962-1996
Status: Metadata only on-line

Study Code: SP02
Study Title: Comparison of vegetation cover and soil moisture
relationships for different harvest treatments
Lead PI: Levno
Core Areas: 2,4,5
Study dates: 1960-1983
Status: Metadata only on-line

Study Code: SP04
Study Title: Trace gas emissions from forest soils of the HJ Andrews
Experimental Forest
Lead PI: Griffiths
Core Areas: 4
Study dates: 1992-present
Status: Metadata only on-line

Study Code: SP05
Study Title: HJ Andrews 1993 REU synoptic soil respiration of
permanent forest sites
Lead PI: Griffiths
Core Areas: 4
Study dates: 1993-1994
Status: Metadata only on-line

Study Code: SP06
Study Title: HJ Andrews 1994 REU study of soil chemical and
microbiological properties
Lead PI: Griffiths
Core Areas: 4
Study dates: 1994-1994
Status: Metadata only on-line

Study Code: SP07
Study Title: Disturbance effects on soil processes
Lead PI: Griffiths
Core Areas: 4
Study dates: 1995-present
Status: In preparation; metadata and/or data will be coming on-line

Study Code: SP08
Study Title: Effect of thinning pole stands on soil processes
Lead PI: Griffiths
Core Areas: 4,5
Study dates: 1994-1996
Status: In preparation; metadata and/or data will be coming on-line

Study Code: SP09
Study Title: High resolution plot study of correlations between forest
floor attributes and soil processes
Lead PI: Griffiths
Core Areas: 3,4
Study dates: 1994-1996
Status: In preparation; metadata and/or data will be coming on-line

Study Code: SP10
Study Title: Factors influencing forest floor respiration at different
temporal and spatial scales
Lead PI: Griffiths
Core Areas: 1,4
Study dates: 1992-present
Status: In preparation; metadata and/or data will be coming on-line

Study Code: GIS
Study Title: HJ Andrews 1964 soil survey
Lead PI: Sollins
Core Areas: 1,3,4
Study dates: 1990
Status: Metadata only on-line with graphical displays of Arc/Info
coverages

Study Code: GIS
Study Title: HJ Andrews soil resource inventory
Lead PI: Lienkaemper
Core Areas: 1,3,4
Study dates: 1995
Status: Metadata only on-line with graphical displays of Arc/Info
coverages

Study Code: GIS
Study Title: HJ Andrews log decomposition sites/locations
Lead PI: Harmon

Core Areas: 3
Study dates: 1993
Status: Metadata only on-line with graphical displays of Arc/Info coverages

6. Geomorphic/Stream

Study Code: GS02
Study Title: Stream cross-section profiles: HJ Andrews & Hagen
Block RNA

Lead PI: Grant
Core Areas: 4
Study dates: 1978-present
Status: All metadata and some or all data on-line

Study Code: GS06
Study Title: HJ Andrews tagged log inventory (log debris)
Lead PI: Gregory
Core Areas: 3
Study dates: 1982-present
Status: Metadata only on-line

Study Code: AS06
Study Title: Population studies of rainbow and cutthroat trout in the
HJ Andrews Forest

Lead PI: Gregory
Core Areas: 2
Study dates: 1975-present
Status: Metadata only on-line

Study Code: GIS
Study Title: Geology of the HJ Andrews
Lead PI: Swanson
Core Areas: 3,4,5
Study dates: 1991
Status: Metadata only on-line with graphical displays of Arc/Info coverages

7. Landscape/Dynamics/Disturbance

Study Code: DF05
Study Title: Fire history database of the western United States
Lead PI: Swanson
Core Areas: 5
Study dates: 1993-1994
Status: All metadata and some or all data on-line

Study Code: GE07
Study Title: Upper Blue River landslide hazard evaluation
Lead PI: Swanson
Core Areas: 5
Study dates: 1992-1994
Status: Metadata only on-line

Study Code: GIS
Study Title: Digital Elevation Model:
Example products: slope, aspect, contours,
spot elevations
Lead PI: Lienkaemper
Core Areas: 1-5

Study dates: 1994
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: HJ Andrews debris flow tracks
Lead PI: Swanson
Core Areas: 3,5
Study dates: 1992
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: HJ Andrews landslide locations
Lead PI: Swanson
Core Areas: 5
Study dates: 1992
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: HJ Andrews 1991 fire locations
Lead PI: Swanson
Core Areas: 5
Study dates: 1992
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: Salvage sales in the HJ Andrews 1954-1974
Lead PI: McKee
Core Areas: 5
Study dates: 1994
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: Road construction history of the HJ Andrews
Lead PI: McKee
Core Areas: 5
Study dates: 1991
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: HJ Andrews coarse woody debris flood hazard
Lead PI: Swanson
Core Areas: 3,5
Study dates: 1992
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: Debris flow hazard in the HJ Andrews
Lead PI: Swanson
Core Areas: 5
Study dates: 1992

Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: Earthflow susceptibility in the HJ Andrews
Lead PI: Swanson
Core Areas: 5
Study dates: 1992
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: Streamside slide hazard in the HJ Andrews
Lead PI: Swanson
Core Areas: 5
Study dates: 1992
Status: Metadata only on-line with graphical displays of Arc/Info coverages

Study Code: GIS
Study Title: GPS permanent monuments
Lead PI: McKee
Core Areas: 1-5
Study dates: 1993
Status: Metadata only on-line with graphical displays of Arc/Info coverages

8. On-line Model Information and Software Packages

ANRAD: Estimates potential direct and diffuse radiation at 120 m resolution grid for target days of interest (Greenland 1995)

Lead PI: Greenland
Core Area:1
Date: 1996
Status: Software package available on-line

BIOPAK: Calculates the biomass, area, height, length, or volume of plant components (leaves, branches, stem, crown, and roots) using existing prediction equations. (Means et al. 1994)

Lead PI: Means
Core Area:1
Date: 1994
Status: Software package available on-line

CLAWS: Simulates hydrologic and geomorphic responses of watersheds based on landscape scenarios.

Lead PI: Duan, Grant
Core Area:4
Date: 1995
Status: Model information available on-line

FRAGSTATS: Offers a comprehensive choice of landscape metrics to quantify landscape structure. Separate versions exist for vector and raster images. (McGarigal & Marks 1995)

Lead PI: Marks
Core Area:5
Date: 1995
Status: Software package available on-line

HARVEST: Estimates amount of woody slash remaining after timber harvest (Harmon et al. In press a)

Lead PI: Garman
Core Area:3
Date: 1996
Status: Model information available on-line

PRISM: Spatially interpolates precipitation based on topography and observed precipitation. (Daly et al. 1994)

Lead PI: Daly
Core Area:1-5
Date: 1994
Status: Model information available on-line

SOLARRAD: Estimates the solar radiation input to a site based on its latitude, elevation, aspect, slope, and cloud cover

Lead PI: Harmon
Core Area:1
Date: 1995
Status: Model information available on-line

STREAM ECOSYSTEM MODEL: Simulates temporal trajectories of ecological processes in stream ecosystems. (McIntire & Colby 1978)

Lead PI: McIntire/Gregory
Core Area:2
Date: 1995
Status: Model information available on-line

XSPRO: Analyzes stream channel cross-section data including stage-to-discharge relationships and changes in channel cross-sectional area. (Grant et al. 1992)

Lead PI: Grant
Core Area:4
Date: 1996
Status: Model information available on-line

Core Area Definitions

LTER Core Area

1. Pattern and Control of Primary Production
2. Spatial and temporal distribution of populations selected to represent trophic structure
3. Pattern and control of organic accumulation in surface layers and sediments
4. Patterns of inorganic inputs and movements of nutrients through soil, groundwater, and surface waters
5. Pattern and frequency of disturbance to the research site

Section 2. Research Plan.

By their very nature LTER programs are complex, multidisciplinary efforts which incorporate long-term measurements, field experiments, and synthesis. Given the length constraints on text for this proposal it is not possible to provide detailed methods and links among the many study elements of the Andrews LTER program. What we present in this LTER4 (1996-2002) proposal is best described as a strategic plan for the next six years. This will contrast with the more tactical approach of typical NSF proposals, where specific methodological details form the bulk of the text. Since many of the methodological details in our proposed work can be found in publications, past LTER proposals, and LTER Site Reviews (where their scientific credibility has been subjected to rigorous peer review) we have focused on the broader issues and programmatic vision.

Our proposed work is guided by a **Central Question** which links three key drivers of landscape change to three key ecosystem properties ([Fig. 1.1](#)), ([Fig. 2.1](#)). We describe the research needed to answer this central question in two parts: **Components** and **Synthesis Areas**. The seven Components are discipline-focused research that address the LTER core areas by means of long-term measurements and experiments. These studies all had their origin in LTER's 1 to 3, and therefore serve as our link to the past. Our plan is to carry this long-term research forward in LTER4 (1996-2002). In addition, the four proposed Synthesis Areas represent new, cross-disciplinary, synthetic research projects that address specific questions required to help answer our central question. Synthesis Areas therefore serve as our path to future understanding of how the dynamic and important Pacific Northwest ecosystems will respond to three drivers of change.

2.1. Central Question and Conceptual Framework.

The Andrews LTER program seeks to understand the long-term dynamics of forest and river ecosystems of the Pacific Northwest. The Andrews LTER is typical of this region, where the steep, rugged topography, massive forests, and seasonally wet/dry climate create strong interactions between biotic and abiotic systems and between forests and streams ([Fig. 2.2](#)). These systems are dynamic, driven by the interaction of succession, climate, and disturbances. Wildfire, wind, landslides, floods, and other natural disturbances have created the template on which succession plays out over seres spanning up to many centuries. This region of extensive public lands has experienced profound changes in management policy over the last two centuries that have repeatedly shifted the balance between succession and disturbance. On these public lands the pre-settlement wildfire period (pre-1850) in which the interplay of natural disturbance and succession dominated the landscape, gave way to the pre-exploitation period (1900-1950) when fire suppression and limited logging created a landscape dominated by reduced disturbance and relatively uninterrupted succession. This was followed by a period of dispersed-patch clearcutting (1950-1990) in which wildfire was suppressed, small disturbance patches were regularly spaced across the landscape, and succession was truncated. Since 1990, an ecosystem management perspective has replaced the dispersed clearcutting system, with greater attention on landscape level planning and mimicking natural disturbance regimes. LTER science at Andrews has played important roles in these evolving new policies, which hinge on sustaining biodiversity and watershed properties (Sections 1.1, 6).

Set in this biophysical and social context, the Central Question of Andrews LTER4 proposal is: **How do land use, natural disturbances, and climate change affect three key ecosystem properties: carbon dynamics, biodiversity, and hydrology?** We selected these three ecosystem properties because they are scientifically and socially important, tractable, and their responses are posited to represent different classes of ecosystem behavior at the landscape scale (Turner 1989). We selected climate, land use and natural disturbances as the major drivers of change because they are dominant factors in forests of the Pacific Northwest region. These three drivers of change also may interact, potentially reinforcing rather than offsetting important changes in landscape conditions. For example, clear cutting may increase windthrow incidence in uncut areas, leading to a greater than anticipated reduction of mature forests.

The conceptual framework of Andrews LTER consists of four elements. First, **the structure and function of Pacific Northwest forested landscapes is largely controlled by the interaction of natural disturbance, land use, and succession.** As stated in the preceding paragraphs, changes in the balance of these three factors have historically altered how forests in this region look and function. Second, **understanding how ecosystem properties respond to change requires that we consider the system at several scales of time and space.** Although analysis at the landscape level is our ultimate goal, we arrive there by examining how species, patches, and small watersheds interact to influence ecosystem properties at the landscape scale. Third, **we view landscapes as comprised of a basic environmental template (i.e., climate, topography, soils) and two landscape elements: patchworks and networks (Fig. 2.3).** While patchworks have received much attention by ecologists (Urban et al. 1987, Turner and Gardner 1991, O'Neill et al. 1992, Baker 1994, Spies et al. 1994, Baskent and Jordan 1995), the properties of networks have largely been studied in geomorphic and hydrologic sciences (Beven and Kirkby 1993). In the Pacific Northwest, the time is right to include both landscape elements in our conceptual framework so that stream/riparian networks can be linked with the surrounding upland patchworks. Fourth, **the response of ecosystem properties to drivers of change depends on the sensitivity of these properties to patterning at the landscape scale (Turner 1989).** We posit three classes of landscape behavior: 1) properties that can be estimated in a simple additive manner without consideration of spatial arrangement of landscape units, such as vegetation patches (e.g., carbon stores); 2) biotic properties that react to spatial and temporal arrangements of landscape patches (e.g., habitat selection by organisms); and 3) flows of material and energy that interact with landscape structure (e.g., streamflow, disturbance propagation). Combined, these elements of our framework provide guidance on how to address the central question posed above.

To address our **Central Question**, the Andrews LTER will focus on a broad range of time-space scales. The principal spatial scale of LTER studies is the Andrews Forest and adjacent upper Blue River watershed (total area: 16,000 ha) (Fig. 2.2). This work will be tightly coordinated with larger scale studies funded from other sources aimed at regional questions. Within the 1,200,000-ha central Cascades area and throughout the Pacific Northwest region, studies are underway, for example, on remote sensing of forest structure, age, and succession; carbon sequestration in forests; hydrology; biodiversity; and wildfire history (Fig. 2.4). As part of intersite research within LTER and the international community, our research extends beyond the Pacific Northwest to the continental and global scales. The principal temporal scale of LTER studies spans the dendrochronologically-accessible past (500 yrs) and up to several centuries

projected into the future. At a broader temporal scale Andrews LTER coordinates closely with studies of Holocene vegetation and fire history in western Oregon (Sea and Whitlock 1995).

2.2. Component studies.

The seven Components described below are discipline-focused studies that address the LTER core areas by means of long-term measurements and experiments. Although each Component has its origins in past LTER's, their continuation is a major feature of our proposed research in LTER4. Continued Component research is crucial as it provides data and tests concepts to be used in the Synthesis Areas. Additionally, within each Component we are developing models that summarize the observed system behavior, so that novel conditions over space and time may be projected in larger scale analyses.

2.2.1. Climate.

[Greenland]

The principal objectives of climate studies at Andrews are: 1) identify, document, and interpret climate variability at the site, 2) characterize the climate field (temperature, precipitation, solar radiation) of Andrews and vicinity to support ecological studies, and 3) place Andrews in its regional climate context. Climate and its past, current, and future variability are crucial to understand because climate is a key driver of change outlined in our central question. Climate variability, including cycles, episodes and events (Greenland and Swift 1991), imprints on many aspects of ecosystem behavior of interest in Andrews LTER. For example, Greenland (1994a, b) showed variability of annual temperatures and precipitation values in climate episodes at Andrews on 3-7-yr (El Nino) and 20-yr time scales. Understanding climate variability at scales over which we have solid data on both climate and ecological response is also critical to projecting responses to longer-term, global climate change.

Many other Component studies are supported by our system of long-term observations of climate at stations distributed over Andrews and neighboring areas ([Table 1.2](#)). This recently reorganized system is now hierarchically based: four main stations are supplemented with three classes of more numerous stations where fewer variables are observed. In LTER4 we will draw on this long-term database to model and map precipitation, solar radiation, and temperature values over the Andrews landscape at monthly and annual time steps. Models such as PRISM (Daly et al. 1994) and MT-CLIM (Running et al. 1987), when coupled with our long-term databases, allow us to simulate values for other climate variables and time resolutions as required by other Andrews LTER studies. In addition, radiation modeling studies will be extended to include values of reflectivity (albedo) of solar radiation to estimate the effect of forest cutting and growth on the surface heat energy budget of the Andrews. Clearcuts, young, and mature stands differ substantially in albedo, and the proportions of area covered by these age classes has changed over the last 100 years. This new work is timely because some have suggested modifications of land cover may have as large an effect on temperature as the increase in atmospheric carbon dioxide concentrations. The proposed model will therefore simulate values of these heat fluxes for patches and landscape patterns that result from different land use and natural disturbance regimes.

In LTER4, we will also continue to place the Andrews in a temporal and spatial context linking this key control to processes operating at the regional and larger scales. New short-term studies will include analysis of the synthetic record of monthly and annual temperature and precipitation (1914-present) for climate variation as cycles or step functions, such as the one of 1975-1976 (Ebbesmeyer et al. 1991). Both the synthetic and real (1952-present) Andrews precipitation records will be examined to identify drought length and severity in terms relevant to ecosystem function. We will also use regional records to evaluate the histories and geography of storms and droughts (c.f. Hayden 1989), which strongly affect terrestrial and aquatic systems.

Supplementing these studies will be a retrospective analysis of the largest storms on record for the region from meteorological and ecological perspectives (c.f. Greenland 1995). The Andrews Forest will be placed in its regional climate context to develop a rigorous basis for extrapolating Andrews-based results. Statistical analyses will be used to compare climate variables among the major physiographic provinces of the region, with Climate Divisional data serving to characterize each province.

2.2.2. Hydrology.

[Grant, Jones]

The general objective of the hydrology component is to clarify the patterns of and controls on streamflow generation in small and large watersheds, particularly with respect to the influences of climate, vegetation, and geomorphology. Our streamflow records include 100-year floods and extreme droughts, and span up to 30 years of vegetation succession at various elevations and aspects ([Table 1.3](#)). In LTER4, we will examine hydrographs to improve our understanding of these three controls on streamflow at a range of temporal scales ([Fig. 2.5](#)). We will also continue to build process-based models of streamflow generation such as the Modular Modeling System (Leavesley et al. 1983) to explore the sensitivity of streamflow to vegetation succession and climatic variation. Development of such process-level understanding is an essential step in scaling up to examine hydrologic response to regional or global climate change (Neilson 1995) which we pursue through coordination with R. Neilson (USFS) and D. Marks (USGS) who are modeling climate change effects at GCM-grid and larger scales.

In LTER 4 we plan to continue measuring climate and streamflow in eleven watersheds ([Table 1.3](#), [Fig. 2.2](#)), including the small watershed experiments examined in our Synthesis Areas. The Andrews' strongly seasonal climate interacts with topography (aspect and elevation) such that different portions of Andrews receive different types and amounts of precipitation and have different capacities to store moisture in soil and snow. We will concentrate on relating streamflow to climate variation at three temporal scales ([Fig. 2.5](#)): 1) interannual cycles of drought and wet years identified in the climate component, 2) variation among seasons, and 3) variation among storm events, particularly in precipitation type (rain, snow, or rain-on-snow), an important control on peak streamflows in the Andrews (Harr and McCorison 1979, Harr 1986). We will attempt to relate summer minimum streamflows, which are critical for aquatic organisms, to solar radiation loading, ambient humidity, and air temperatures. Understanding the strength of these climate controls on streamflow will put us in a good position to predict the influence of future climate variation on streamflow in the Andrews. Streamflow variation that cannot be explained by variation in climate at any temporal or spatial scale may be attributable to

the hydrologic behavior of different vegetation types; these relationships will be explored in the proposed Synthesis Areas.

The second major area of focus for the hydrology component in LTER4 is modeling the relationship among climate variation, topography, precipitation type (rain, snow, rain-on-snow) and streamflow. Major floods in the Andrews are attributable to rain-on-snow events (Harr 1986) and openings created by forest harvest are believed to modify snow accumulation and melt rates, thereby increasing the magnitude of large floods (Connelly and Cundy 1992, Jones and Grant in press). However, snowpacks in the Pacific Northwest are variable (Phillips et al. 1992) so even small changes in air temperatures could alter the timing and locations of snow and thus affect streamflow (Swanson et al. 1992a). We will continue to develop topographically explicit models to predict snow accumulation and melt rates, validate them with continued monitoring of snowpacks, and use them to test the sensitivity of current streamflow patterns to climate warming.

The third major area of focus for hydrology in LTER4 is improved understanding of the relationships among channel form, flood generation processes, and dynamics of coarse woody debris, following work in LTER3 (Nakamura and Swanson 1994, Grant and Swanson 1995). We will continue monitoring channel cross-sections and grain size distributions in first- to fifth-order streams to estimate the hydraulic properties of channel reaches where aquatic habitat is also being monitored. Because of our 20-year history of channel monitoring, we can describe the effects of frequent and rare flood events on channel morphology, including boulders and wood, and their role in structuring refugia and other forms of aquatic habitat.

2.2.3. Disturbance regimes/landscape dynamics.

[Garman, Swanson]

The objective of our landscape dynamics studies is to understand past and future disturbance regimes of Cascade Mountain landscapes, based on knowledge of interactions among disturbance processes, vegetation, and landforms. This component relates to a major element of our conceptual framework and is where the properties of two of the drivers of change are examined. Natural and anthropogenic disturbance regimes have profound effects on landscapes of the Pacific Northwest (Swanson et al. 1992b, Agee 1993). In the upland vegetation patchwork we have made good progress interpreting the history of disturbance by fire, cutting, landslides, roads, and windthrow. In the stream/riparian networks of the Andrews and neighboring landscapes, we have interpreted the history of various stream geomorphic processes. The next step is to understand the longer-term disturbance regimes (frequency, severity, location) of these processes, because we believe they constrain species distributions and other ecosystem properties, such as carbon stores and hydrologic output.

In LTER4, we will be continuing our long-term observations of various disturbance processes, such as landslides, changes of monumented channel cross sections, and forest cutting and regrowth as measured by remote sensing. These observations and measurements cover large watersheds with contrasting land use histories and disturbance susceptibility. This has resulted in several undesigned landscape experiments ([Fig. 2.6](#)). Timber cutting in the Andrews, for example, began in 1950 and largely ceased in 1970, while upper Blue River experienced cutting

mainly during 1960-1990. Therefore, the density of younger roads and clearcuts in upper Blue River is higher than in the Andrews, which we hypothesize makes upper Blue River more susceptible to landslides and increased peak flows than the Andrews. The Andrews, in essence, represents "ecosystem recovery" 25 yrs ahead of the millions of hectares of other partially logged, Pacific Northwest landscape that are just now starting on this "recovery" track under the new Northwest Forest Plan (FEMAT 1993). We will continue to observe natural disturbance, land use, and succession in the Andrews and Upper Blue River watersheds and study the consequences of these two different landscapes in terms of streamflow and other variables for which we have long-term data.

In LTER4, we will also use existing data, new analytical approaches, and models to characterize disturbance regimes of the Andrews landscape. Using existing dendrochronology data on fire history (Teensma 1987, Morrison and Swanson 1990), new field data for a large area to the north and west, and GIS not available to the earlier studies, we will reconstruct wildfire history and interpret the wildfire regime for Andrews and a much larger surrounding area. The larger study area is important because some topographic controls on the fire regime operate at scales greater than the Andrews. The product of this effort will be quantitative descriptions and maps of topographic and vegetation controls on fire frequency and severity that will be used in the Synthesis Areas. We will also examine interactions between land use and natural disturbances, in particular the extent and geographic pattern of windthrow associated with stand edges created by cutting and other disturbance processes. We will reconstruct windthrow history along stand edges using air photo interpretation, field observations, and written records (Gratkowski 1956). Results of these disturbance history studies will be used to develop and implement a landscape dynamics model capable of simulating wildfire, cutting, and windthrow disturbance patterns. We have recently completed a review of this type of model (Garman et al. in press) and will use this experience and that of others (e.g., Baker 1989) in the development of our proposed model.

2.2.4. Vegetation Succession.

[Acker, Franklin, Garman, Halpern, Harmon, McKee, Spies]

The overall objective of this component is to enhance understanding of the successional processes of Pacific Northwest forest ecosystems, and to predict dynamics of vegetation under different scenarios of natural disturbance, land use, and climate change. In the conceptual framework of LTER4, vegetation succession interacts with disturbances to determine stand- and landscape- level ecosystem patterns and dynamics, so succession is central to our overall efforts. We have used chronosequence studies to develop general conceptual models of natural succession involving both deterministic and stochastic processes (e.g. Franklin and Spies 1991; Halpern and Spies 1995). Our long-term experiments and observations, including chronosequence work with time-series data ([Table 1.4](#)), allow us both to document succession at the stand-level and address mechanistic hypotheses. We can: 1) empirically derive successional trends of several stand attributes such as biodiversity, primary productivity, biomass, and leaf area (e.g. Halpern and Spies 1995); and 2) develop and test hypotheses about patterns and mechanisms, such as changes in mortality rates with age or the role of the legacy of regenerating plant parts (seeds, sproutable rhizomes/roots) (e.g. Acker et al. in press a). Data and models developed here have and will continue to be used extensively in the Biological Diversity and Carbon and Nutrient Dynamics Components.

The approach for this Component consists of a large network of permanent vegetation plots ([Fig. 2.4](#)) across a wide range of stand ages, habitats, management histories, and disturbance types (Acker et al. in press b). We have capitalized on natural disturbances (fire, volcanic eruption, debris torrents) and experimental manipulations (logging, broadcast burning) to understand and characterize the mechanisms and processes of succession ([Table 1.4](#)). We have documented changes in species composition and structure (diameter, height, biomass, leaf area, horizontal/vertical heterogeneity) of live and dead vegetation components ([Table 2.1](#)). Several short-term studies have been conducted to provide information such as phenology of leaf fall, diameter/height relationships (Garman et al. 1995), soil attributes and small-scale vegetation patterns, and allometric biomass equations, many included in Means et al. (1994).

In LTER4 we will continue our long-term measurements in the permanent plots with emphasis on those plots that contribute to the Synthesis Areas. A major product from the permanent plots will be continued development of the ZELIG.PNW model, basing improvements on our increasing understanding of factors (e.g., biological legacies) that influence successional dynamics of upland and riparian coniferous forests in the Pacific Northwest. We will summarize patterns and underlying controls on productivity, tree mortality, and stand structure/biodiversity along major environmental gradients and successional trajectories following logging and wildfire. Our short-term studies will include continued development of allometric equations for biomass and leaf area, development of methods for mapping stand attributes at watershed and landscape scales, and description of stand attributes and community characteristics in areas of unusually fast or slow succession, as mapped from remote-sensing imagery. Other short-term studies will explore key successional transitions, especially tree canopy closure of post-logging conifer stands. Vegetation in experimental watersheds is currently in the process of tree canopy closure; thus, the period of LTER4 is a critical time to document and explain variation in rates and causes of canopy closure and its effects on establishment of herbs, shrubs, and other organisms.

2.2.5. Biological Diversity.

[Acker, Garman, Lattin, McKee, Miller, Moldenke, Schowalter]

We have two objectives for the Biological Diversity Component: 1) further our understanding of species richness and diversity through continued surveys and monitoring; and 2) employ models to predict the effects of disturbance, land use, and climate change on biodiversity. In LTER4 we will shift emphasis to the latter objective. This is timely, as we have completed our first compilation of species lists for 13 taxa for the Andrews Forest area (Section 1.3). This will be a continuing effort, involving identifying species and compiling information on their trophic status, life-history, and habitat-association attributes. Substantial biodiversity studies also occur in conjunction with the Vegetation Succession and Forest-Stream Interactions Components. The database for arthropods is especially rich, with over 3,700 species recorded from the Andrews Forest (Parsons et al. 1991) out of an estimated 7,000-plus probable species. The Lepidoptera (moths and butterflies) are well studied, and all are herbivores in the immature stage with host plant specificity often known. Results of current work indicate strong geographic and temporal patterning of moth and butterfly ([Fig. 2.7](#)) populations on the Andrews indicating they are ideal subjects for field and modeling studies. Other well-studied arthropod groups that lend themselves

to further studies of biological diversity include spiders, soil arthropods, Coleoptera, and Hemiptera: Heteroptera (Parsons et al. 1991, Moldenke and Lattin 1991, Lattin 1993).

Modeling is a key part of the Biological Diversity Component because it allows us to extrapolate to novel conditions (e.g., new harvest schemes) and larger scales than the data were originally collected. In LTER4 we will expand work on models, with an initial focus on herbs and shrubs, birds, and Lepidoptera. We will further develop and validate the model ZELIG.PNW (ver. 3.0) for stand-level modeling of the tree species (Hansen et al. 1990, 1993, 1995a,b, Garman et al. 1992). We will also add a herb and shrub plant component to this model, thus facilitating habitat modeling for selected arthropods and birds. A database containing life history attributes for over 100 shrub and herb species is nearing completion and will greatly facilitate this effort. Shrub and herb data collected as part of the Vegetation Succession Component will serve as a preliminary corroboration of the modified model's predictions. Stand and landscape assessment of bird habitat will be made with an existing model, HABPATCH, that is based on life-history and habitat attributes of bird species derived from literature and field data (Garman 1994). This model accounts for size, shape and spatial arrangement of habitat patches in predicting potential habitat suitability and has already been used to assess bird diversity response to varied land use patterns for a study area encompassing the Andrews. Lepidoptera habitat will be predicted from existing knowledge on host plant specificity, other habitat factors such as temperature, and vegetation characteristics predicted from the modified ZELIG.PNW model. These predictions will be checked against new field data on Lepidopteran distributions. Moths and butterflies will be collected in black-light traps placed in several successional stages at different elevations, and aspects. The location of these traps will overlap with existing permanent vegetation plots and any new vegetation plots used to characterize areas of unusually fast or slow succession.

2.2.6. Carbon and Nutrient Dynamics.

[Acker, Gartner, Griffiths, Harmon, Perry, Sollins]

The main objective of this component is to determine how disturbances, land use, and climate affect decomposition, soil nutrient cycling, plant production, and carbon dynamics. Conceptually, we view decomposition as key to understanding soil nutrient availability and carbon fluxes from the soil. Soil nutrient availability, in turn, is key to understanding the plant productivity of a site. Finally, the coupling of decomposition, nutrient cycling, and plant production in the context of their responses to disturbances allows us to examine changes in carbon flux. Our past and future LTER studies have grown to cover progressively larger spatial scales while retaining a focus on combining field, archival, and remote sensing data with modeling to address a variety of questions.

Decomposition process and soil nutrient cycling have been major elements of past Andrews LTER work. A number of long-term experiments have been initiated to examine the effects of litter type, substrate quality, and climate on the decomposition of detritus (Harmon 1991, LIDET 1995) ([Table 1.1](#)). As part of our effort to measure decomposition rates, we are also measuring rates of nutrient immobilization and release in all forms of detritus (Griffiths et al. 1993, Harmon et al. 1994, Harmon and Sexton 1995). In addition to these experiments, the decomposition of logs of various tree species throughout the western US (Harmon et al. 1987), Mexico (Harmon et al. 1995b), and Russia (Krankina and Harmon 1995) is being observed. To examine the

consequences of nutrient dynamics on forest productivity, we initiated the Young Stand Productivity experiment ([Table 1.1](#)). This study, started in 1981 in 20-yr old Douglas-fir plantations, examines how tree stocking density, leaf area, and fertilization regimes influence plant growth and self-thinning (Velazquez-Martinez 1990, Velazquez-Martinez et al. 1992). As these experiments form the basis for much of our terrestrial ecosystem modeling, we plan to continue measurements throughout LTER4.

Characterization of soil properties and dynamics has occurred at several spatial scales in Andrews LTER. This work contributes to several other Components and to our understanding of terrestrial carbon dynamics. Therefore in LTER4 we will continue to characterize soils to support various Andrews-based studies at plot, watershed, and regional scales. The Andrews soil map will be used to improve estimates of C and N pools at the watershed scale after within map-unit variability has been analyzed. This assessment will be based on two independent georeferenced data sets: 70 pedons subjectively located in prior studies, and 60 sites systematically located in a current study. A landscape sampling network of 184 sample sites for the study of decomposition dynamics of soil organic matter (SOM) and soil nutrient cycling was established in the Andrews during LTER3 ([Fig. 2.8](#)). The data gathered from this network will be analyzed during LTER4 and used to verify the decomposition portions of the STANDCARB model (Harmon et al. 1995a). At the regional scale, the relation of mineral-soil C pools to climate and site characteristics examined during LTER3 (Homann et al. 1995) will be expanded to include additional pedons, organic-horizon C, and more rigorously documented site characteristics. A particularly useful database for this purpose are soils sampled at 60 of the permanent vegetation plots distributed throughout western Oregon and Washington ([Fig. 2.4](#)).

Estimates of carbon fluxes of forests during LTER3 were based largely on simulation models which were in turn based on observations and experiments on decomposition, litterfall, mortality, and growth conducted in Component research. Our primary emphasis in LTER3 was to link remotely sensed data on forest condition (e.g., age structure) and land use to the landscape level ecosystem carbon flux model called LANDCARB (Cohen et al. in press, Wallin et al. in press a). We have also examined the historical changes in carbon stores associated with changes in timber harvest practices (Harmon et al. in press a) and forest products (Harmon et al. in press b). Harmon is currently completing a stand-level simulation model, STANDCARB, that integrates growth, litter production, and decomposition to assess the effect of disturbances and climate on carbon stores and fluxes (Harmon et al. 1995a). In LTER4, we plan to continue developing the STANDCARB model and to corroborate model predictions with field observations from existing LTER permanent plot data and other measurements that have been collected within the region (Acker 1995, Zenner 1995).

2.2.7. Forest-stream interactions.

[Gregory, McKee, Swanson]

Our main objective of this Component is to understand stream/riparian networks in their historic and watershed contexts (Gregory et al. 1991). The work is organized as a series of long-term observation programs, experiments, and modeling efforts building on these databases and understanding of processes. Studies are designed to explore long-term processes that shape aquatic ecosystems, identify critical links between forests and streams, and examine the

influences of natural disturbances and land use on stream communities and processes. These studies will form the basis for exploring network processes in stream/riparian systems.

Changes in water quality and their influence on trophic interactions is a cornerstone of this Component. LTER water quality studies consist of long-term observations, such as stream chemistry and temperature measurements at Mack Creek, and Watersheds 2 and 10. These measurements when combined with six other, non-LTER-funded watershed monitoring stations in the lower McKenzie and Willamette Rivers provide a basis for understanding downstream chemical trajectories and watershed nutrient dynamics ([Fig. 2.9](#)). In LTER4, these observations will be used to define and interpret downstream trends in nutrient concentrations and other measures of water quality. These observations also provide a context for site-specific nutrient dynamics experiments. The influence of water quality on trophic interactions and nutrient dynamics has been explored in an experiment in which ammonium was added continuously to Lookout Creek in summers of 1991-1993. This experiment examined trophic responses to increased primary productivity and helped refine our understanding of nitrogen flows through the food web and downstream. This project ended in 1995, but is proposed for an LTER intersite study of nitrogen dynamics using ^{15}N tracer addition, thus allowing us to expand this research in LTER4.

Woody debris is an extremely useful focal point for this Component because it is a key habitat feature, connects forests and streams, augments disturbance by floods, and interacts with geomorphic processes and landforms (Harmon et al. 1986, Nakamura and Swanson 1994). During earlier LTER's we initiated several studies to understand the dynamics of woody debris and its impact on aquatic vertebrate habitat. In LTER4, we will continue observations of stand dynamics, mortality, delivery, storage, decomposition, and redistribution of coarse woody debris in a 1-km reach of Mack Creek where we have annually documented amounts, locations, movement, and new inputs of wood since 1982. Long-term decomposition, mechanical breakdown, and redistribution of woody debris will continue to be examined in the aquatic portion of the Stream-Upland Log Decomposition Experiment ([Table 1.1](#)).

Past management has greatly reduced the amount of stream and riparian woody debris in the Pacific Northwest. Recently there have been attempts to restore instream woody debris, but the best approaches and ecosystem responses to this restoration are still uncertain. In LTER4, we will continue two long-term, manipulative experiments designed to evaluate stream response to restoration of woody debris ([Table 1.1](#)). The first experiment, initiated in 1988, has detailed responses of channel form, hydraulics, fish, and salamanders in Quartz (south) Creek and will be continued. The second experiment, the Pool Complexity Study, tests the mechanisms controlling aquatic vertebrate response to habitat structure. This randomized-block experiment is replicated in three separate creeks in the Andrews and Upper Blue River. It is designed to test the hypotheses that 1) aquatic vertebrate abundance increases with increasing pool habitat complexity, and 2) rate of wood accumulation increases with increasing standing-crop volume of wood. A major goal in LTER4 is to integrate this database of riparian forest dynamics, wood inventory, riparian landscape context of streams, and manipulative experiments in a spatially-explicit model of stream/riparian wood dynamics (Meleason and Gregory, in progress). This model will operate across spatial scales of reaches to basins and over time scales of years to centuries.

Population dynamics of aquatic vertebrates in undisturbed and disturbed stream/riparian systems is the third major activity in this Component. Changes in population dynamics of cutthroat trout and Pacific giant salamanders population have been observed since in 1973 in clearcut and old-growth sections of Mack Creek. This study represents one of the longest records of fish populations (or any aquatic population) in the western United States and we will continue it during LTER4. A culvert, erected in 1965, has formed an upstream barrier between the two populations. Isozyme analysis indicates genetic differences between the populations have emerged in less than 30 years. This barrier was removed in 1994, offering the opportunity to study the movement and genetics of the subpopulations. In addition to the response to clear-cutting, we are examining the recovery of aquatic communities following a 1986 debris flow in Quartz (north) Creek. This debris flow occurred in a site where we had pre-disturbance measures of the riparian-aquatic ecosystem (Lamberti et al. 1991). In LTER4 we will continue sampling of fish populations, woody debris, and riparian vegetation.

In LTER4, we will improve our conceptual model of how forest-stream interactions change from small headwater streams to large rivers. Exploration of these patterns and processes formed the basis of the River Continuum Concept (Vannote et al. 1980), of which the Andrews was part, and our previous concepts of forest-stream interactions (Gregory et al. 1991). To build on this background, it is necessary to understand controls on downstream change of varied ecosystem properties and to augment this downstream focus with an understanding of the distinctive properties that network structure confers on stream and riparian systems. First, we will assess how riparian vegetation composition, distribution, and dimensions vary in the McKenzie River basin (including Andrews) using satellite images (30-m resolution). Finer resolution (1-m) ADAR imagery will also be used for Andrews. Analysis of these data began in LTER3, and it is apparent these data are useful in defining the range of variability and effects of roads and clearcuts on riparian vegetation. The second step will be to further delineate and analyze downstream trajectories of individual system properties (e.g., [Fig. 2.9](#)). Mechanisms responsible for longitudinal changes will be identified where possible, and existing process models (e.g., woody debris - Van Sickle and Gregory 1990, Meleason and Gregory in progress; stream ecological processes - McIntire and Colby 1978, D'Angelo et al. 1995; nutrient flux - D'Angelo et al. 1995, Bruce Peterson, Woods Hole MBL will be used to analyze behavior of selected ecosystem properties and to identify where network structure modifies downstream changes in ecosystem properties.

2.3 Synthesis Areas.

The four Synthesis Areas presented below represent new, cross- disciplinary, projects that address 10 questions required to help answer our central question ([Table 2.2](#)). The Synthesis Areas are presented in increasing order of spatial scale, moving from species variation within patches to patches to small watersheds and ending with integration at the landscape scale. Despite the seemingly different flavor of the Synthesis Areas, each considers how some aspect of pattern influences ecosystem properties. Synthesis Areas draw heavily on the Component Studies for data, concepts, and the models needed to conduct the proposed analyses.

2.3.1. Synthesis Area A: Effects of Species on Ecosystem Function.

[Acker, Harmon, Gartner]

This Synthesis Area considers the effect species have on the carbon and hydrologic dynamics of ecosystems at the spatial scale occurring within landscape patches. Numerous studies have demonstrated that the three drivers of change in our central question can dramatically alter species composition at all trophic levels (e.g., Halpern 1988, Sousa 1984, Webb 1992). However, theoretical and empirical studies of the effects of individual species on ecosystem properties are few (Lawton and Brown 1993, though see Jones and Lawton 1995). Competing hypotheses have been advanced: that all species are essential for ecosystem function, or that there is essentially complete functional overlap between species within broad functional groups such as primary producers, consumers, and decomposers (Lawton and Brown 1993). Although the assumption of a high degree of overlap may be appropriate for some analyses, other cases require separate treatment of individual species (Schimel et al. 1995). For example, while conifers are frequently used as a functional group, in our landscape treating conifers as a group aggregates species with differing responses to light, moisture, and temperature as well as those with very different abilities to accumulate organic matter. Thus locations and successional stages that differ functionally might be misleadingly viewed as identical. Moreover, even if one can develop an acceptable model based on aggregating today's mixtures of species (e.g., Rastetter and Shaver 1995), this does not mean that past (Sea and Whitlock 1995) or future mixtures (Urban et al. 1993) will be adequately represented unless the functional attributes of all the species are taken into account. Given these concerns, the main objective of this Synthesis Area is **to assess how the abundance and distribution of species influence ecosystem function**. Progress in this Synthesis Area has several long-term implications for our program. First, it will supply many of the species- and functional-group attributes required to conduct the planned analyses at the patch, small watershed, and landscape scales. Second, it increases the spatial and temporal resolution of our assessments by allowing us to move beyond steady-state analyses (where species mixes are typically constant) to consider transient responses (where species mixes change over space and time).

To achieve this objective it is necessary to answer two questions. First, **to what degree do the attributes of species that affect ecosystem processes overlap?** Traditionally, ecologists have dealt with this issue by dividing the ecosystem into broad functional groups such as primary producers, consumers, and decomposers. While this division is easy to grasp, it is very general and is little help in defining ecologically-relevant subsets of these functional groups. Logically one might subdivide on the relative overlap or redundancy of species (e.g., Woodward 1993). In practice, however, one rarely finds this analysis beyond the coarsest level (e.g., hardwoods versus conifers), leaving the functional redundancy of many species poorly defined. Although it has often been assumed in ecosystem studies that there is great functional overlap among species (Schimel et al. 1995), there are several other possible structures of functional redundancy ([Fig. 2.10](#)). Furthermore, species may be functionally redundant in one attribute (e.g., litter production) and not in another (e.g., litter substrate quality). Answering this question will allow us to move the discussion beyond the current extreme positions (i.e., no overlap or total overlap) to a more practical middle ground.

The second question is: **in which situations can the attributes of species be aggregated and in which must species-specific values be retained?** If there are marked differences in the attributes of species, it might be possible to include them by aggregating values or segregating the landscape into spatially and temporally homogeneous units. Possible strategies for

aggregating species include using the attributes of the dominant species, using a weighted average of the species present, and creation of a "mega-species" that encompasses the entire range of attributes present. As long as one focuses on the prediction of the general and non-transient (i.e., comparison of steady-states) ecosystem response, these approaches may suffice. Our analysis, however, indicates at least two cases in which this approach can give misleading results: 1) when species with differing attributes shift in abundance over time (Fig. 2.11; see also Rastetter and Shaver 1995) and 2) when functional attributes are nonlinear (Fig. 2.12). In each of these cases, the aggregation of species attributes gives different transient responses than an analysis that preserves these differences. There are also several other examples where species aggregation has obscured rather than revealed key functional relationships (see Reich et al. 1994, 1995). Answering this question will allow us to identify situations in which species can be aggregated in a manner that enhances rather than decreases our ability to examine transient response to disturbance and climate change.

The approach outlined below can be used on a wide range of broad functional groups. During LTER4, however, we will focus on primary producers as they are an important group in terms of carbon and hydrologic dynamics. Our first step will be to perform a sensitivity analysis using simulation models such as ZELIG.PNW and STANDCARB (Harmon et al. 1995a) to determine which attributes of plant species have the greatest effect on ecosystem response. These models are ideal for this purpose, because they incorporate multiple life-forms (i.e., herbs, shrubs, and trees) and variable species mixtures. Attributes explored initially will include: light absorption, light compensation point, maximum photosynthetic rate, water use efficiency, respiration rate, litter production, and substrate quality of litter. Once the most influential attributes are identified, we will compile species-specific values from the literature and unpublished datasets. For some attributes we will also make new measurements, with emphasis on fast, inexpensive indices that allow us to rank species (e.g., lignin:nitrogen ratios rather than field decomposition studies). The next step will be to test the degree to which attributes of plant species overlap using discriminant and cluster analysis methods. The final step will be to identify further cases where retaining species differences affects ecosystem response using the ZELIG.PNW and STANDCARB models. The response to disturbances and projected climate change of simulated stands that have either mixtures of species, an average of species' attributes, or a mega-species will be compared, with emphasis on transient responses. The final product of this Synthesis Area will be a better understanding of how to define functionally meaningful patches that are robust over space and time.

2.3.2. Synthesis Area B: Early succession.

[Acker, Cohen, Griffiths, Harmon]

To understand the ecological consequences of land-use, natural disturbances, and climate change, it is necessary to quantify and explain the variability of vegetation succession following disturbance. The most common early successional sequence in our region, starting with dominance by herbs and broadleaf shrubs and ending with dominance by coniferous trees (e.g., Franklin 1988, Halpern and Franklin 1990), is expected to cause significant changes in ecosystem function (Long 1982). Earlier landscape studies (e.g., carbon fluxes; Harmon et al. 1990, Cohen et al. in press), assumed that this transition occurs at a uniform rate across the landscape. However, current remote sensing studies on the Andrews indicate that the rate of

succession after clear-cut harvest varies considerably, and may cause differences between sites in ecosystem processes such as carbon flux (Fig. 2.13). These remote sensing studies reveal that clear-cut sites can be grouped into three, statistically distinct classes of time to conifer dominance: <20, 20-40, and >40 years (Fig. 2.14). A pilot study completed by Griffiths in 1995 indicates that ecosystem variables in addition to carbon flux are altered by the rate of succession, including nitrogen cycling, ectomycorrhizal mat distributions, soil structure, and the presence of buried decaying wood. Given the observed variation in rates of succession and potential effects on ecosystem function, the objective of this Synthesis Area is **to understand how variation in the rate of development of conifer dominance influences ecosystem function**. This objective is a critical step in addressing our central question, because the rate of succession in large part determines the state of the vegetation, and it is largely through the vegetation that land-use, natural disturbances, and climate change affect carbon dynamics, biodiversity, and hydrology.

We will answer two questions to achieve the objective of this Synthesis Area. First, **why does the speed with which conifers attain dominance after clearcut harvest vary across the landscape?** Although in our region intensive plantation forestry practices are considered much more effective than natural processes of stand regeneration (see Cafferata 1986, Hermann and Lavender 1990), our preliminary work has identified many cases in which it has taken >40 years for conifers to achieve dominance (see also Spies et al. 1994). Many factors can slow conifer establishment, ranging from too much or too little moisture, extremes of temperature, predation of seeds and seedlings, pathogens, competition with other plants, and antagonistic soil biota. Rather than examine each of these factors separately, we propose a conceptual model that emphasizes three general classes of constraints on early succession in our forests: 1) disturbance characteristics, 2) environmental stresses due to physical site characteristics, and 3) biotic interactions (Fig. 2.15). A key feature of this conceptual model is that several constraining factors may have similar impacts on ecosystem reorganization. Also important is that several of the constraining factors operate in a temporal sequence. The type, severity, and frequency of disturbance determines the "legacy" (e.g., snags, downed logs, soil nutrient stores, propagules) from the pre-disturbance ecosystem that is the starting place for succession (Swanson and Franklin 1992). Site characteristics, especially those associated with stress, then influence the success with which plants become established and make critical connections to other, beneficial organisms (e.g., mycorrhizae, Perry et al. 1989a,b). Long-term succession may be determined by subsequent interactions between the biotic components. By answering this question we will determine if the slow development of conifer dominance is a common phenomenon. Identifying the proximal factors influencing conifer establishment will enhance our understanding of how the landscape responds to disturbance, allowing us to predict where and when slow development of conifer dominance is likely to occur and whether this successional trajectory will be more common with changes in climate.

The second question is **which ecosystem functions are most sensitive to the rate of the development of conifer dominance?** Although the factors influencing conifer establishment following timber harvest and fire have been a major focus of past forestry research in the Pacific Northwest, the effects on ecosystem function (as opposed to effects on timber supply) have rarely been examined. Many ecosystem functions will be influenced by the degree of conifer dominance, but they may differ in their sensitivity. Hydrological processes may be the least sensitive to the rate of development of conifer dominance. Although broadleaf shrubs and trees

may have less foliage than conifers, their water use efficiency is far lower, which may lead to a similar evapotranspirational loss and effect on water stores (Marshall and Waring 1984). In contrast, biodiversity, at least in terms of species richness, is probably most sensitive to conifer dominance because many species of plants and invertebrates are associated with the pre-conifer stages of succession (Schoonmaker and McKee 1988, Parsons et al. 1991, McIver et al. 1992, Richardson 1995, Torgerson et al. 1995). Carbon flux and stores are predicted to be of intermediate sensitivity to the rate of development of conifer dominance, because the legacy of snags, logs, and other organic matter left from the previous stand dampens the effect of the current vegetation. Answering this question is a key step as it identifies the ecosystem-level significance of alternative successional trajectories; answers to this question will also influence our landscape-level analyses.

We will answer the two questions with the following approaches. For the first we will use satellite and aircraft imagery to categorize clear-cut sites by their rate of canopy closure by conifers. The minimum area for characterizing vegetation in this remote sensing analysis will be 1 ha, although many of the clear-cut harvest units exceed 10 ha. We will then test the correlations between the successional trajectory classes and the type and severity of site disturbance (estimated from harvest records and other site-history data), and physical site variables associated with stress (e.g., extreme temperature, southern aspect, or soils of low water holding capacity). Our final step will be to identify sites where conifers have not attained dominance over the long-term (>40 years). Where appropriate, potential explanatory factors (e.g., soil water holding capacity, temperature extremes, and species composition) will be measured using subplots within the 1 ha areas defined by the remote sensing analysis. Based on the complex of constraining factors described under the first question, we would expect that long-term exclusion of conifers is due to biotic interactions (e.g., competition or antagonistic soil biota) occurring on these sites. We will therefore design a series of long-term studies that will test the degree abiotic stress and biotic interactions are preventing conifers from becoming dominant on these sites (Amaranthus and Perry 1987).

To answer the second question, we will select sites with a range of rates of conifer development and sample them for key state variables (e.g., carbon and minimum water stores, biodiversity) and processes (e.g., interception, soil nutrient cycling, and soil respiration). Our emphasis will be on variables and indices that are easy and inexpensive to measure, but that will allow us to rank functional responses. To help eliminate differences associated with location rather than successional stage, we will also sample adjacent old-growth forests as a "reference" condition. We will analyze data from our permanent vegetation plots to devise a sampling scheme that takes into account the heterogeneity of old-growth forests. To test our proposed ranking of the sensitivity of ecosystem functions (i.e., species richness most sensitive, carbon dynamics least sensitive), we will standardize functional variables relative to values for the adjacent old-growth, and then compare the standardized responses to the degree of conifer dominance. This will allow us to compare the changes in species richness, carbon, and hydrology to one another directly, avoiding the problem of different units of measure. We will also combine the vegetation inventory data taken at the sites with the species-specific parameters (from Synthesis Area A) to provide preliminary estimates of differences in some ecosystem functions (e.g., decomposition rate). We will then undertake field studies to test directly these estimated differences in process rates.

2.3.3. Synthesis Area C: Small Watersheds.

[Grant, Jones]

Streamflow is a key ecosystem property at Andrews. Peak stormflows dominate the fluvial and riparian disturbance regime in winter, and low flows limit aquatic ecosystems in summer months in this wet-winter/dry-summer climate (Fig. 2.5). Long-term small watershed studies in Andrews indicate that hydrologic processes may be sensitive in unexpected ways to vegetation succession after harvest. Originally established to examine effects of management treatments on vegetation and watershed processes, these 10 to 100 ha watersheds now provide the longest-running records of hydrology and post-clearcut vegetation succession available in the Pacific Northwest (Table 1.3, Table 1.4). These small watersheds display different vegetation successional patterns (Halpern 1988, Halpern and Franklin 1990) and streamflow responses (Fig. 2.16) after the same treatment, forest harvest. Results from long-term, small, paired watersheds elsewhere (Blackie et al. 1979, Day et al. 1987, Swank et al. 1987, Swift et al. 1987, Keppeler and Ziemer 1990, Wright et al. 1990) suggest that streamflow in Andrews small watersheds may be controlled by patterns of vegetation succession, such as post-disturbance dominance of riparian zones by broadleaf hardwoods, or later suppression of broadleaf understory shrubs by conifer canopy closure (Fig. 2.17). We propose that temporal response of streamflow to land use practice cannot be predicted from treatment alone, but depends on biotic factors (e.g., inherited biological legacies such as seedbanks, sprouting vegetation), disturbance, and geophysical properties (e.g., radiation, topography, soils), which lead to the emergence of zones of vegetation with distinct hydrologic behaviors. We further propose that in the wet-winter/dry-summer climate of the Andrews, the degree of conifer canopy closure on hillslopes may control snow accumulation and soil moisture conditions and hence the magnitude of winter storm peak flows, while water loss from broadleaf vegetation in the riparian zone may largely determine the magnitude of summer low flows. Therefore, the objective of this Synthesis Area is **to understand the influence of post-clearcut vegetation successional patterns on streamflows from small watersheds**. This objective is central to our overall theme because it addresses how land use influences key ecosystem properties over 40-year periods. Using the vegetation succession units defined at the scales of individual plants (Synthesis Area A) or vegetation patches (Synthesis Area B), this Synthesis Area defines patches and explores their influence on a network process (streamflow) at the small watershed scale. It thus lays the groundwork for studies at still larger spatial scales addressing stream network and disturbance patch dynamics (Synthesis Area D).

To achieve this objective we will address three questions. First, **what are the spatial patterns of broadleaf and conifer succession within small watersheds, and how do they differ between riparian zones and hillslopes?** Building upon the sequence of factors controlling post-disturbance conifer establishment from Synthesis Area B, we expect to identify spatially-explicit patches of distinct vegetation succession within each small watershed correlated with differences in severity of harvest disturbance, physical site characteristics, and biotic factors. While we expect the system to be complex because of continued stochastic processes (e.g., seed rain, snow damage), we do expect certain conditions to set the stage for the development of vegetation components with distinctive hydrologic properties. By mapping the location and extent of vegetation patches, such as broadleaf *Alnus rubra* (red alder)-dominated riparian areas, shrubs on south-facing hillslopes, or closed-canopy conifers on north-facing hillslopes over the 40+ yr

period, we aim to decompose the "black box" of the small watershed into hydrologically relevant patterns of vegetation.

Second, what are the potential mechanisms by which upland and riparian vegetation patches influence streamflow? Small watersheds have experienced both large and small increases in peak stormflows, as well as both increased and decreased summer low flows after harvest (Fig. 2.16). This puzzling variety of responses appears to be related to the varying proportions of conifer and broadleaf cover in time and space after harvest in these watersheds, and different hydrologic behaviors of coniferous and broadleaf vegetation in the climate of the Andrews (Fig. 2.17). During early post-harvest succession, treated watersheds have greatly reduced conifer leaf area and increased area of broadleaf herbs, shrubs, and trees (Dyrness 1973, Rothacher et al. 1967, Hawk 1979, Gholz et al. 1984, Halpern 1989, Halpern and Franklin 1990). Also, regenerating vegetation is patchy, with conifers confined to hillslopes where they compete with understory broadleaf shrubs, while broadleaf hardwoods dominate in riparian areas of some watersheds. In Andrews control watersheds, conifers have very high leaf area compared to broadleaf vegetation and hence high interception and potential evapotranspiration. However, their actual water use may be limited in winter by near-freezing temperatures and on hot dry summer days by low soil moisture, high air temperatures and high vapor pressure deficits (Running et al. 1975, Teklehaimanot and Jarvis 1991, Waring and Schlesinger 1985). In contrast, summer water use by broadleaf shrubs, such as *Ceanothus* spp., may remain high on hillslopes because they transpire even at high soil moisture stresses (Conard and Radosovich 1981), while summer water use in riparian zones may remain high because saturated soils impose no stress on broadleaf hardwood trees. After harvest, conifer-related fog-drip interception and evapotranspiration may be drastically decreased, while broadleaf-related evapotranspiration may be increased (Fig. 2.17). Therefore, we propose that winter peak flows will respond most strongly to the extent of conifer canopy cover on hillslopes, via changes in interception, snow accumulation/melt, evapotranspiration, and soil moisture, whereas summer low flows will respond to broadleaf riparian vegetation close to the stream outlet. By coupling findings from the first two questions we will gain improved ability to predict watershed response to succession for different combinations of upland and riparian vegetation states.

Third, how do vegetation properties that affect the hydrology of small watersheds vary in the western Cascades of Oregon? Our long-term, small watershed data, valuable as they are, represent a very limited sample. It is important to understand how representative these watersheds are of the larger landscape. We propose that temporal trends in water fluxes from unmonitored small basins can be predicted, given information on their climate, topography, disturbance severity, and initial vegetation. By combining findings from the three questions, we should be able to identify the geophysical conditions and vegetation succession patterns that are likely to produce strong streamflow responses to land use disturbance in Andrews and the western Cascades.

Our approach will be to examine connections between vegetation succession and hydrologic processes using retrospective analyses of long-term data and modeling. We have developed new statistical techniques to quantify the change in streamflow in treated/control watershed pairs which control for seasonal and interannual variation in streamflow (Jones and Grant, in press). Using these techniques, we will complete retrospective studies of peak and low streamflows in

the five clearcut-control small basin pairs in Andrews ([Fig. 2.2](#), [Fig. 2.16](#)). We will also reconstruct the history of pre- and post-disturbance vegetation development in small watersheds from plot data, the remote sensing record, and historical air photos. Using spatially-detailed, long-term vegetation, soils and geomorphic data collected in LTER3 and earlier ([Table 1.4](#)), we will construct hydrologically meaningful map units composed of vegetation with distinctive hydrologic behavior (i.e. leaf area, available soil moisture, transpiration potential). As a starting point we will characterize vegetation succession in terms of hydrologically-relevant distinctions between commonly-occurring groups of species in Andrews, such as broadleaf vegetation in riparian areas, broadleaf shrub understory on hillslopes, and conifer canopies on hillslopes. This approach is based on the notion that stand-scale evapotranspiration is controlled not so much by variation at the individual leaf scale (Jarvis and McNaughton 1986, McNaughton and Jarvis 1991) but rather by structural changes in vegetation (Specht and Specht 1989), differential exposure to radiation (Russell et al. 1989) or differential soil moisture (Korner 1993). In later analyses we will move to consideration of the water use behavior of distinctive and dominant species, such as Douglas fir, red alder, *Ceanothus* spp. using published literature values (e.g., Waring and Schlesinger 1985, Shainsky et al. 1994) augmented with additional measurements, if necessary.

To approach the third question, we will examine the representativeness of these small watersheds over the western Cascades region, using results of Synthesis Area B; remote sensing- and GIS-supported landscape analysis of topography, soil, vegetation, and climatic patterns; and streamflow data from seven additional small watershed pairs located 100 km north and south of the Andrews (Harr et al. 1975, Harr et al. 1979, Harr 1982). In LTER3, Duan and Grant constructed a spatially-explicit hydrologic model that accurately predicts streamflow from the Andrews small watersheds by decomposing them into riparian and hillslope units. Building upon earlier Andrews IBP work (Sollins et al. 1980, Waring et al. 1981, Running 1984, Running and Coughlan 1988), we propose to augment this model with a component that incorporates vegetation-mediated water inputs and outputs for each vegetation map unit. Because this synthesis involves description of pattern, correlation with response, model simulations, and GIS comparisons of vegetation patterns, we will not measure mechanisms directly, but we expect to identify the most likely mechanisms regulating peak and low streamflows.

2.3.4. Synthesis Area D: Landscape Dynamics.

[Garman, Grant, Gregory, Jones, Lattin, Miller, Swanson]

Pattern and scale are central issues in ecology (Levin 1992, Wiens 1989); and Pacific Northwest landscapes are a great place to explore these issues. Many important science and management issues must be approached at the landscape scale. Syntheses undertaken in Synthesis Areas A, B, and C lead to the landscape scale by examining effects of pattern across a range of spatial and biotic scales, spanning species effects on ecosystem function up to vegetation patch effects in small watersheds. The objective of Synthesis Area D is **to examine the effects of landscape-scale vegetation patterns on carbon dynamics, elements of biodiversity, and hydrology**. This is our central question considered at the landscape scale ([Fig. 2.1](#)). We expect that each of these key ecosystem properties responds differently to pattern. Our three key properties are representative of the three categories of pattern-process effects in terrestrial landscapes defined by Turner (1989): 1) ecosystem processes (e.g., primary production), 2) movement and

persistence of organisms, and 3) redistribution of matter and nutrients. Understanding of pattern-process interactions in terrestrial, patchwork systems is well developed, such as patch-dynamics and percolation concepts and models (Pickett and White 1985, Forman and Godron 1986, Turner 1989, Turner et al. 1989, Baker 1989, 1994). However, in a recent review of landscape ecology literature we observed little work addressing pattern-process interactions in networks, particularly stream networks, which are a dominant element of the Andrews landscape. Therefore in this Synthesis Area we build on the perspectives of Turner (1989) and others by considering how natural disturbance and land use interact to create vegetation patterns, linking terrestrial vegetation patterns with stream network patterns and processes, and using a common landscape to analyze pattern effects on examples of each of Turner's three categories of pattern-process relations.

To accomplish our objective we address three specific questions ([Fig. 2.18](#)). First, **what are the historical and future potential ranges of vegetation patterns under natural disturbance, land use, and climate variability?** Natural disturbances and land use can create quite different spatially and temporally variable landscape patterns of vegetation age classes (Franklin and Forman 1987, Mladenoff et al. 1993, Turner et al. 1994, Wallin et al. in press b) ([Fig. 2.19](#)). In general, wildfire created larger patches than recent clearcutting on public lands ([Fig. 2.6](#)) (Morrison and Swanson 1990, Spies et al. 1994). However, land use and natural disturbance processes can interact to create landscape patterns that may offset or reinforce ecological consequences. Dispersed clearcuts, for example, create forest edges vulnerable to windthrow, leading to aggregation of patches (Franklin and Forman 1987). Climatic factors include influences on occurrence of wildfire and other disturbances and possible delay of conifer establishment, as addressed in Synthesis Area B. By examining this question we will gain understanding of controls on vegetation patterns in response to various drivers of change.

Our second question addresses the functioning of stream networks, which governs hydrology and aquatic biodiversity, two key ecosystem properties. These properties are influenced by vegetation patches adjacent to streams (Section 2.2.7, Gregory et al. 1991), by upstream factors (the River Continuum Concept of Vannote et al. 1980), and also by the arrangement of tributaries and other aspects of channel network structure (Beven and Kirkby 1993). The relative importance of these factors determines how stream ecosystem properties are likely to respond to changes in upland vegetation patchworks. Therefore, the second question we address is **how is stream network behavior influenced by the arrangement of upland vegetation patches?** Network structures, such as arrangement of tributaries and their junction angles, control the routing of disturbances and materials, such as streamflow (Jones and Grant in press) or coarse woody debris (Nakamura and Swanson 1993, 1994, Benda 1994) contributed from upland patches. An approach to this question will help us to test our initial concepts of stream network functions ([Fig. 2.20](#)).

Our third and final question is **how do interactions among vegetation patches and stream networks affect carbon dynamics, biodiversity, and hydrology?** These ecosystem properties represent three fundamentally different categories of landscape behavior: those with weak spatial interactions (e.g., carbon stores); those with strong, multi-directional, biotic, interactions among vegetation patches (e.g., habitat use by animals); and flows of material and disturbances which interact with vegetation pattern (e.g., hydrology, coarse woody debris movement). Furthermore,

we expect to test this categorization during LTER4 by examining multiple variables. While understanding of each property is valuable in itself, collective understanding of these putative different categories of ecosystem properties will improve our general knowledge of ecosystem function at the landscape scale. This effort represents a comprehensive approach to our Central Question ([Fig. 2.1](#)).

We will approach the first question with retrospective studies of landscape change (e.g., [Fig. 2.6](#)) and by integrating models, geographic data (e.g., vegetation patterns, topography, stream and road networks), and other pertinent information into a spatially-explicit, simulation modeling framework. The proposed retrospective work will extend our past studies (Wallin et al. in press b) to a larger geographic area representing a wider range of landscape conditions than found in the Andrews and will extend the analysis of the range of natural variability from uplands (Swanson et al. 1993) to stream/riparian networks. Landscape dynamics models (Component 2.2.3) will be employed to simulate trajectories of vegetation patterns under various combinations of frequency, intensity, severity, timing, and pre-existing land-use and natural disturbance patterns. Modeling experiments will simulate future vegetation patterns based on specific land use strategies, including the new, science-based conservation strategy for the region (FEMAT 1993) and its possible interactions with natural disturbances. We will use experimental designs to select the temporal and spatial sequencing of disturbance types. Reconstructed history of landscape patterns provide examples of actual patterns created by wildfire and land use ([Fig. 2.6](#)). Results will indicate how land use and natural disturbances, independently and jointly, can create distinctive vegetation patterns.

We will approach the second question by combining results of previous work on disturbance propagation (Grant and Swanson 1995), mapping of geomorphic disturbance potential (Section 1.3), and biotic response to the Quartz Creek debris flow (Lamberti et al. 1991, Component 2.2.7). Extensive data sets exist of mapped debris flow tracks and related streamside and in-stream disturbances in the 320 km of stream network in the Andrews and adjacent Blue River basins. These records demonstrate that disturbances within stream networks are often related to upland vegetation disturbance (Swanson and Dyrness 1975, Swanson et al. 1992b). We will use these spatial data sets to examine how the history of vegetation patch disturbances has influenced the routing of streamflow and the spatial distribution of refugia for aquatic organisms in response to debris flows ([Fig. 2.20](#)). This will be combined with process observations from ongoing studies of disturbed and undisturbed reaches in Quartz (north) Creek. Supplemental field studies will be conducted to examine recently disturbed and undisturbed portions of the stream network from a refuge perspective, which we have not taken previously. We expect to find that the spatial patterns of key ecosystem properties, such as refugia and coarse wood accumulations, in stream networks are significantly related to the interaction of network stream structure with arrangement of upland vegetation patches.

For the terrestrial aspects of the third question we will use models of ecological attributes to evaluate carbon dynamics and taxa selected to represent a range of responses to vegetation patterns. These ecosystem elements will be examined over the duration of model simulations (e.g., 200+ yrs) and relate their trends and rates of change to the underlying treatments and resulting spatial patterns. Carbon sequestration under alternative landscape patterns will be assessed using the model LANDCARB (Cohen et al. in press, Wallin et al. in press a).

Biodiversity will be considered in terms of taxa with different types and scales of responses to habitat conditions, based on a variety of field studies (Component 2.2.5). A range of habitat-association models for Lepidoptera are anticipated from the Biodiversity Component, with some species keying in on specific host-plant species and others more highly associated with seral condition. We will apply these models and the HABPATCH model for birds to historical and future potential landscapes to characterize potential animal-habitat diversity. Additionally, extensive data exist for spotted owl demographics in the Andrews and adjacent areas (Forsman et al. 1984, Miller et al. in press). We will use these data in a viability assessment using a spotted owl Population Viability Assessment model (McKelvey et al. 1992) to assess effects of alternative landscape patterns. To approach the stream/riparian network aspects of the third question, we will evaluate hydrologic responses to alternative landscape conditions using the Modular Modeling System, developed by G.Leavesley (Leavesley et al. 1983 and updates). Assessment of fish-species diversity will consider the local influence of woody debris, canopy openings on stream temperature, and peak and low flows on habitat availability for each species, using the habitat modeling approach developed by D'Angelo et al. (1995). This analysis will incorporate concepts of network dynamics and will include external factors of geologic and evolutionary history that can influence potential species pools (Hughes and Gammon 1987, Li et al. 1987).

Overall, the Landscape Dynamics Synthesis Area aims to explore two important general questions in ecosystem science. The first question, "how does scale matter?", will be addressed by identifying the sensitivity of our three key properties (carbon dynamics, biodiversity, hydrology) to landscape pattern at several scales. Carbon sequestration or Lepidoptera habitat may be most sensitive to pattern at the scale of a patch or host plant species, while terrestrial and aquatic vertebrates, streamflow, and coarse woody debris routing may be most sensitive to the arrangement of vegetation patches and stream/riparian network structure. The second question, namely "how do terrestrial and aquatic systems interact?", will be addressed by developing a conceptual model of forest patchwork-stream network relations and examining them in field studies.

2.4. Conclusion.

Our proposed strategic research plan is built around a Central Question that concerns the response of three key ecosystem properties to three key drivers of change ([Fig. 2.1](#)). Understanding how Pacific Northwest ecosystems respond to these drivers of change requires an approach that balances observation versus experimentation, short-term versus long-term studies, as well as conceptual versus simulation modeling. Past and proposed LTER Component studies position us well in this regard, providing many of the data and tools for answering the 10 questions raised in the four Synthesis Areas ([Table 2.2](#)), which are the path to addressing our central question. These answers will increase basic understanding of how individual species, variations in successional pathways, and sensitivity to spatial pattern affect ecosystem properties. Our proposed research will have practical implications. Over the past decade, management of Pacific Northwest ecosystems has moved up to the landscape scale and increased in complexity to meet increasingly diverse social demands. Effective communication among LTER scientists, resource managers, and policy makers has been a crucial part of these changes. Although these have been welcome developments, management planning and assessment now threaten to outpace

the underlying sciences, especially at the landscape scale. Our proposed research will help insure a firm scientific base for future management of forest and stream ecosystems.

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Section 4. Management of Andrews Forest LTER Site.

The Andrews LTER Project is part of a much larger research and education program centered around the Andrews Forest ([Fig. 4.1](#)). We manage the Andrews Forest as a regional, national, and international research and education resource, in keeping with its designation as an Experimental Forest, an LTER site, and UNESCO Man and the Biosphere reserve. The overall management of the greater Andrews Forest program is by a Local Site Management and Policy Committee ([Fig. 4.2](#)) which meets the first Friday of every month. The Site Committee is composed of OSU faculty from 11 Departments in four Colleges, scientists from the US Forest Service, Pacific Northwest Research Station, and managers from the Willamette National Forest (WNF), including the District Ranger and Research Liaison from the Blue River Ranger District, as well as other managers from the WNF Supervisor's Office. The meeting is chaired by one of the two Site Co-Directors, Fred Swanson (PNW Officer-in-Charge of the Andrews Forest, with courtesy appointments in both the Departments of Geosciences and Forest Science) or Art McKee (OSU Director of the Andrews Forest, and faculty member, Dept. of Forest Science).

The monthly Site Committee meetings are open to all interested parties, and normally conclude with a seminar and/or science discussion dedicated to a specific research topic. The meetings are well attended by faculty, graduate students, Deans, scientists, and administrators from OSU, US Forest Service, EPA, and NBS. About 25-30 people attend during the academic year, with half that during the field season. As a result, the monthly meetings provide an important forum for ecological science and ecosystem management in the Corvallis area. The minutes of the monthly meetings are currently distributed to about 100 people, and all are welcome to be added to the mailing list.

Over the 15-year period of LTER funding, we have come to appreciate the value of these monthly meetings. They provide frequent opportunities for communication and collaboration among researchers using the Andrews Forest. New projects can arise as common interests emerge or opportunities appear. Mid-course corrections can be made in a timely fashion, or ancillary projects designed, or new investigators invited to participate. A variety of funding options are explored and discussed. Short courses for natural resource managers are created, and college undergraduate and graduate courses discussed, developed, or modified.

An obvious benefit to having natural resource managers as part of the Site Committee is the speed with which new research findings can be translated into management and policy or tested in practice. The managers provide a reality check to the scientists and students who learn first-hand about management problems.

The monthly Site Committee meetings cover all aspects of research and management at the Andrews Forest, including LTER studies. Should an LTER-related item arise which cannot be covered adequately during a monthly meeting, separate meetings are scheduled to address the topic. A good example would be annual budget allocations among the LTER components. That issue is dealt with in separate meetings involving the principal LTER scientists. It is important to note that we work on the principle of consensus in our decision making. To date, we've been able to achieve consensus on all issues -- but, we have agreed that should the group get to an impasse, the PI (Swanson) will cast the deciding vote.

The Andrews LTER Project is divided into Components and Synthesis Areas with an investigator in charge of each and separate budgets. Allocations are adjusted annually by review of projects, their accomplishments, and funding needs. In LTER4, in order to assure objectivity in this review process, the co-investigators will be joined by two scientists/administrators from outside LTER (Deans of Colleges of Forestry and Science or their designees). In addition to research areas, we maintain a Core budget (Swanson/McKee) and a Data Management budget (Stafford). The Core budget covers meteorological and hydrological monitoring, national travel, and some infrastructure costs of operating the Site for LTER. This organizational structure has served us well during LTER 1, 2, and 3, and we see no reason to change. We also enjoy great leadership depth as many group members have the skills, experience, and institutional backing to move into leadership roles.

Our National Advisory Committee provides guidance in research direction and scope, including a desirable balance among regional, national/inter-site, and international efforts. Over the years, they have also proved to be valuable sources for technical and methodological advice. The current members of our National Committee are: Jim Gosz (Univ. New Mexico); Dave Schimel (Colorado State Univ.); and Diane Wickland (NASA).

The Andrews Forest has a long history of being open to any interested researcher. We have repeatedly advertised that fact in the Bulletin of the Ecological Society in the "Of Interest to Ecologists" section, at national meetings such as AIBS and ESA, and through personal contacts among our colleagues. The success of those efforts can be measured in several ways: number of active projects at the Andrews in any given year (over 125); number of universities and labs with users of the Site (over 50); or percent of the roughly 80 beds on-site that are occupied during the field season (100%). Our facilities are fully used from mid-June to September.

Finally, the Andrews Forest LTER scientists are aware that there is great interest on the part of NSF in making the LTER Sites focal points for ancillary and complementary research. We have done well in the past, and substantial new collaborations continue to develop--most recently through two large EPA-funded regional studies of land use and climate change effects.

Section 5. Andrews LTER Data and Information Management.

Introduction: Information management needs for the Andrews Forest site have been the primary driving force for the creation and maintenance of the Forest Science Data Bank (FSDB), a twenty-plus year effort to maintain and store scientific data in a readily retrievable and usable form. We have a systematic approach (Stafford et al. 1988) beginning with the PI working with the consulting statistician and data manager on study design before initiation of any new study. This communication is continued throughout the duration of the study. This is provided under an overarching structure, the Quantitative Sciences Group (QSG), which Stafford directs. QSG is regularly represented at monthly LTER meetings. The FSDB is dedicated to the long-term preservation and availability of environmental databases. Four principles guide information management at the Andrews LTER site:

1. Information Management is a significant and unifying theme running through the fabric of our LTER enterprise. Over 15 positions in OSU and USFS are involved with information management tasks-- data bank, statistical consulting, hardware and software support, connectivity, Geographic Information Systems (GIS), and remote sensing.
2. Our Information System will always be dynamic, interactive, and facilitate data access and analysis both in and outside the LTER network. Specifically, this will include more WWW page development, and getting more data on-line. Long-term, baseline, monitoring data sets are updated semi-annually or as needed on the WWW, and site policy recommends all other data sets become available within two years of collection.
3. Technology Transfer is a major part of our mission and obligation at site, network, and international levels ([Table 5.1](#)). We have and will continue to develop training workshops for researchers at field stations on connectivity and portability. Recent efforts with colleagues Brunt (Sevilleta) and Nottrott (NET) are focusing in Central and South America.
4. We feel we have an obligation to play a key leadership role in developing the human capital for information management. We are embarking on developing curricula in environmental information management with other participating LTER sites.

Historical Perspective: Initial efforts to manage our scientific information began with the International Biome Programme (IBP) from 1968 to 1978. Early efforts focused on developing documentation forms (abstracts, formats, codes) for ASCII data sets, and structuring these in database tables. This effort became more formalized in the 1980s as data managers from the LTER network began developing standards jointly for documenting and maintaining research information (Stafford et al. 1986a, b). The original standards covered conventional research data, computer programs, and publications, although most of the activity focused on data and their metadata. More powerful tools, including Relational Database Management Systems (RDBMS), were employed once the early mainframe tape library was transferred to a Novell server. Subsequently, much of the early LTER effort was directed toward file restructuring, editing, and applications programming, and today the emphasis has shifted toward development of generic maintenance tools. The rapid rate at which diverse databases are created at our site demands we develop generic solutions in lieu of project-specific programming. We have recently added specific database rules as part of the standard set of metadata. Standards for spatially explicit data associated with GIS, image processing, and modeling are in an earlier stage of implementation at Andrews.

We have operated in conjunction with the community of information managers across the LTER Network. Our system has evolved continually as we find solutions to our site-level problems with full recognition of the broader, LTER network-level issues. The LTER Data Managers have a statement [<http://lternet.edu/>] that recognizes both site and network needs. Both must be considered as we wrestle with information management issues within the LTER Network.

The Current System: The FSDB currently stores conventional, non-spatial data on a Novell network file server; spatial data, including GIS coverages and remote sensing imagery data, reside on UNIX (SUN) servers within the same local area network (LAN). We will continue to have a tandem system: Windows NT and UNIX (Sun workstations) linked together by our LAN. We are also evolving toward an information system that uses a central database server to access information and process user queries (i.e., a client server architecture).

The Andrews LTER stores databases from diverse scientific disciplines in the FSDB for access by original researchers and secondary users. We rely on voluntary cooperation by the researchers to contribute their data and metadata to the FSDB. A database consists of one or more data tables and a standard set of metadata required to access and use the data appropriately, independent of original data producers or data bank personnel. Comprehensive quality control for both metadata and data precedes database archival.

Data production activities include assembly of interpretative descriptions of databases, data entry, metadata, quality control, and archiving. Quality control (QC) of metadata checks for completeness and consistency. Data QC is based on metadata specifications applied to the data by a generic program. We check nulls, domains (ranges, codes), entity and referential integrity, integrity of temporal sequences, and specific database rules, as required. As an incentive for researchers, we offer supervised data and metadata entry, with QC.

The Andrews LTER metadata system conforms substantially to the original standards established by LTER data managers (Kellogg Report 1982) as well as the more recent updates to those standards (Michener et al. 1996). It consists of a set of central catalogs and a set of study-specific tables. The central catalogs store information about databases, table structures, and data files. Dedicated server subdirectories house individual study databases, including both data and metadata tables. Metadata guide users in understanding and accessing databases. All metadata are stored in the Foxpro DBMS easily made accessible as column-formatted ASCII files.

We have had over 200 documented requests for information (both internal and external) since March 1991. These data requests are handled by a specific program which requires permission from researchers (when proprietary restrictions apply) and tracks all information requests. This does not include hits to our Web page [<http://www.fsl.orst.edu/lterhome.html>] which includes selected data sets and metadata, as well as a collection of GIS coverages available to remote users (Section 1.3). Local, original researchers and secondary users (with permission) have direct access to metadata and data on the Novell file server. Information is updated quarterly or annually, depending on the study sampling intensity. We are exploring with OSU Information Services, most particularly the library, how some of this information might be made more generally available to faculty and students across the OSU campus.

Future: Our information system is evolving to one where production, storage, and access of diverse data objects (e.g., nonspatial data, GIS coverages, image files) are more uniform and integrated. We are in the initial stages of designing a client-server based information system with an enlarged scope and a metadata structure which is shared by all 'data domains', including spatial and non-spatial data, images, and bibliographies. Metadata provide a suitable basis for integration efforts because we can adopt standards in data domains where none exist as well as improve those already in existence. Once standard metadata are defined for all data domains, we propose to build a normalized metadata database. This will serve as a basis for queries within and across data domains as well as dynamically creating web pages and future capabilities to handle queries.

We propose to go through a formal development cycle starting with a specification of the scope and functionality of the system with broad input from PI's and other researchers. We propose to establish minimum metadata standards in each data domain, assemble them into a single relational metadata database, and define how metadata connect to the multiple data objects in the system. While each data domain will be free to create its own tailor-made environment(s), we envision needing to specify a few generic applications related to production and access. We see the development and implementation of the new system as a gradual and long-lasting process, progressing unevenly across the various domains and tasks. We see future opportunities to host workshops among LTERs to help develop a prototype Network Information System for the LTER Network, building on our experience with LIDET, NASA, and other interdisciplinary, intersite research projects.

Another major focus of our future efforts will be working with other LTER Information Managers to develop a curriculum for Environmental Information Management. We perceive a new niche developing for graduates who have a grounding in both the science as well as the technical aspects of information management. Critical issues confronting scientists and policy-makers (e.g. global change, sustainability, and biodiversity) are requiring interdisciplinary collaboration and syntheses across cultural, spatial, and temporal scales much larger than traditional ecological studies. These individuals must be scientists who can create a cohesive information management strategy interfacing the analytic and technical developments in science. Currently there is no one place to learn and build the requisite set of skills to tackle such critical issues.

We have plans to augment Stafford's existing graduate course, FS 523: Natural Resources Data Analysis, to help meet this need. We intend to make more of our FSDB data accessible via the WWW and develop a prototype "collaboratory", i.e., researchers working together despite their geographic separation, with colleagues at the Sevilleta LTER video conferencing over the Mbone using SHOWME software on Sun workstations. The Sevilleta LTER has a similar course, Research Information Management. Students would take these two courses and then do internships at various LTER and other participating sites, such as the San Diego Supercomputer Center. This approach will facilitate our ability to extend our curriculum and instruction off-campus through electronic means. We envision students acquiring skills enabling them to move freely within this electronic information environment. The development of this prototype will promote an interactive learning style with both colleagues and information accessible via the WWW. Eventually, we envision extending this prototype across the LTER and ILTER sites.

Section 6. Outreach efforts.

Outreach efforts of Andrews LTER and related programs have been intensive and far reaching with audiences of scientists, students, land managers, public, and policy makers. All of these activities have been boosted by national and global attention to the region's natural resource issues and the important place of the Andrews Forest program in the changes in policy and management.

Communications take place through our respective institutions, such as the university's Resident and Continuing Education and Forest Service technology transfer programs. In 1991, we established the Cascade Center for Ecosystem Management, a research-management partnership involving Andrews-based researchers of Oregon State University and USDA Forest Service's Pacific Northwest Research Station and land managers of the Willamette National Forest, where the Andrews Forest is located. The mission of the Cascade Center is to develop new information about forest and stream ecosystems of the Pacific Northwest, develop and test management applications, and publicly discuss findings and their implications. Outreach to the public and land managers, a major role of the Cascade Center, is facilitated in part by John Cissel, Research Liaison, and Pam Druliner, Public Education Specialist, employed by the Willamette National Forest. The resulting close ties between land managers and researchers have contributed substantially to the development of new approaches to management of forest stands, riparian zones, landscapes, and watersheds in the Pacific Northwest.

In light of their scientific credentials, relevant science, and first-hand acquaintance with management issues based on these close working relations, many Andrews scientists have been called upon to provide input to policy makers on varied issues ([Table 6.1](#)). Andrews Forest-based science has contributed to public and policy discourse on old-growth forests, protection of stream and riparian networks, changes in silvicultural practices to sustain biological diversity, and possible hazards from introduction of pests on imported logs. Scientists' roles have varied. Federal scientists, for example, dominated in the Forest Ecosystem Management Assessment Team, that wrote the basic plan for management of 10,000,000 ha of Federally-managed lands in the Pacific Northwest, while university scientists have been part of National Academy of Sciences/National Research Council reviews of Federal policies. The opportunities for working at the science-policy interface have been highly varied. Information has been delivered to Federal Executive, Legislative, and Judicial branches. Written products of these efforts include the lengthy policy-input documents themselves (e.g., FEMAT 1993), publications concerning the scientific rationale for change in management (e.g., Hansen et al. 1991; Franklin 1992; Swanson and Franklin 1992; Lattin 1993), and examination of approaches to implementing new policies (e.g., Grant et al. 1994, Montgomery et al. 1995).

An important dimension of outreach is direct participation in public processes where research has a central role. Our past actions at the research-management interface resulted in the Andrews Forest being the nucleus of one of the 10 Adaptive Management Areas (AMA) in the Northwest Forest Plan (FEMAT 1993). The objective of AMAs is to develop new approaches to forest and watershed management with more effective community involvement. AMA activities include sponsoring social science work with Forest Service funds (e.g., Shindler et al. in press) and participation in public involvement and education efforts.

Educational activities associated with Andrews LTER include university classes in forest, stream, and landscape ecology, entomology, zoology, geomorphology, and information management on campus and in the field. Over a dozen classes from universities and colleges have regular annual field trips to Andrews. Over 45 graduate students currently have Andrews-based thesis projects. Over 70 undergraduate students from more than 50 institutions have worked and studied at Andrews during LTER3 in our summer Research Experience for Undergraduates programs.

Training and two-way communications with land managers are extremely important outreach efforts of Andrews LTER through the Continuing Education program of OSU and the Cascade Center. LTER and other research yields information communicated to managers through field demonstrations of actual practices, prototypic planning for management of large (7000-20,000 ha) landscapes, workshops, field tours (ca. 50 per yr), videotapes and publications targeted for the land manager audience, individual consultations, classroom training, and other media.

Communications with the general public have occurred through the popular media, public field tours, and programs sponsored by the Cascade Center ([Table 6.2](#)). Major, Andrews-based articles have appeared in the New York Times, Science, Discover, Wilderness, as well as theregion's largest newspapers. The thrust of these articles covers a broad range--general appreciation of the wonders of nature, new scientific findings, policy change, conservation, and conflict resolution.

Our program for visiting foreign scientists has been very active during LTER3. Extended visits (3 mo to 2 yr) include scientists from Sweden (1), Japan (3), Israel (1), France (2), Russia (1), and China (5). Some of these visitors have returned home to write articles in their native language about science and management lessons learned (Li and Franklin 1988, Nakamura 1992a, b). Most of the visiting Chinese scholars have come for training in remote sensing, data management, and biodiversity research under support from the World Bank to the Chinese Ecosystem Research Network.

Collectively, these activities have had a tremendous impact on changes in natural resource management in the region and beyond. On public lands, a major shift has taken place from commodity extraction with mitigation of ecological effects to using an ecosystem basis for management. Andrews Forest long-term research has been the major source of information for this science-based, ecosystem perspective. A change of this magnitude is a long-term, cumulative process--public, policy makers, land managers require a certain level of common understanding and agreement to make such a change. This is an excellent example of how long-term science has been and will continue to be an important contributor to society's efforts to learn how to live in ecosystems.

Section 7. Budget and Budget Justification.

A total of \$3,360,000 is requested for the next 6-year funding period for the Andrews Forest LTER program. The itemized requests reflect the changing nature of the Andrews LTER program and the general changes in funding for basic research nationally. Budget reductions and future uncertainties from several funding sources (university, Forest Service, National Science Foundation, NASA, etc.) have forced us to be conservative with the proposed LTER4 budget. The flat funding for LTER projected for the next six years amounts to about a 30% budget cut based on a 4% inflation rate. Given these circumstances, we will rely on our annual review of progress and planning for the next year (Section 4) to steer through LTER4.

Early in the Andrews LTER program we installed large experiments and designed a research measurements/monitoring program to track long-term behavior of selected systems and populations. During each previous funding period various projects were sequenced and the budget reflected their phased startup. Our program has evolved into one that is best characterized as a blend of long-term experiments, synthesis efforts and smaller, more targeted studies and experiments to examine selected processes. As a consequence, the LTER4 budget remains quite balanced among the Components and Synthesis Areas throughout the 6-year funding period.

The bulk of the budget supports long-term experiments and measurement programs and information management that comprise the Component research program. In order to undertake the Synthesis Area work we plan some cost savings in continuation of past Component studies and redirection of some scientist effort not LTER-funded and contributed. Cost savings will be gained by reducing sampling frequency in long-term studies where experimental designs permit and using field data loggers (see equipment) to reduce data entry costs. We plan to conduct work in each Synthesis Area during much of the LTER4 with some scheduling of intensive periods--the Species-Ecosystem Function and Landscape Dynamic Synthesis Area will get greatest attention in the middle years of LTER4. In each case we expect to budget adequate funds to accomplish a significant level of work (several significant publications), and then, if the line of study is fruitful, ancillary funding would be pursued to support further work. No new experiments are planned for LTER4 because they require a substantial infusion of new support that will not be possible given the projected flat funding for LTER4 and the priorities we place on continuing essential studies developed over the past 15 years of LTER and the Synthesis Area.

Our primary intent in this proposed budget is to guarantee enough salary support for our scientists and technicians to ensure the success of continuing our Components and addressing Synthesis Areas. New areas of research, described in the Synthesis Areas, capitalize heavily on existing data derived from previous Component studies.

The single biggest request in the budget is for salaries/wages totalling about \$1,616,000, or roughly 60% of the total direct costs. The size of the request is indicative of our stabilizing the long-term field measurements programs associated with our Components and providing support for the research to be conducted in the Synthesis Areas. The request includes fractional FTE (full-time equivalents) for 3 senior personnel (Harmon, Griffiths, Garman) who play critical leadership roles in several of our Components as well as Synthesis Areas. Harmon and Griffiths

share responsibilities for the Carbon and Nutrient Cycling Component. Harmon will head the Effects of Species Synthesis Area, and works closely with McKee and Acker in the Vegetation Component. Griffiths will head the Early Succession Synthesis Area. Garman has key roles in modeling efforts in several Components (Vegetation, Biodiversity) and Synthesis Areas (Biodiversity and Function, Landscape Dynamics).

The salaries and wages also includes fractional FTE for 6 professionals, such as our LTER data manager (Spycher), Andrews Forest local area network manager and on-site data manager (Bierlmaier), leader for the aquatic LTER field crew (Ashkenas), and other research assistants in several Components (Biological Diversity, Carbon and Nutrient Cycling, and Hydrology).

In addition, we make extensive use of both graduate students and undergraduates as field assistants, and about \$285,000 is requested for student salaries and graduate student support, and about \$65,000 for their tuition.

Oregon State University's rates for fringe benefits vary greatly among and within categories. Rates for academic and classified employees are a function of monthly salary, and vary between 38 and 45 percent of monthly gross. We are assessed 10 percent for summer students and 5 percent for student salaries during the academic year. There is no charge for graduate research assistants.

The Andrews Forest is located 95 miles (2 hours) from campus and study sites in Andrews Forest and satellite areas accounts for substantial additional travel. This requires a substantial budget for local travel and just under \$150,000 is requested for the funding period.

Only \$13,000 is requested for equipment for this funding period. This request is for 2 field computers/data loggers. The Vegetation Succession Component has been very successfully using these machines to reduce data entry costs, shorten the time to begin analyses, and generally make field data acquisition more efficient. These 2 new units would be shared among the Component projects.

The amounts requested for supplies and services include \$4000 per year for publication costs, and \$20,000 per year for chemical analyses and supplies and materials among the 7 Components. About \$4500 per year is requested for computer support, which is primarily for fees for use of the workstations in the GIS lab. We also budget about \$25,000 for consultant services over the first 3 years, which is for assistance in mapping leaf area over our experimental watersheds as part of the Small Watersheds Synthesis Area.

In the past we have enjoyed strong institutional support from Oregon State University and the US Forest Service's Pacific Northwest (PNW) Research Station. This support has taken the form of contributed time of the scientists involved (11 Departments, 4 Colleges of OSU and numerous PNW scientists and professional staff), direct salary support for McKee (Director of Andrews Forest), and infrastructural support for our data management activities in general as well as specifically for Stafford's Quantitative Sciences Group.

We expect OSU to continue their support for LTER. Indeed, Dr. Joy Hughes, Associate Provost for Information Services, has promised \$12,000 per year for 6 years to Stafford's Information Sciences Group to help pick up the shortfall from reduced LTER funding. Negotiations are underway concerning additional College of Forestry and University matching funds. A letter documenting decisions will be forthcoming.

The Washington (D.C.) Office of the Forest Service has contributed \$50-60,000 per year directly to Andrews LTER-related activities for the past five years. We have used this support for the hydrological and meteorological measurement programs and headquarters facilities. We are told to expect this support to continue.

At the PNW Station- and Project-levels we enjoy continued support in excess of \$200,000 per year for the hydrology research and the meteorological network at the Andrews Forest as well as support for the permanent vegetation plot network. A high degree of support will remain (see letter of support from H. Gucinski).

In summary, we feel the proposed budget best balances our needs and resources in this uncertain time. Two things that will not change--LTER will continue the central to the overall Andrews Forest program and LTER funding will be used to leverage support from other sources.

Figures and Tables

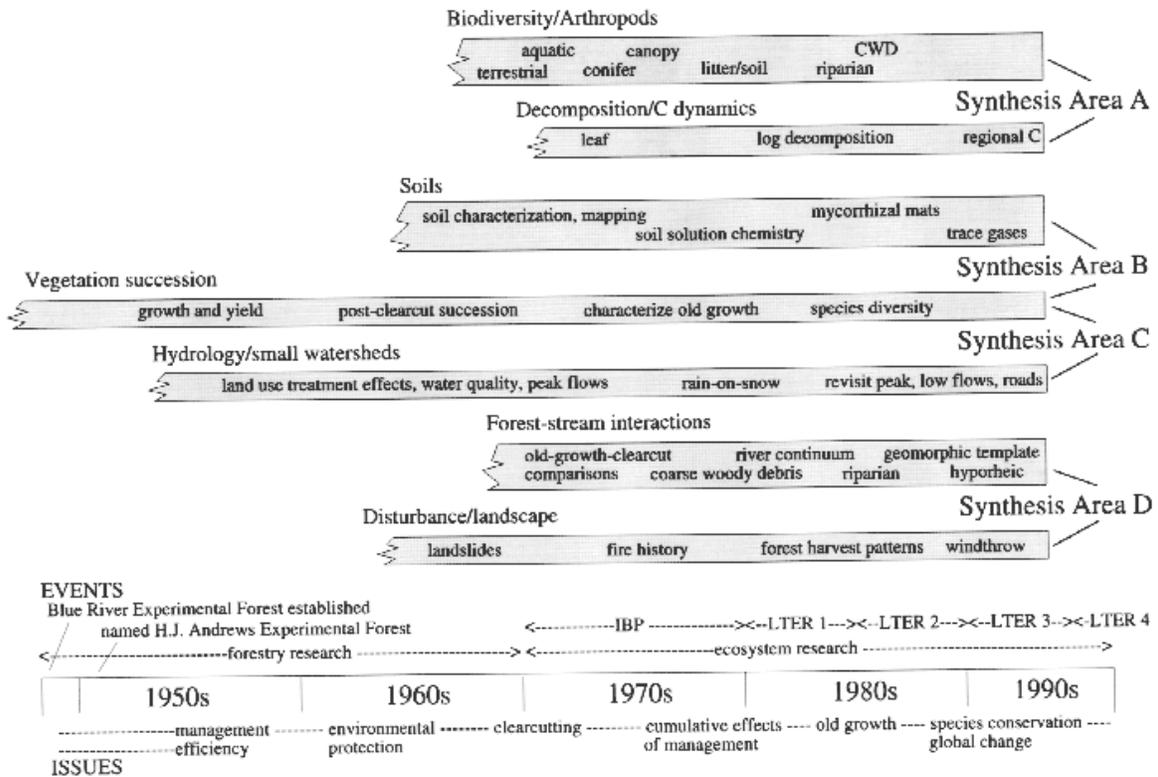


Figure 1.1. Time line of selected, LTER-related research, programmatic, and issue history of Andrews Forest leading to synthesis areas in LTER 4. All research components, shown as gray bars, will continue in LTER 4.

Figure 1.1 Historic time line of LTER-related programs and issues of the Andrews Forest.

Figure 1.2. Major (\$100,000+), current research grants/projects closely linked with Andrews LTER. See Current and Pending (Section 9) for information on funding level, duration, and co-PI's. Underlined headings indicate the LTER component most related to these research projects. Ecosystem management heading refers to science-management-policy programs. PNW indicates USDA Forest Service, Pacific Northwest Research Station.

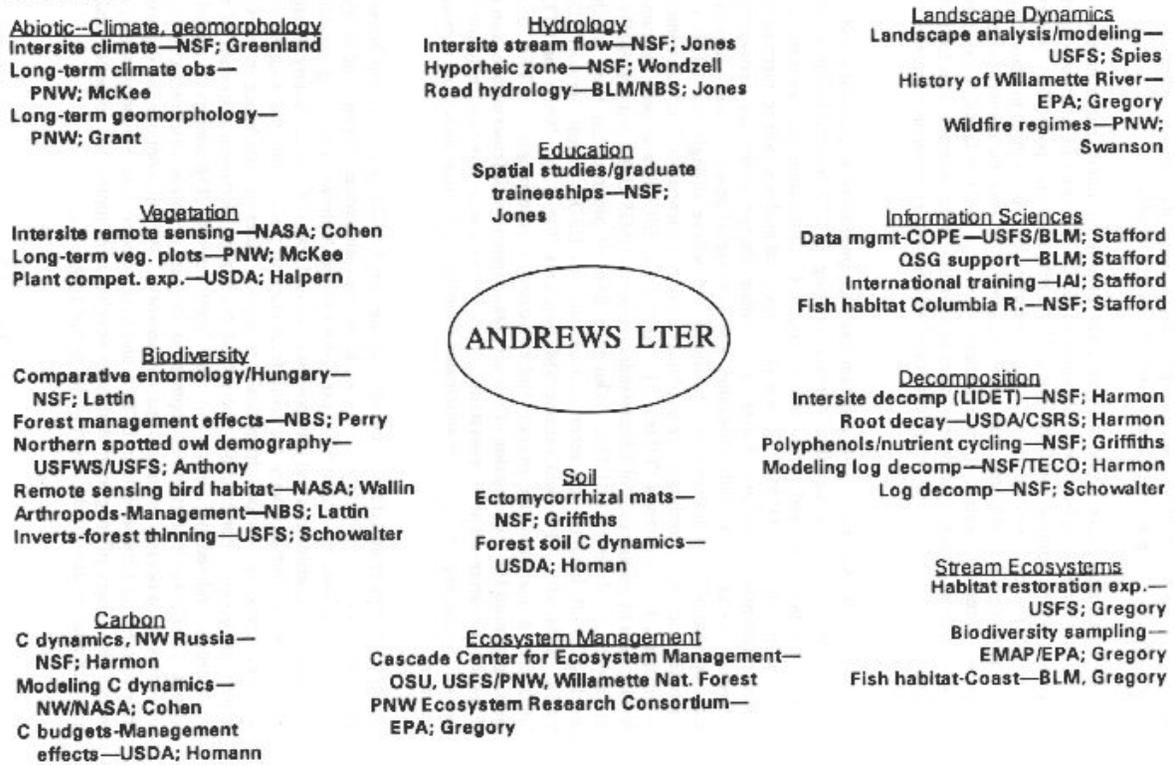


Figure 1.2 Major research grants/projects closely linked with Andrews LTER.

Table 1.1 Long-term experiments currently maintained by the Andrews LTER.

Table 1.1. Long-term Experiments Currently Maintained by the Andrews LTER.

Experiment	Objective	Duration	Sampling Interval (Years)
Young-stand productivity	Test influence of stand structure and nutrient availability on production in Douglas-fir plantations	1981-	1-5
Young-stand thinning and diversity	Test influence of thinning on future stand structure and non-timber production in ~40 year-old plantations	1995-	1-5

Terrestrial log decomposition	Test effect of substrate quality and decomposer colonization on decomposition and nutrient release	1985-2185	2-5
Stream/terrestrial log decomposition	Test the effect of moisture in controlling decomposition and nutrient release	1985-2015	4
Woody litter size decomposition	Test the effect of size of woody debris on decomposition and nutrient release	1985-2005	2
Root decomposition	Test effect of species and size of woody roots on decomposition and nutrient release	1995-2015	1-2
LIDET--long-term litter decomposition	Test effect of substrate quality and climate on rate of litter decomposition and formation of stable organic matter	1989-2000	1
Native litter decomposition	Compare native litters to LIDET standard species to test for substrate decomposer interactions	1993-2000	2
Quartz Creek log introduction	Test effects of logs on channel morphology and fish populations	1988-1994	1-5
Pool complexity	Test effects of different degrees of woody debris complexity on vertebrate communities in streams	1995-	1
Small watersheds - 1,2,3, 6,7,8,9,10	Test effect of timber harvest, site preparation and road construction on hydrology, sediment, vegetation succession, and nutrient balances	1962-	Continuous to 5

Table 1.2. Meteorological network at the Andrews Forest, operated jointly by Oregon State University and the U.S. Forest Service, Pacific Northwest Research Station. A more detailed description of the network is available at the Andrews Home Page [<http://www.fsl.orst.edu/lter>].

Station Type	Start Date	Elevation (m)	Variables	Time Resolution
AEF Tier 1 * Stations			Wind speed & direction	hourly
Primet	1972	430	incoming visible radiation	15 min
CenMet	1995	1020	precipitation	5 min
VanMet	1987	1265	air temperature (@ 1.5, 2.5, 3.5, 4.5 m)	15 min
UpLMet	1994	1300	soil temperature (@ -10, -20, -	

			50, -100 cm)	hourly
			soil moisture (@-10, -20, -50, -100 cm)	daily
			relative humidity (@1.5 or 4.5 m)	hourly
			dewpoint (@1.5 or 4.5 m)	hourly
			vapor pressure deficit (@ 1.5 or 4.5 m)	hourly
			snow, moisture equivalency	5 min
			snow melt lysimeter intake	5 min
Precip. chemistry				
Chem shed	1968	430		
			precipitation chemistry	weekly
NADP	1980	430		
HI-15	1987	925		
Precipitation only				
3 recording	1952	430-	precipitation	hourly - recording
5 storage		1330		daily - storage
Thermograph only				
In-stand - 13 stations	1970	420-	air temperature (heights vary)	daily
			soil temperature (10, 20, 30 cm depth)	
In-stream - 6 stations		1500	stream temperature	

*(exceeds a Level-3 LTER station)

Table 1.3. Gauged watersheds and associated programs of long-term measurements in the Andrews Forest. Forest vegetation in watersheds 1, 2, 3, 9, and 10 was predominantly 400-500 year-old Douglas-fir/western hemlock. Watersheds 6, 7, and 8 were 100-130 year-old Douglas-fir. Andrews Forest occupies the entire Lookout Creek watershed.

Watersheds	Area (ha)	Elevation (m)		Management History	Start of long-term measurement record				
		Min.	Max.		W	C	S	B	V
Experimental									
1	96	460	990	100% clearcut (1962-1966)	1955	1962	1957	1957	1962
2	60	530	1070	control	1955	1962	1957	1957	1981
3	101	490	1070	6% roads (1959) 25% clearcut (1963)	1955	1962	1957	1957	1962
6	13	880	1010	100% clearcut (1974)	1964	1972	1972	----	1971
7	15	910	1020	100% partial cut (1974)	1964	1972	1972	----	1971
8	21	960	1130	complete cut (1984) control	1964	1972	1972	----	1971
9	9	425	700	control	1967	1969	1969	1973	1971
10	10	425	700	100% clearcut (1975)	1967	1969	1969	1973	1973
Other									
Mack Creek	600	760	1600	10% clearcut (1965-1985)	1980	1980	1980	----	1977
Lookout Creek	6400	400	1600	22% clearcut (1949-1991)	1949				
Upper Blue River	11900	400	1600	25% clearcut (1957-1991)	1949				

W = water discharge

C = water chemistry, typically N, P, K, Ca, Na, Mg

S = suspended sediment

(C and S sampled with grab samples and proportional sampler (Fredriksen 1969), water chemistry record varies in continuity and diversity of variables among watersheds.)

B = bedload sampled in ponding basin

V = vegetation sampled on permanent plots (Table 1.4)

Table 1.4. Permanent vegetation succession plots maintained under the auspices of Andrews LTER.

Plot type	Number of plots	Size	Start date	Sampling interval (yrs)
Experimental watersheds				
# 1 & 3 1				
Trees	192	250 m ²	1980	3-4
Understory	192	4 m ²	1962	1-4
# 6 & 7 2				
Tree seedling & understory	111	4 m ²	1972	1-9
# 103				
Trees	36	150 m ²	1973	2-6
Understory	36	16 m ²	1977	2-6
Undisturbed watersheds				
4				
Trees	163	0.1 ha	1981	6
Shrub, herb	163	line intercept	1981	10
Reference stands & Growth-and yield plots				
5				
Sitka spruce zone	20	0.4-4.0 ha	1935	5
Western hemlock zone	70	0.2-4.0 ha	1910	5-6
Pacific silver fir/ mountain hemlock zone	36	0.25-6.9 ha	1972	5-6
Other	23	0.5-4.5 ha	1938	5
Other disturbances				
Quartz Ck - debris torrent	262	1 m ²	1986	5
Mt. St. Helens - eruption	120	250 m ²	1980	1-5

1 clearcut logged, broadcast burned (see Table 1.3 for dates)

2 clearcut logged, broadcast burned (#6); shelterwood logged, partially broadcast burned (#7)

3 clearcut logged, not burned

4 one watershed in mature forest and one in old-growth forest

5 45 to >500 year-old stands in major forest zones of western Oregon and Washington

Table 1.5. Major LTER and International LTER intersite projects involving Andrews LTER site and at least two other sites.

See Section 9 for more information.

Project Investigator	Project Title	Other Sites/Countries	Funding Source
LTER INTERSITE PROJECTS			
M.E. Harmon	LIDET - Litter decomposition	All	NSF
M.E. Harmon	Predicting decomposition dynamics of woody detritus in forest ecosystems	Mexico, Russia, USA	USDA-CSRS-TECO
D. Greenland	Intersite Climate Project	All	NSF
W.B. Cohen	Remote sensing of LAI, NPP, land cover	All	NASA
J. Jones G. Grant F.J. Swanson	Intersite streamflow	CWT, HBR, LUQ	NSF
T.D. Schowalter	Canopy invertebrates/response to disturbance	CWT, LUQ	NSF
T.D. Schowalter	Decomposition of oak logs	CDR, CWT, KNZ	NSF
INTERNATIONAL LTER INTERSITE PROJECTS			
S.G. Stafford M.E. Harmon	Chinese Ecosystem Research Network -- Training in ecosystem studies and data management	China	World Bank to CERN
M.E. Harmon W.A. McKee O.N. Krankina W.B. Cohen	Carbon dynamics of two conifer ecosystems	Russia	NSF
M.E. Harmon	Woody detritus dynamics of taiga forests	Russia	NSF
M.E. Harmon D.F. Whigham	Response of tropical forests to hurricane disturbance	Mexico	Smithsonian
J.D. Lattin	Commission on LTER -- Invertebrate biodiversity	Hungary	NSF

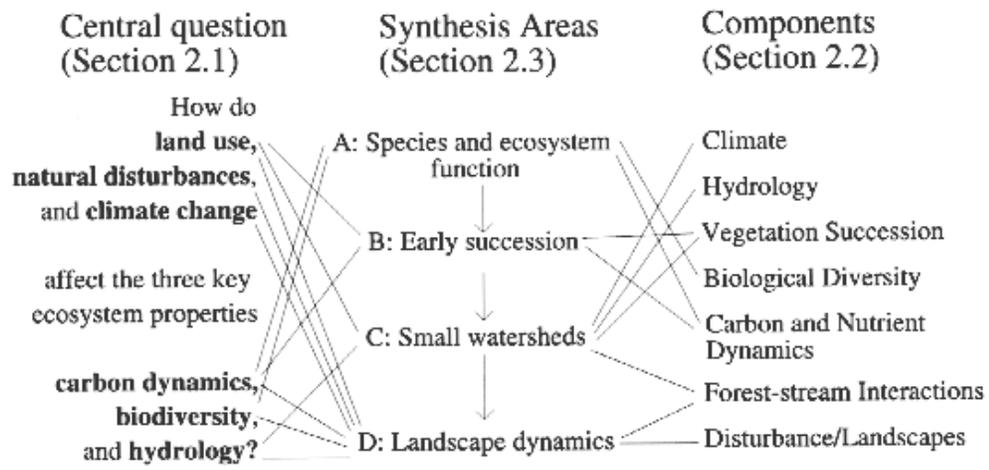


Figure 2.1. Relationships among central question, Synthesis Areas, and Components of Andrews LTER 4. Each synthesis area combines ongoing research from two or more components to address some aspect of the central question. Lines represent connections emphasized in the proposal, not all possible connections. Synthesis areas A, B, C, and D examine pattern influences on ecosystem properties at the species, patch, small watershed, and landscape scales.

Figure 2.1 Relationships among Central Question, Synthesis Areas, and Components of Andrews LTER4.

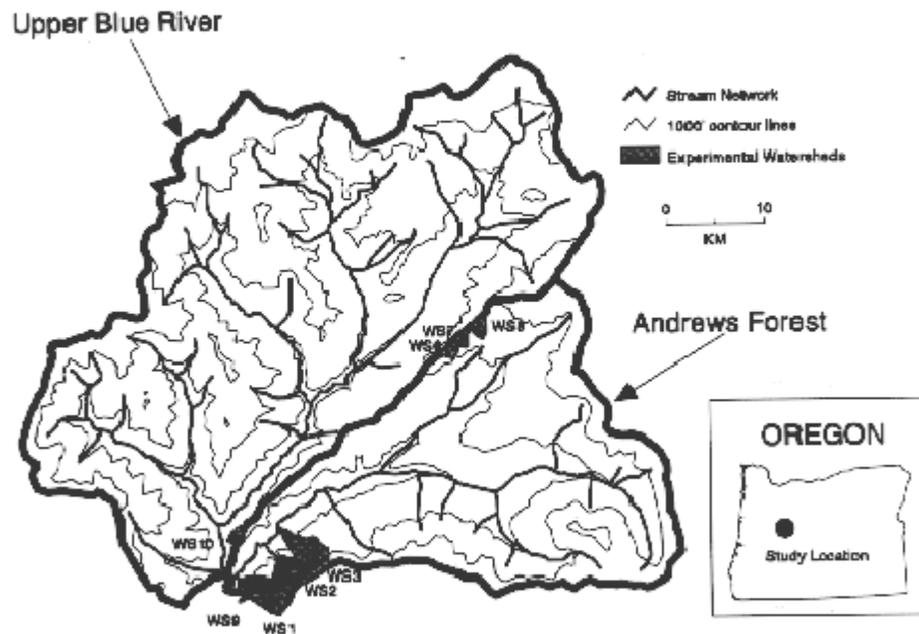


Figure 2.2. Map of the H.J. Andrews Experimental Forest, which includes the Lookout Creek watershed, and adjacent upper Blue River watershed. Also shown are locations of other gauged watersheds (Table 1.3).

Figure 2.2 Map of the H.J. Andrews Experimental Forest.

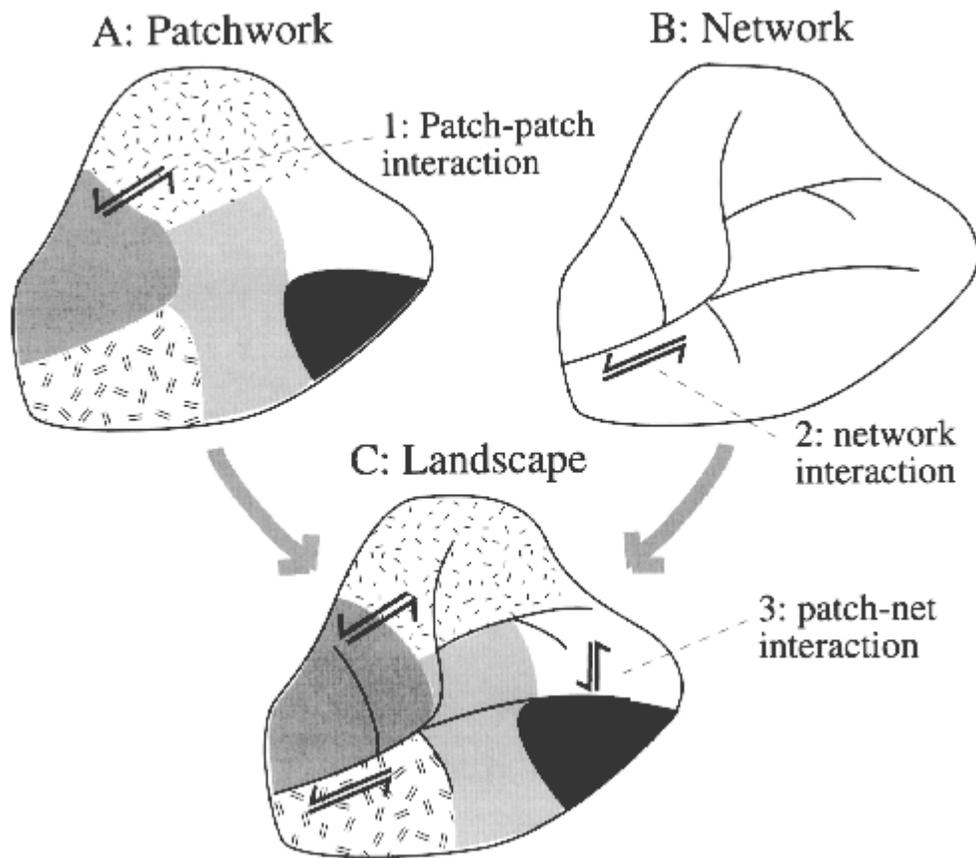


Figure 2.3 Landscapes: patchworks and networks.

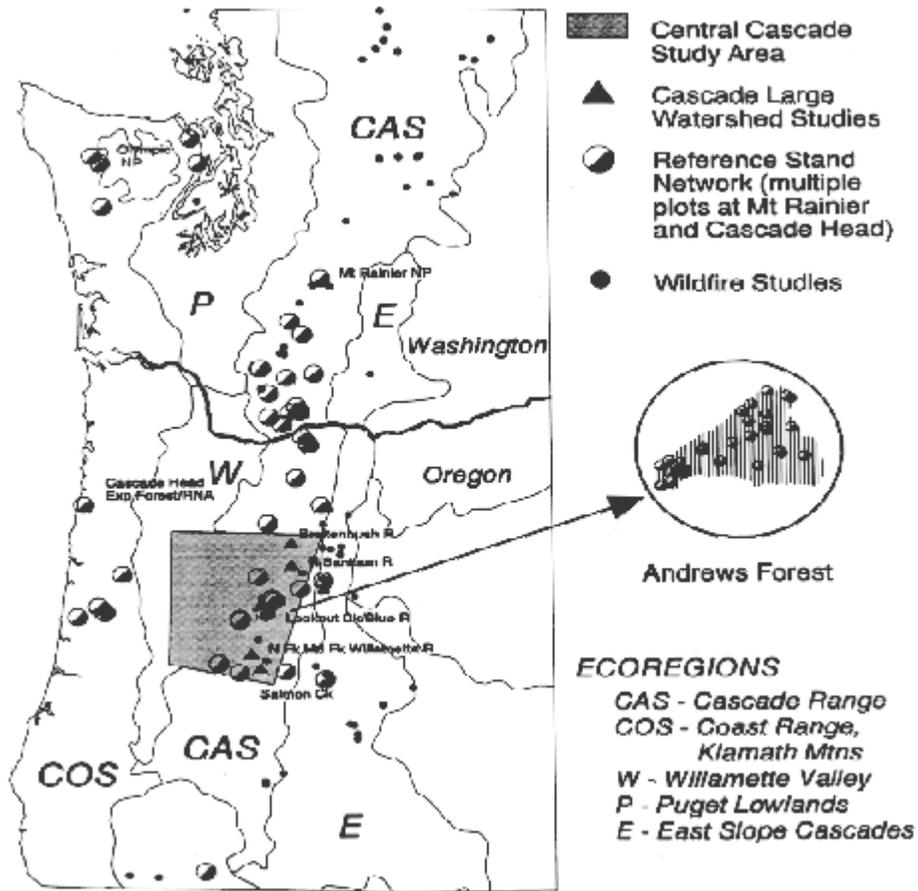


Figure 2.4 Regional context of Andrews LTER.

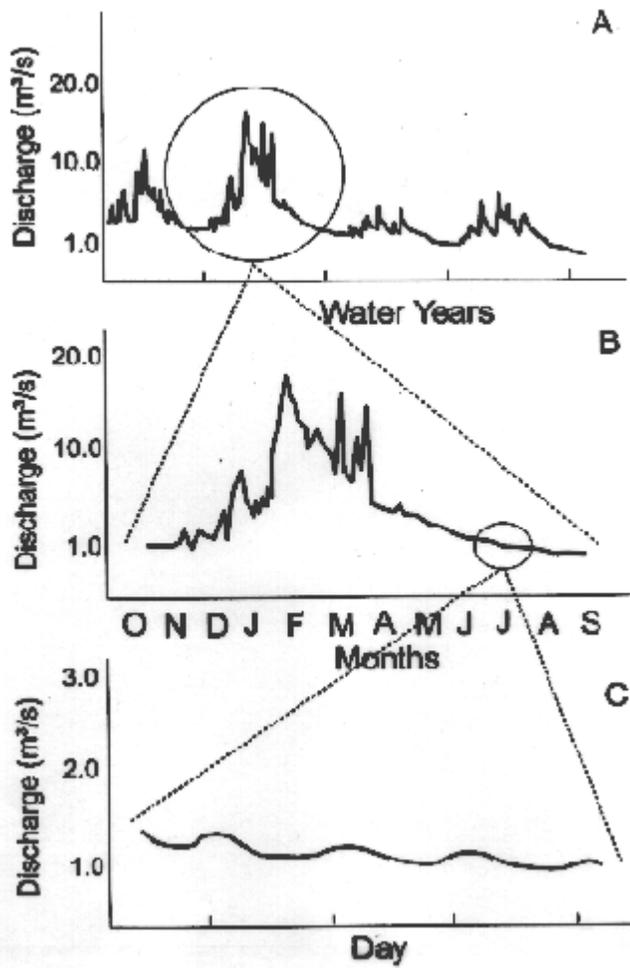


Figure 2.5 Inter-annual, annual, and daily hydrographs from the Andrews.

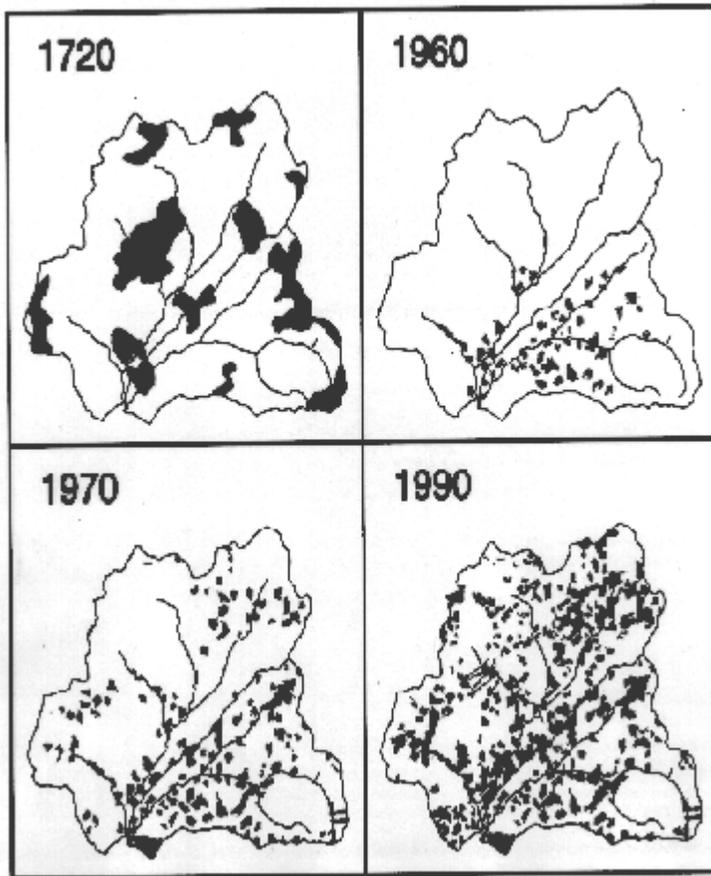


Figure 2.6 Map of Andrews Forest and upper Blue River watershed.

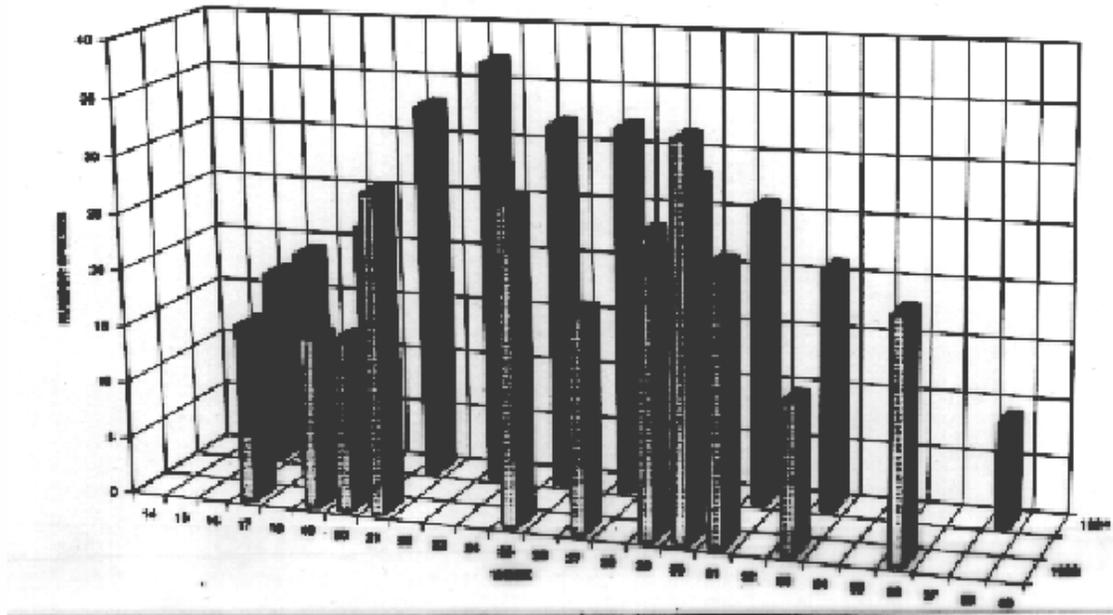


Figure 2.7 Temporal patterns of species richness of butterflies at the H.J. Andrews Forest.

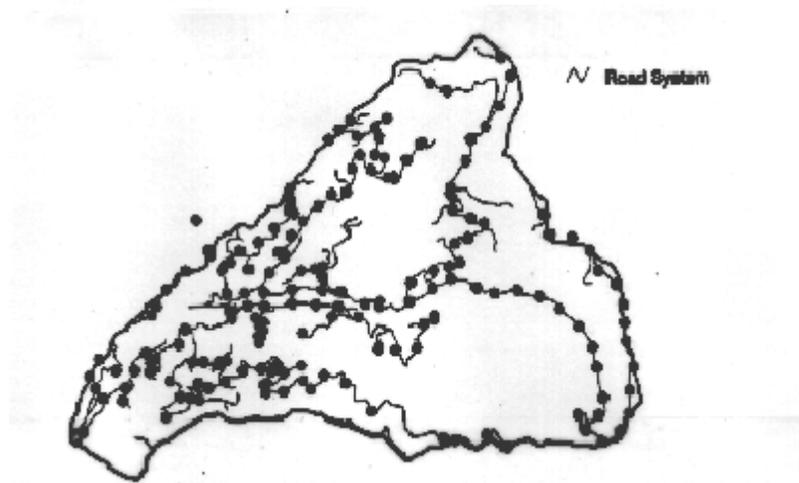


Figure 2.8 Locations of 184 Soil Processes Monitoring Sites.

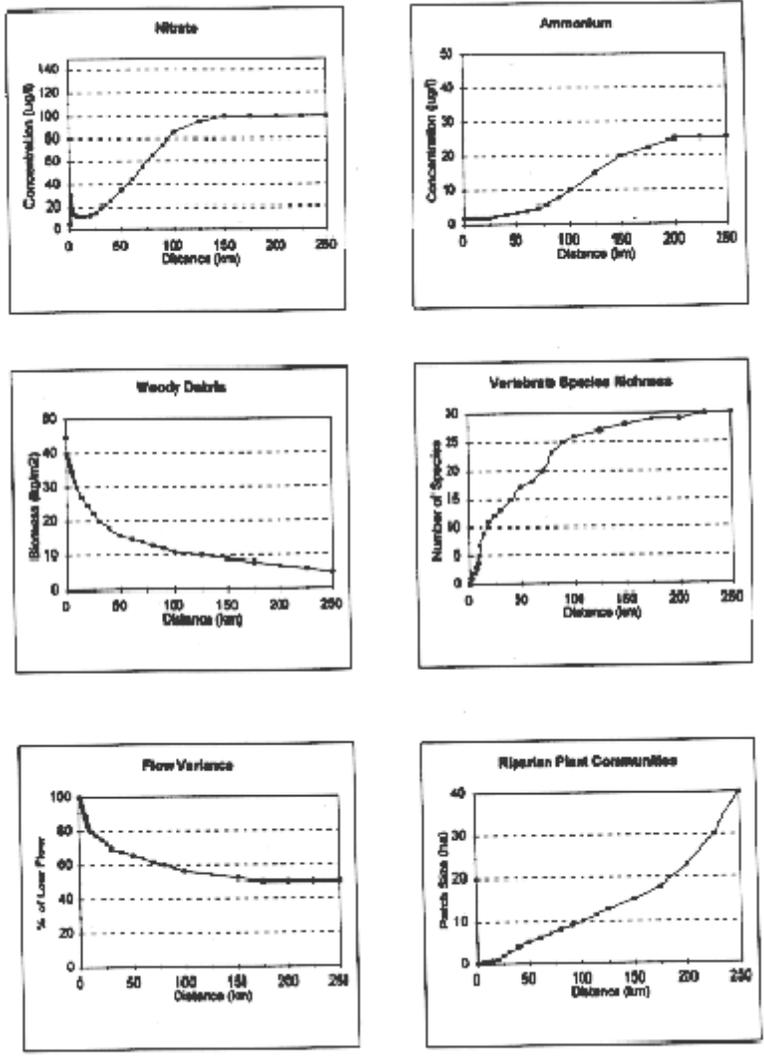


Figure 2.9 Results show how key stream ecosystem properties covary systematically downstream.

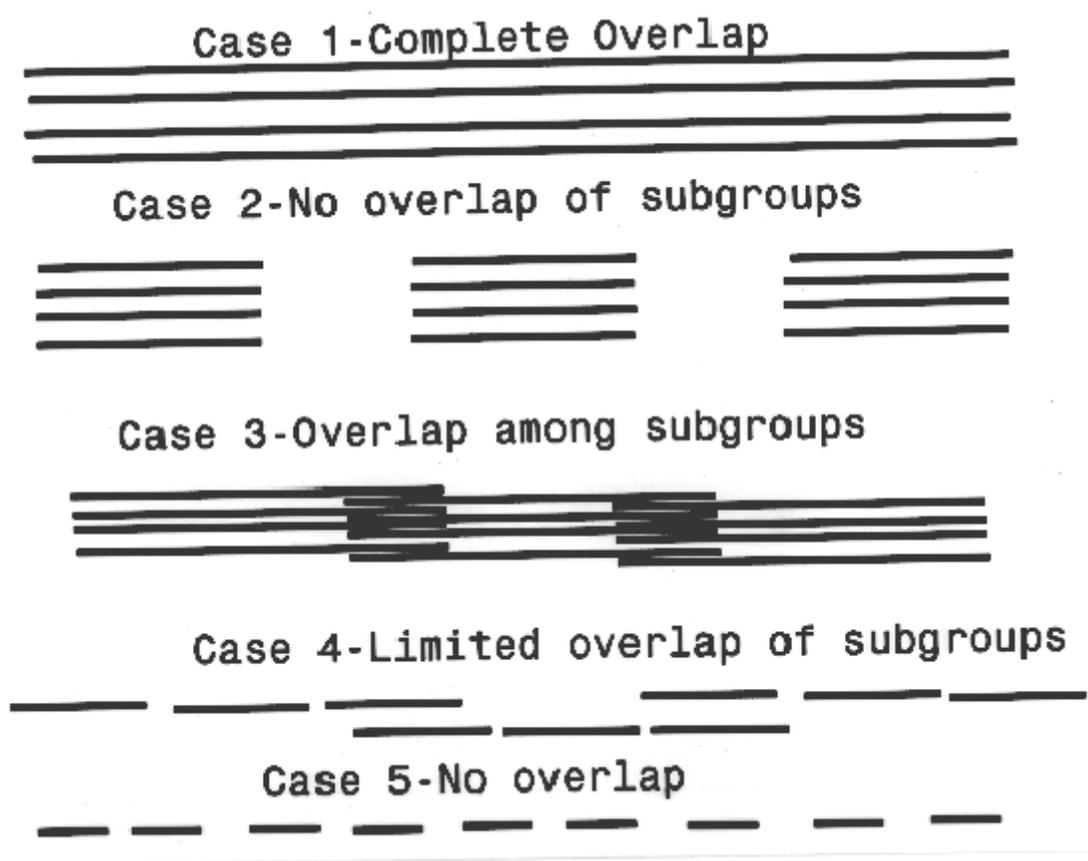


Figure 2.10 Possible structures of functional redundancy or overlap of species.

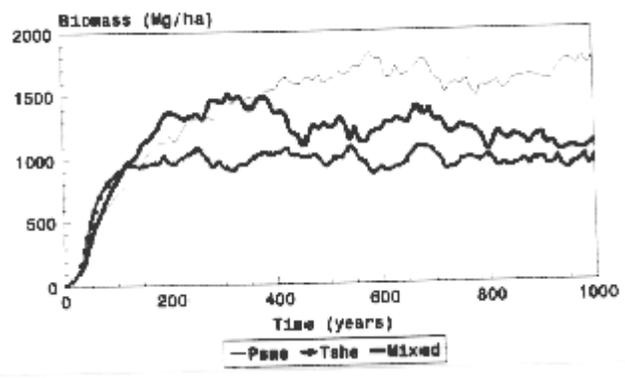


Figure 2.11 Comparison of hypothetical changes in live biomass following disturbance.

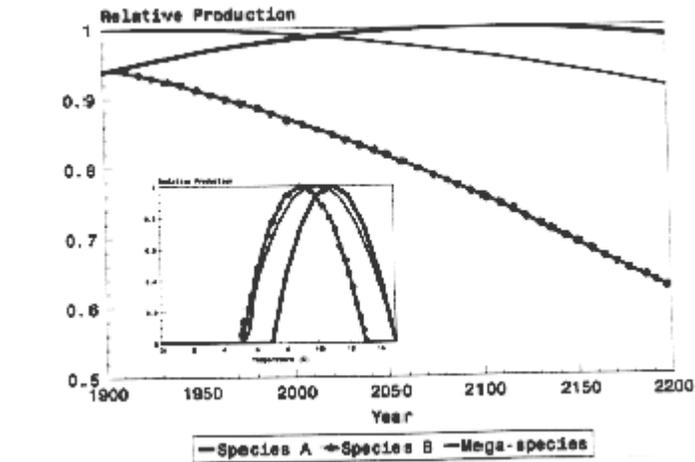


Figure 2.12 Hypothetical response to temperature increase of two conifer species.

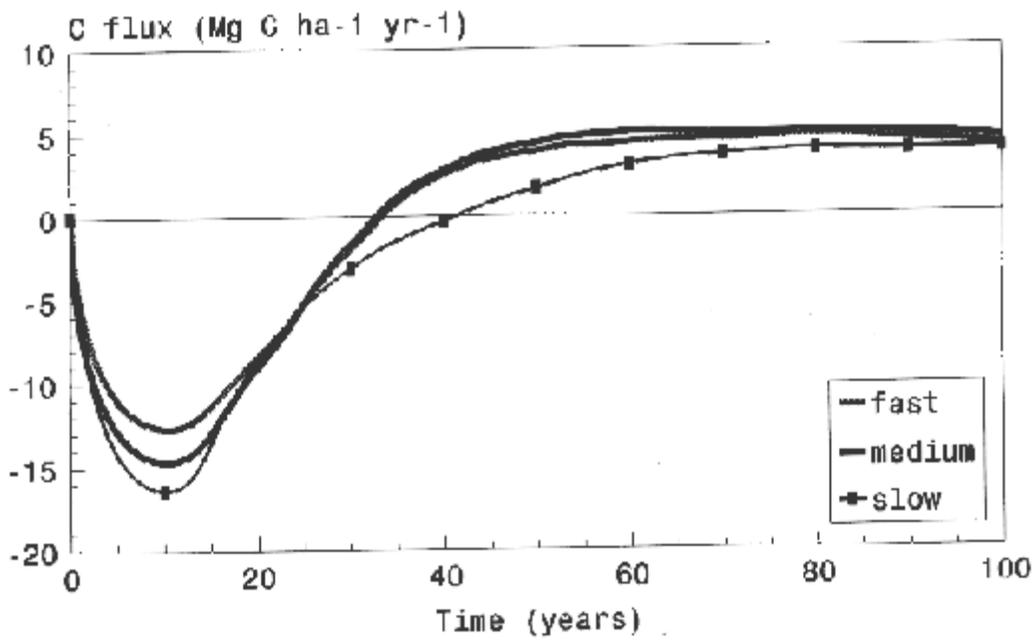


Figure 2.13 Hypothetical change in carbon flux following clear-cutting.

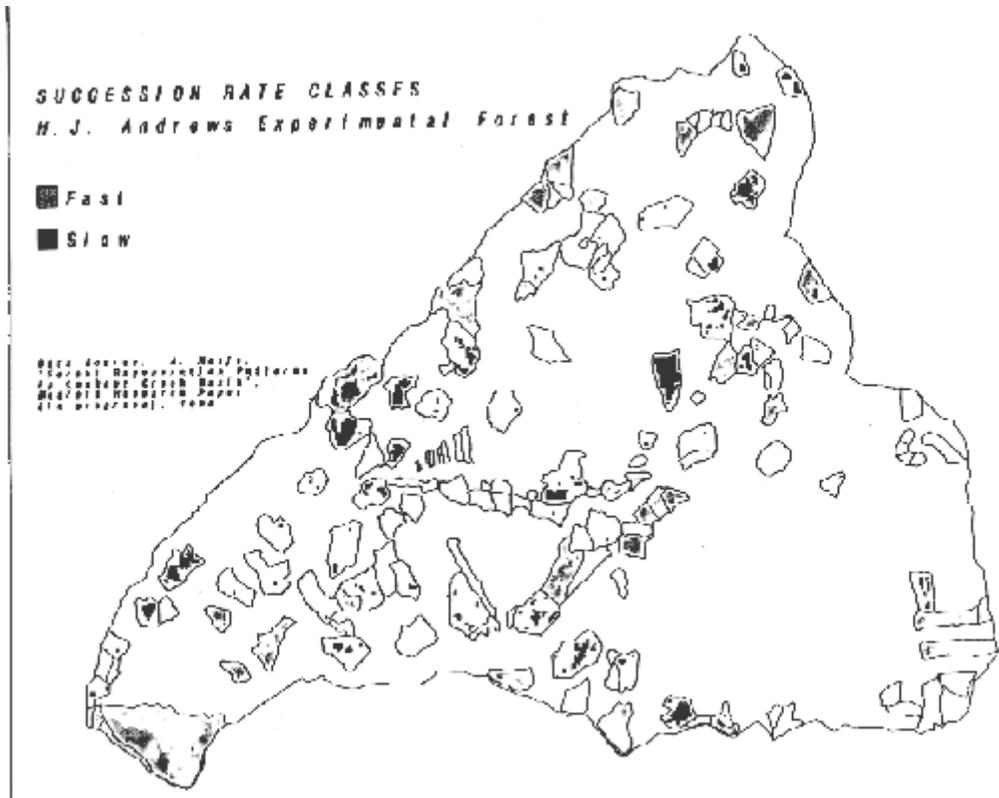


Figure 2.14 Location of clear-cut areas on the H.J. Andrews Experimental Forest.

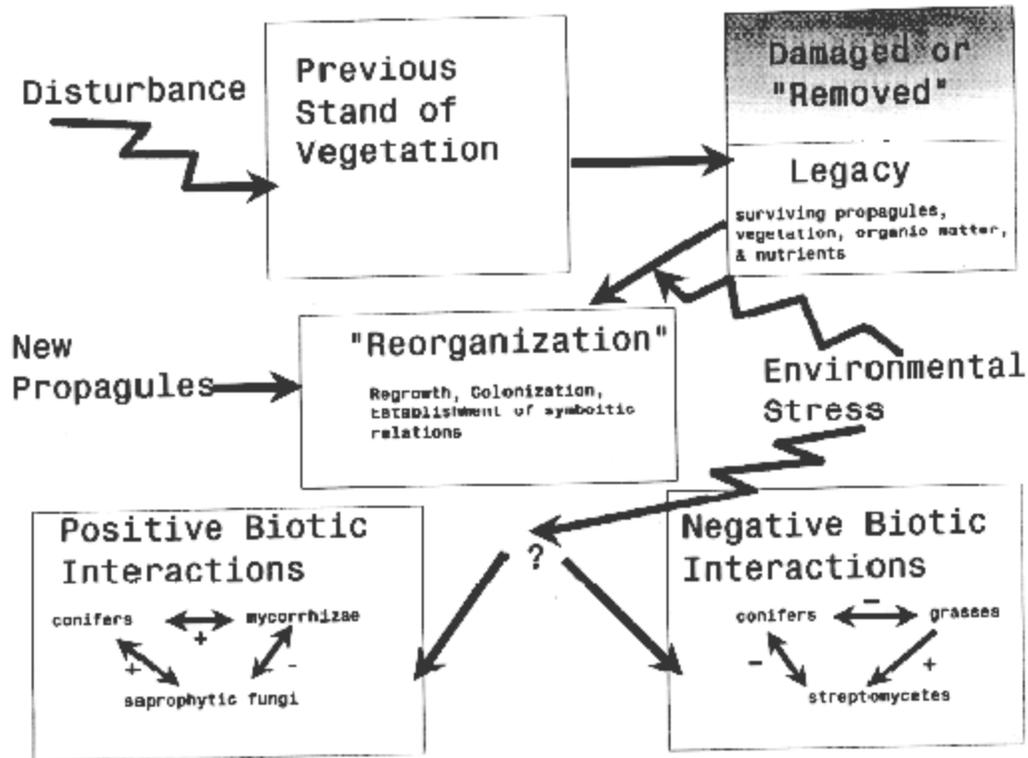


Figure 2.15 General conceptual model of disturbance, environmental stress, and biotic interactions.

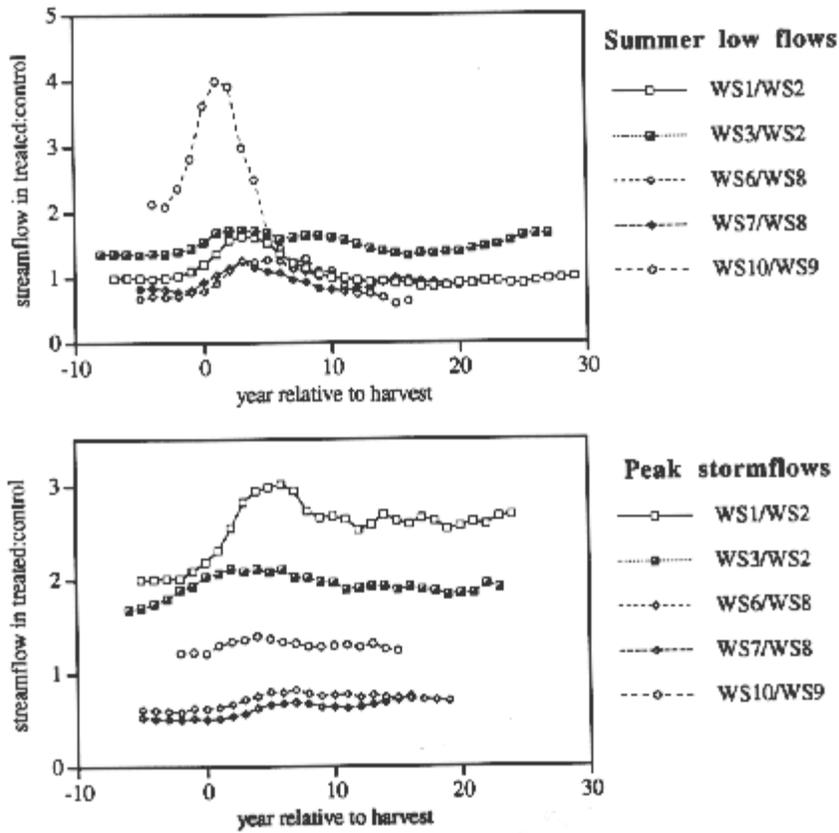


Figure 2.16 Long-term trajectories of streamflow in treated versus control watersheds.

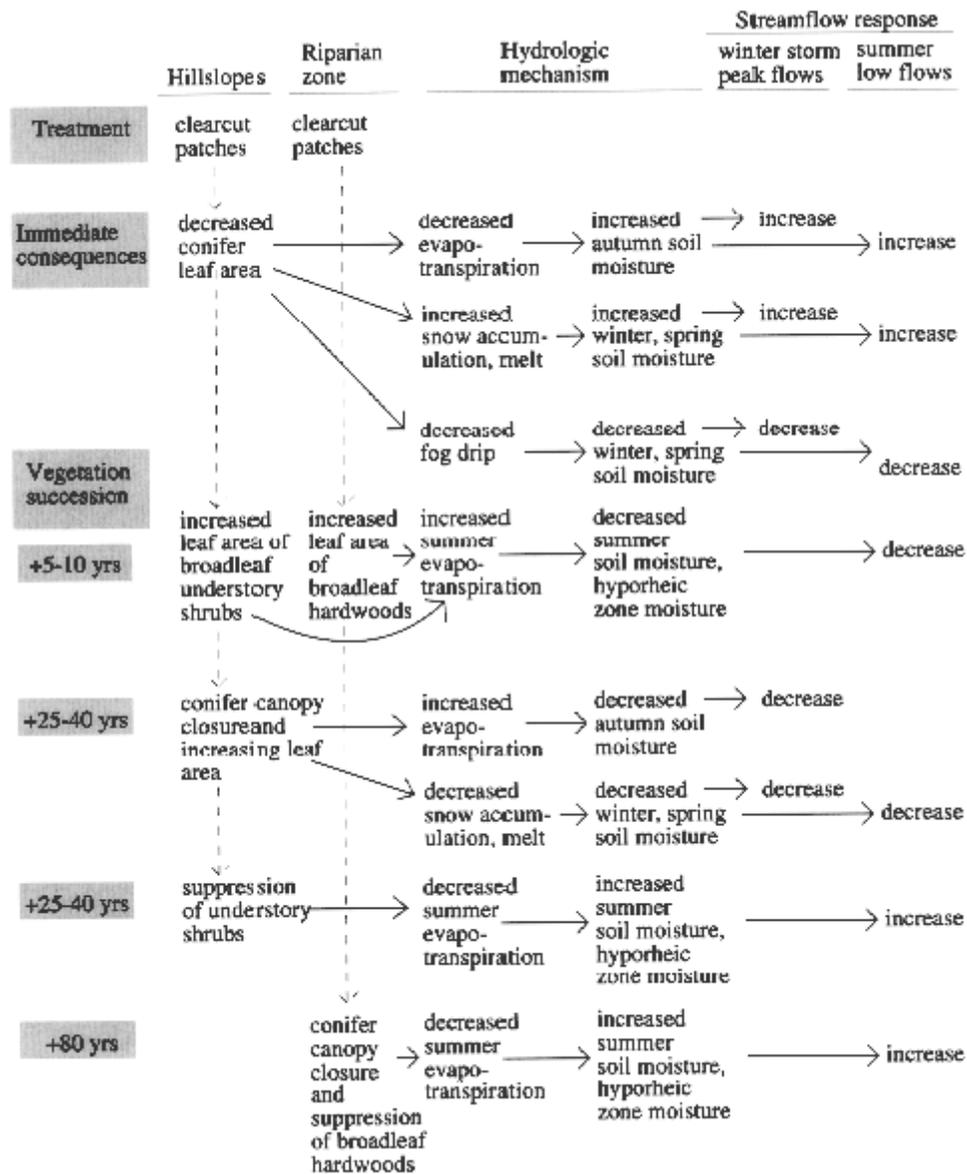


Figure 2.17 Conceptual model of post-clearcut vegetation succession. .

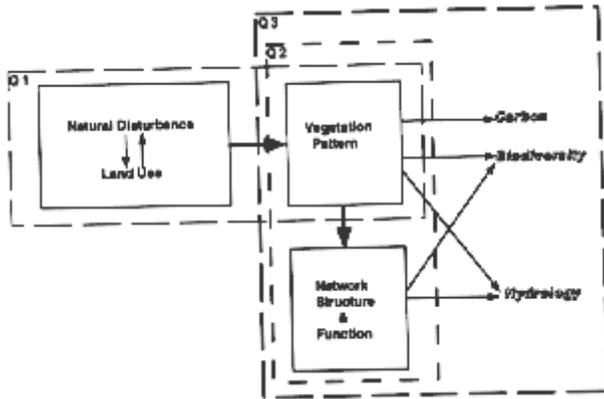


Figure 2.18 Schematic of the relationships among the three questions addressed in Synthesis Area D.

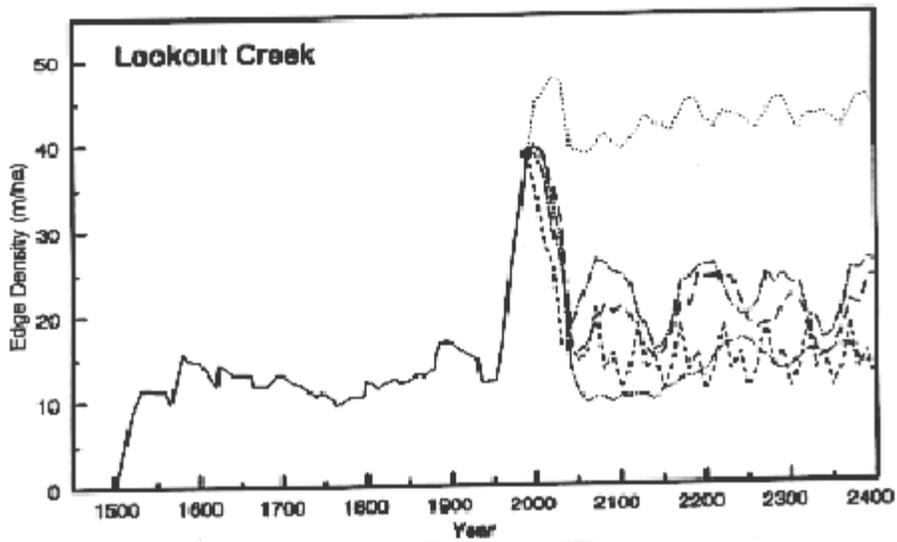


Figure 2.19 Variation in edge density in the Andrews Forest/Lookout Creek landscape.

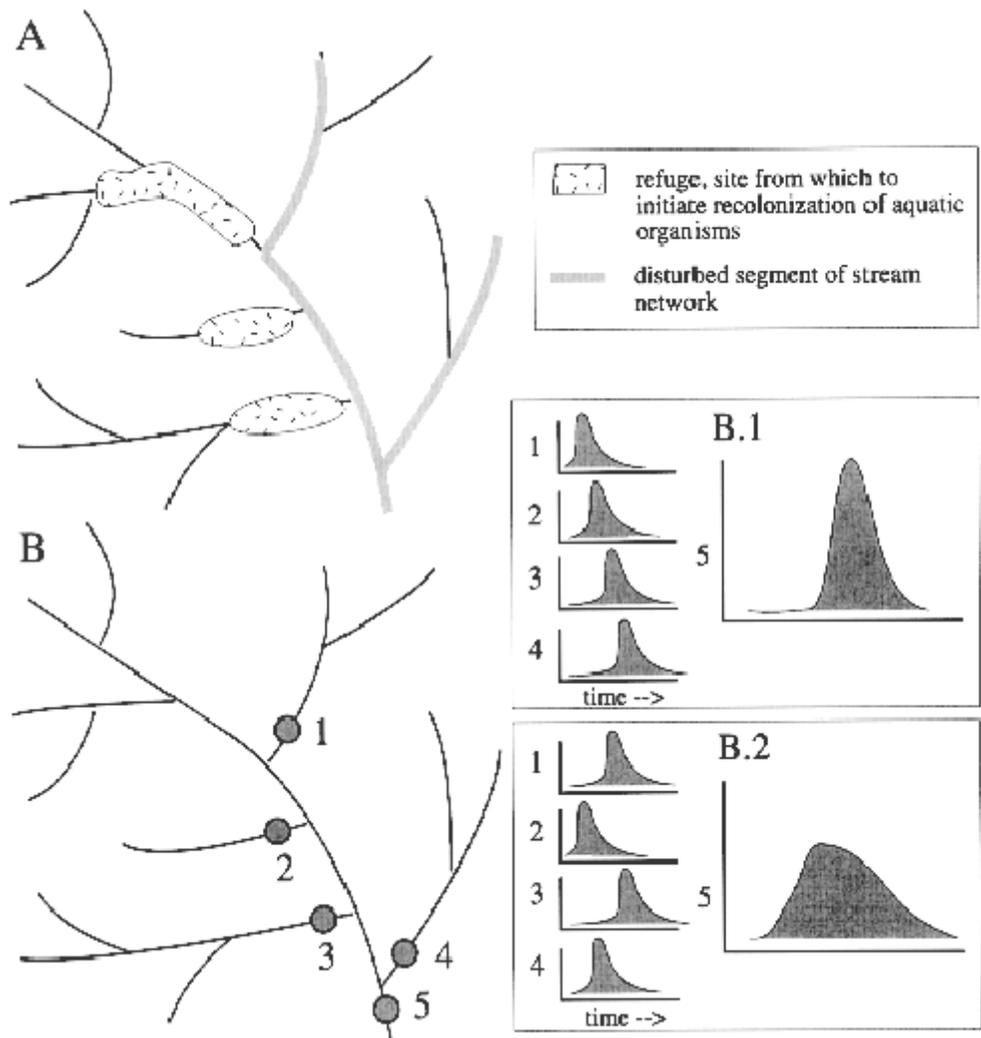


Figure 2.20 Examples of how stream/riparian network structures respond to upland patch disturbance.

Table 2.1. Variables measured in vegetation successional studies.

Measurements	Sampling intervals (yr)
Composition	3-4
Biomass	3-4
Growth of trees	3-6
Mortality of trees	1

Leaf area	3-6
Litterfall	12
Seedfall	2
Standing crop of woody debris	6
Inputs of coarse woody debris	1-5
Soil chemistry	6

Table 2.2. Questions to be answered by Synthesis Area research proposed during LTER4.

Central Question: How do land use, natural disturbances, and climatic change affect three key ecosystem properties: carbon dynamics, biodiversity, and hydrology?

Synthesis Area A. Effects of Species on Ecosystem Function.

1. To what degree do the attributes of species that affect ecosystem processes overlap?
2. In which situations can the attributes of species be aggregated and in which must species-specific values be retained?

Synthesis Area B. Early Succession.

3. Why does the speed with which conifers attain dominance after clearcut harvest vary across the landscape?
4. Which ecosystem properties are most sensitive to the rate of development of conifer dominance?

Synthesis Area C. Small Watersheds.

5. What are the spatial patterns of broadleaf and conifer succession within small watersheds, and how do they differ between riparian zones and hillslopes?
6. What are the potential mechanisms by which upland and riparian vegetation patches influence streamflow?
7. How do vegetation properties that affect the hydrology of small watersheds vary in the western Cascades of Oregon?

Synthesis Area D. Landscape Dynamics.

8. What are the historic and future potential ranges of vegetation patterns under natural disturbance, land use, and climate variability?
9. How is stream network behavior influenced by the arrangement of upland vegetation patches?
10. How do interactions among vegetation patches and stream/riparian networks affect carbon dynamics, biodiversity, and hydrology?

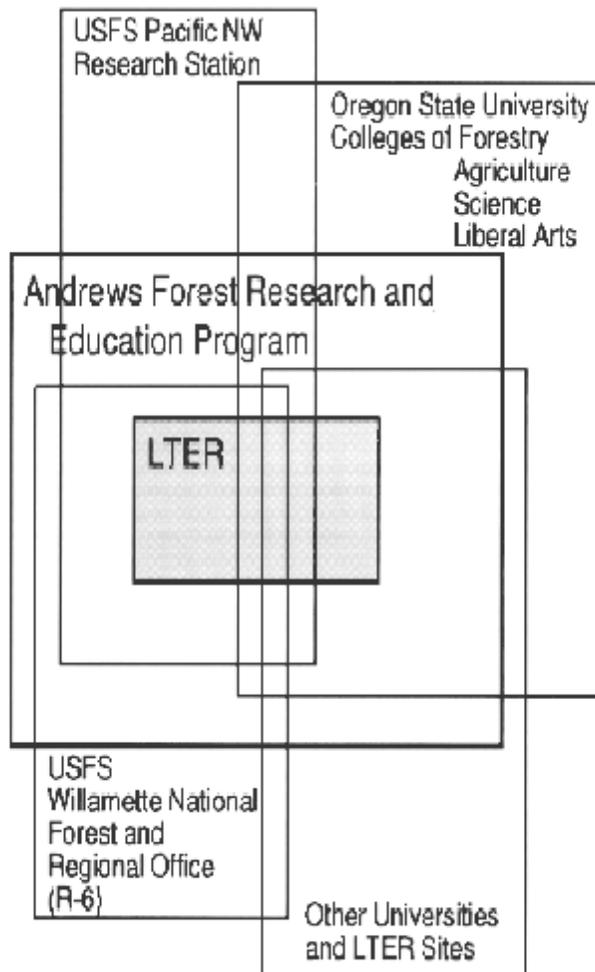


Figure 4.1 Diagram of relationships of LTER to the overall research and education program.

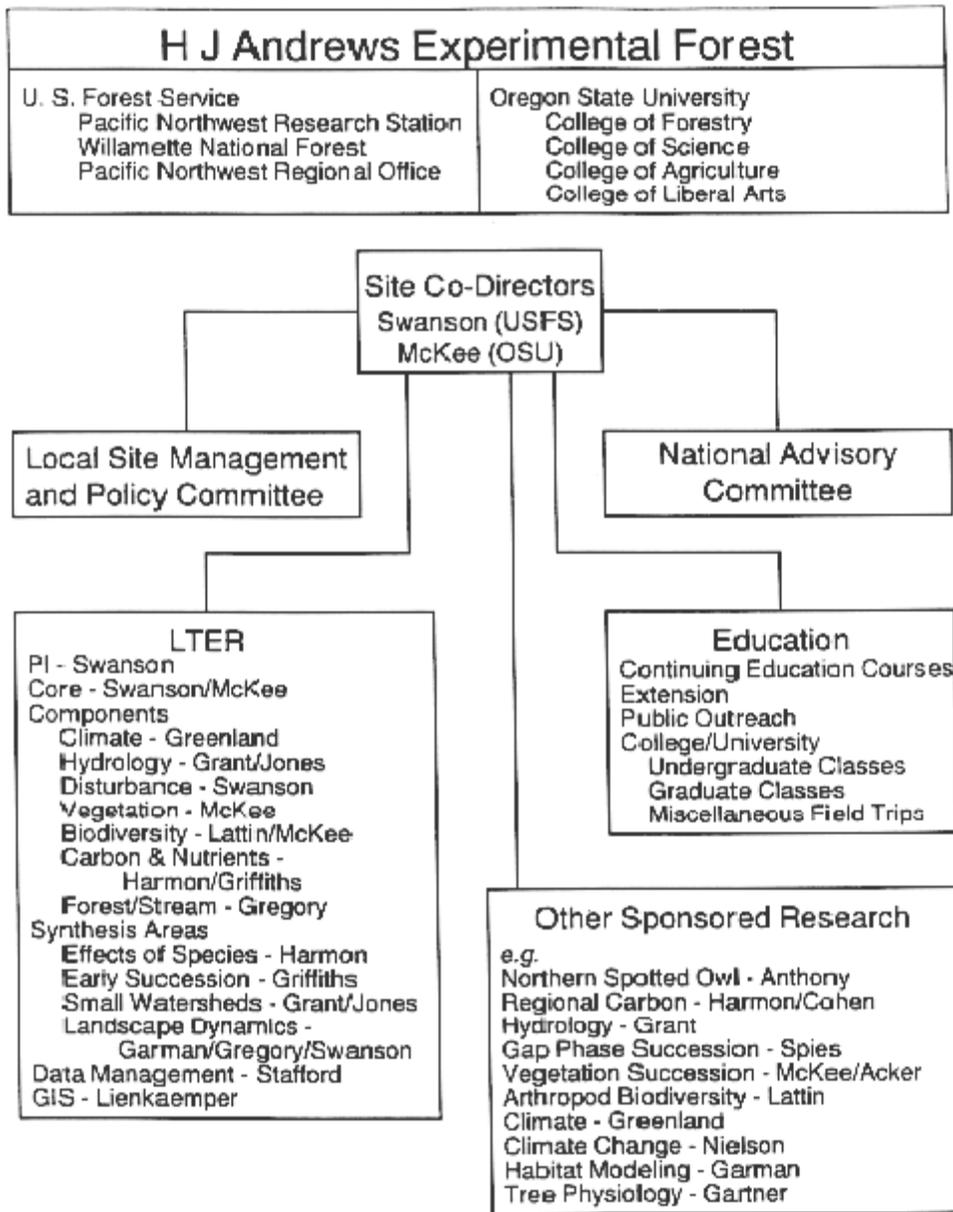


Figure 4.2 Administrative structure of the H.J. Andrews Experimental Forest.

Table 5.1. Workshops and Training Programs (Recent Accomplishments).

Students trained in information management have been successfully shared between the Andrews and Sevilleta LTER sites.

A prototype 3-month intensive data management training workshop was successfully given to Chinese Ecological Research Network (CERN) scientists and data managers for immediate implementation within the CERN network of research field stations. Stafford was a lecturer in this training program, fall 1993.

A similar program is being developed for Latin American LTER collaborators and with similar organizations around the world, particularly developing countries that are beginning to address information management needs of long-term ecological studies. Stafford is working with Brunt (Sevilleta), Gosz (Sevilleta/NET) and Nottrott (NET) on this activity.

In 1993, the first International Symposium and Workshop on Environmental Information Management was held in Albuquerque, NM, resulting in the production of a widely distributed international book (Michener et al. 1994). Several Andrews researchers were contributors and Stafford was a co-convenor of the Symposium and a co-editor of the resulting book.

Table 6.1. List of selected recent (1991-1995) policy-related activities of Andrews Forest LTER Scientists providing technical information and formulation and assessment of management alternatives for policy makers at state and national levels.

1991

Scientific Panel on Late-Successional Forests ("Gang of Four") convened by four Congressional committees/subcommittees--Spies, Grant, Gregory, Swanson served as consultants.

National Academy of Sciences/National Research Council Committee to evaluate EPA's Environmental Monitoring and Assessment Program (EMAP) (1991-1994)--Stafford.

Advisory Panel on the Impact of Non-Indigenous Species on the United States convened by Congressional Office of Technology Assessment--Lattin was a member (1991-1993).

1992

Spotted Owl Recovery Team--Spies, Lattin and Moldenke consulted.

Technical Advisory Team to Pacific Salmon and Steelhead Habitat Strategic Plan (PACFISH) convened by USDA Forest Service Washington Office--Grant member; Swanson consultant.

Technical Committee to Develop a Conservation Strategy for Pacific Yew--Spies was member; Lattin was a reviewer.

Science Team to draft mitigation protocol for raw log importations into the United States convened by USDA Forest Service--Lattin was a member.

1993

Scientific Advisory Team (SAT) for Viability Assessments and Management consideration for Species Associated with Late-Successional and Old-Growth Forests of the Pacific Northwest convened by USDA Forest Service to respond to Judge Dwyer--Grant was a member.

Forest Ecosystem Management Assessment Team (FEMAT) convened by President Clinton to formulate ecosystem management plan for Pacific Northwest federal forest lands--Grant, Spies, Swanson on team; Lattin, Moldenke, Gregory, Harmon, Perry, Schowalter on review teams and viability panels.

National Academy of Sciences/National Research Council Committee on Environmental Issues in Pacific Northwest Forest Management (1993-1994)--Perry, Gregory, Schowalter.

Consultation to Oregon Department of Forestry on management of forest stand and landscapes--Harmon, McKee, Perry, consultants.

Congressional testimony on proposed legislation concerning watershed restoration (House sub-committee)--Swanson testified.

Congressional testimony on ecosystem management (Senate sub-committee)--Swanson testified.

1994-1995

Congressional testimony and briefing of Oregon Congressional delegation on biological risks of raw log importation--Lattin.

1991-1995

Field tours Secretary Babbitt, Senator Hatfield, Governor Roberts, Congressmen Wyden, DeFazio, Vento, Atkins,

Table 6.2. List of selected publications in popular literature that draw significantly on the Andrews program.

Alper, J. War over the wetlands: ecologists v. the White House. *Science* 257:21 August (1992):1043-1044.

Associated Press. Interior secretary: science to guide owl, logging issue. *The Corvallis Gazette-Times*. March 27, 1993, A:1, back.

Brody, J.E. In spring, nature's cycle brings a dead tree to life. *The New York Times*. March 24, 1992, C:1, 8.

Burditt, L., J. Cissel, A. McKee, et al. Cascade Center--examining Northwest ecosystems. *Inner Voice* July/August (1992):8.

Devine, R. Management and the uncertainty principle. *Wilderness Winter*.(1994):11-23.

Durbin, K. Interior secretary tours forests. *The Portland Oregonian*. March 27, 1993, A:1, 16.

Durbin, K. 'New forestry' techniques compatible. *The Portland Oregonian*. November 3, 1989.

Durbin, K. OSU Forestry School plays big role. *The Portland Oregonian*. October 15, 1990, Forests in Distress special report:22-23.

Durbin, K. and P. Koberstein. New Forestry: trying logging with a lighter touch. *The Portland Oregonian*. October 15, 1990.

Hill, R.L. Young forests may need aid also. *The Portland Oregonian*. 1991, E:1-2.

Luoma, J.R. New government plan for national forests generates a debate. *The New York Times*. June 30, 1992, B:9.

Luoma, J.R. New logging approach tries to mimic nature. *The New York Times*. June 12, 1990, B: 5, 8.

Luoma, J.R. Treetops yield their secrets. *The New York Times*. February 22, 1994, B:5, 9.

Luoma, J.R. An untidy wonder. *Discover* October (1992): 86-95.

Luoma, J.R. A wealth of species is found underfoot. *The New York Times*. 7/2/91, C:1, 9.

Munro, M. Researchers still taking insect inventory of rain forest's vulnerable ecosystem. *The Vancouver Sun*. December 31, 1992, B: 6.

Newman, D. Eugene workshop will focus on the future of forestry. *The Eugene Register-Guard*. April 21, 1992, D:5.

OSU News Service. Galaxy of legs. OSU lab has largest display of N.W. arthropods. *The Corvallis Gazette-Times*. March 1, 1991, A:2.

Robertson, L. Ecosystem has 'no cookbook'. *The Eugene Register-Guard*. 4/12/93, A:1, 4.

Robertson, L. Forest history may help future. *The Corvallis Gazette-Times*. 9/5/92, A:4.

Robertson, L. Giant flume lets scientists create slides. *The Eugene Register-Guard*. 6/11/92, A:1, 4.

Robertson, L. History may help forest planning. *The Eugene Register-Guard*. 8/9/92, C:1, 4.

Robertson, L. Research center saved old growth. *The Eugene Register-Guard*. 6/1/1, A:1, 4.

Robertson, L. Workshop stresses new forestry ethic. *The Eugene Register-Guard*. 4/26/92, D:1, 3.

Stauth, D. Study focuses on 'gaps' in forest. *The Corvallis Gazette-Times*. 11/23/90.

Ulrich, R. Babbitt to get preview of forest situation. *The Portland Oregonian*. 3/25/93.

Willamette National Forest. U.S. Forest Service associate chief confers "New Perspectives" award. *Willamette National Forest Forest Service News*. 12/18/92.