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PROJECT SUMMARY

SIE PROJECT NO.
NSF AWARD NO.

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DIRECTORATE/DIVISION	PROGRAM OR SECTION	PROPOSAL NO.	F.Y.

NAME OF INSTITUTION (INCLUDE BRANCH/CAMPUS AND SCHOOL OR DIVISION)

College of Forestry
Oregon State University

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Oregon State University
Corvallis, OR 97331

PRINCIPAL INVESTIGATOR(S)

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TITLE OF PROJECT

Long-Term Ecological Research (II) on the H.J. Andrews Experimental Forest

TECHNICAL ABSTRACT (LIMIT TO 22 PICA OR 18 ELITE TYPEWRITTEN LINES)

We propose continuation of the long-term ecological research program in coniferous forests and associated streams at the H.J. Andrews Experimental Forest in the Oregon Cascade Range for a second 5-year period. There are 6 major program components each involving experiments, observations of pristine ecosystems (including 450-year-old forest), and multiple hypotheses: (1) Changes in composition (including populations), structure, and key processes with succession in a Douglas-fir sere. An artificial gap experiment is a proposed addition; (2) Nature and importance of forest-stream interactions. This component also utilizes a chronosequence and emphasizes geomorphic processes and relation of woody debris and riparian vegetation to aquatic organisms. A major manipulation of wood and riparian vegetation is planned on a 3rd-order stream; (3) Population dynamics of young forest stands as affected by density and nutrient regime; (4) Long-term impact of a N-fixer, Ceanothus velutinus, on forest soils; (5) Patterns and rates of decomposition of coarse woody debris. We plan to create snag populations for long-term study as an addition to the log experiment; and (6) Factors controlling long-term site productivity. This major new experiment is to examine effects of forest harvest practices as well as more drastic research treatments on nitrogen availability and ecosystem productivity. Most goals proposed for LTER I have been achieved including installation of 3 major experiments. Strong Forest Service and University support have made this possible and are essential to the ambitious program proposed for LTER II. Program management during LTER II will emphasize site integrity and availability, data management, scientific continuity, and development of additional funding for short-term process studies. Extensive collaboration with other lter programs is proposed during LTER II.

1. Proposal Folder
2. Program Suspense
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INTRODUCTION

In October, 1980 we initiated research under the National Science Foundation's Long-Term Ecological Research Program in the coniferous forests and associated streams at the H.J. Andrews Experimental Forest (AEF) in the central Cascade Range of western Oregon. The AEF LTER project was designed to build upon existing research, monitoring, and data management programs and to address all five topical areas identified in the original Request for Proposals.

We are currently completing the work outlined in the initial proposal. We now propose to continue the LTER program for another five years, pursuing the studies and experiments already initiated and making logical additions. The original research program dealt with five components:

1. **Changes in composition, structure, and key processes with succession in Douglas-fir--western hemlock forest;**
2. **Nature and importance of forest-stream interactions;**
3. **Population dynamics of young forest stands as affected by density and nutrient regime;**
4. **Long-term impact of nitrogen fixers on forest soils; and**
5. **Patterns and rates of log decomposition.**

The first two components utilized repeated observations of populations and phenomena in permanent sample areas representing a chronosequence of forests. Components 3 to 5 involved major experimental manipulations.

In LTER II we will refine and continue the initial LTER components and add a sixth component, "Factors controlling long-term site productivity". Experimental treatments are being added to: Component 1, creation of forest gaps; and Component 2, manipulation of woody debris and of riparian forest overstories. Component 5 is being expanded by adding studies of snag fragmentation to the log experiments. Component 6 on long-term site productivity is conceptually related to the work on N-fixers and will utilize major forest, forest residue, and forest floor manipulations to test hypotheses on the relation between nitrogen availability and long-term site productivity.

The basic principles in the development and operation of the AEF LTER include:

1. We will use the LTER program to look at important ecological hypotheses and processes that cannot be examined, or at least definitively resolved, using short-term studies;

2. We will maintain a basic terrestrial and aquatic baseline measurement program at AEF;

3. We will use sampling strategies that will be statistically adequate to detect change or to test hypotheses;

4. We will develop and maintain capabilities for rapid reduction of data and convenient, rapid access to the data by interested scientists and collaborating LTER sites;

5. We will actively promote collaborations with other sites conducting long-term ecological research including selection of common measurement techniques, development of common experiments,and exchange of data and personnel; and

6. We will attempt to build a regional perspective around the detailed research at the Andrews.

The experience of LTER I has exposed us to the realities of installing and maintaining long-term experiments. Cost and difficulties in actually implementing major ecological experiments were underestimated; our program has succeeded because of significant Forest Service support. Logistical problems have arisen necessitating revisions in design and/or schedule. Additional research opportunities created by major experiments greatly exceed our capacity for exploitation under existing funding. Optimum utilization necessitates successful development of additional research proposals. Related to this is the tendency toward development of more detailed, often short-term, studies of processes or mechanisms; as our National Committee has reminded us, this can create problems if it dilutes support for the long-term experiments and data bases or the infrastructure needed for their maintenance.

We retain our enthusiasm for the LTER program despite the many problems and frustrations. With most of the studies installed, we expect accelerated production of scientific findings and papers. One major objective early in LTER II is the synthesis of existing information on coniferous ecosystems. During LTER II we also expect increased collaboration with other sites involved in long-term research, including reciprocal experiments and expanded use of common sampling designs.

In the following sections we will present the proposed program using the 6 research components as the primary organization. Subsequent sections of the proposal describe the Andrews site and facilities, aspects of site and program management, and interactions with other programs.

CONTINUING RESEARCH COMPONENTS

Component 1. Changes in Composition, Structure, and Processes with Succession in Douglas-Fir-Western Hemlock Forest

This component deals with changes in composition (including key plant and animal populations), structure (e.g., spacing and leaf area), and key processes (e.g., litterfall and growth) associated with successional development of upland forest stands. The research is largely focused upon 3 important stages in northwestern forest succession: (1) early successional communities -- 10 and 30-year-old clearcuts (Watersheds 1, 3, and 10); (2) mature forest -- a 100-year-old Douglas-fir watershed; and (3) old-growth forest -- a 450-year-old Douglas-fir-western hemlock watershed. The initial time horizon for our research is about 40 years based on the maximum period normally required to complete canopy closure (leaf area stabilization) in cutover areas in the Pacific Northwest. Forty years should also allow us to observe the effects of several "environmental episodes" (e.g., major windstorms and wet and dry years) in the mature and old-growth forests.

Hypotheses. We propose to test hypotheses that concern both ecosystem and population characteristics. The following list is exemplary, not exhaustive as potential uses of the developing data sets are numerous.

Dramatic compositional and population shifts occur in plants and animals during closure of the young coniferous forest canopy in early successional developmental. Incredibly, such shifts have never been systematically observed and documented so that information on patterns and rates do not exist. Our hypotheses concerning the closure process include:

> Species richness values of vascular plant, invertebrate, and vertebrate species are negatively correlated with development of conifer canopy coverage.

This has important implications since, if true, rates of canopy closure will determine the rate at which species diversity declines.

> Vascular plant, invertebrate, and vertebrate species diversity reach minimum levels following conifer canopy closure, remain at these levels throughout the ensuing successional stage of dense, rapidly growing forest, and partially recover in mature forests.

Drastic functional shifts in invertebrate communities occur with the shift from herb/shrub communities to coniferous forest, including reduced abundance, diversity, and consumption of herbivorous invertebrates, with partial recovery in mature forests.

> Vertebrate communities are dominated by generalists in early stages of succession and by specialists in old-growth forests.

Higher diversity in cutover areas may be balanced by a large proportion of highly specialized species in the moderate diversity levels found in old-growth forests.

Several hypotheses involve the population biology of the dominant trees of mature and old-growth forests (aspects of population biology of young stands are in component 3):

> Forest tree mortality is an episodic process in mature and old-growth forest stands and a constant (approximating the 3/2 rule) in young stands

> Episodic pulses in herbivory are triggered by episodic pulses of plant mortality and changes in plant species composition; pulses of herbivory will be accompanied by changes in arthropod species diversity.

> Rates of tree population turnover vary locally with site conditions; the most productive sites will have the highest rate and the least productive the lowest rates of turnover.

Rates of tree population turnover also increase along a regional gradient from coastal Sitka spruce to interior ponderosa pine forests.

Mortality rates of component tree species decline significantly with time and are lowest for the oldest age classes.

Some hypotheses concern processes or structures at the level of the whole ecosystem rather than simply populations, e.g.:

Nutrient losses from a watershed following disturbance decline in direct proportion to the increase in live biomass until the canopy closes and leaf area stabilizes; thereafter, nutrient losses should be essentially contant.

The use of experimental watersheds as part of our basic design allows us to address holistic hypotheses of this latter type.

Design. This component makes use of several sampling sites and designs in order to address the variety of hypotheses and various types of organisms (Table 1). Much of the work is built around a systematic series of permanent sample plots (1/10 ha in mature and old-growth forest, 150 m^2 or 1/250 ha in cutovers) that have been established on 5 experimental watersheds representing: a 10-year-old cutover (WS #10); 20-year-old cutovers (WS #1 and 3); mature forest (Hagan Research Natural Area (RNA)); and old-growth forest (WS #2). A series of permanent plots (reference stands) representative of different site conditions and forest age classes provides a second important sampling system. These plots are typically 1 ha (range 1.4 ha to 4.5 ha) and include mapping of live and dead stems and down logs. Thirty of these are associated directly with AEF; a comparable number provide a regional data base, e.g., for Sitka spruce and ponderosa pine forests. Additional study areas have been established to meet specific objectives of invertebrate and vertebrate research.

Most of the measurement programs use straightforward techniques. Tree demography utilizes tagged individuals and annual mortality checks. Allometric equations are used to estimate biomass by components and leaf area. Litterfall utilizes a series of m^2 littertraps. Inputs of woody debris are based upon mapping and analyses of mortality.

Table 1. Measurement program for study of changes in composition, structure, and key processes with succession in Douglas-fir forests.

Item	Frequency Interval	Watersheds	Reference Stands	Other Plots
Standing crop of vascular plants	3 or 5 yrs	x	x	x
Growth of trees	3 or 5 yrs	x	x	
Mortality of trees	1 yr	x	x	
Canopy closure (photography)	3 or 5 yrs	x	x	x
Leaf area	3 or 5 yrs	x	x	
Litterfall	12/yr		x	
Seedfall	6/yr		x	
Standing crop of woody debris	5 yrs	x	x	x
Inputs of coarse woody debris	1-5 yrs	x	x	
Invertebrate composition & abundance	variable	x	x	
Vertebrate composition & abundance	variable	x		x
Soil chemistry	5 yrs	x		

The invertebrate research has ranged widely in its objectives and, consequently, sampling locations and techniques; all primary LTER study sites are included, however. Much of the research has focused on specific functional groups in response to criticisms of the original proposal. Primary examples are analyses of (1) arthropod herbivores on early successional vegetation, including pioneer n-fixers <u>Alnus</u> <u>rubra</u> and <u>Ceanothus</u> <u>velutinus</u> as well as Douglas-fir and (2) litter arthropods associated with different successional stages. These foci have been selected because of their importance in ecosystem functioning.

The vertebrate research has differed from the original plan, largely because of dramatically increased interest in wildlife associated with old-growth forests and with riparian zones. In LTER I we proposed population monitoring of selected mammal and bird populations (e.g., deer mice) on the primary study watersheds. Instead, we collaborated with a major project studying (1) the composition of vertebrate communities associated with young, mature, and old-growth forests and (2) vertebrate partitioning of the riparian zone in forests of varying successional stage. A variety of sampling techniques are being utilized in these studies which include reptiles, amphibians, mammals, and birds. Numerous study areas are involved and include the primary LTER locations.

<u>Accomplishments</u>. Essentially all of the planned research has been accomplished during LTER I, including the establishment and initial measurement of the permanent sample plots in Watershed 2 and Hagan RNA (68 and 96 0.1 ha plots, respectively). There is remarkably little difference in average diameter and density of trees >5 cm diameter at breast height (dbh) in the 100 and 450-year-old stands. Density averages 322.4 and 424.5 individuals/ha in mature and old stands, respectively. Species diversity is similar in the 2 age classes but evenness is higher in the old-growth stand where several species share numerical dominance with the Douglas-fir. Size class

distributions do contrast sharply with a much broader size range and reverse j-shaped distribution in the old-growth forest.

Tree mortality studies have provided some of the most interesting scientific results from Component 1 in LTER I, including initial tests of several hypotheses. Existence of long-term data sets initiated between 1910 and 1935 by the Forest Service, annual mortality checks on reference stands initiated in 1976, and a sabbatical study by Dr. Paul Harcombe of Rice University assisted in advancing the LTER work.

Mortality appears to be a mixture of continuous and episodic processes (Franklin et al. 1985). Annual mortality averages 0.51 and 1.10 percent per annum for old-growth and mature stands respectively at H.J. Andrews; the difference is highly significant. The higher rate and identification of competition or suppression as the primary cause of mortality suggest that self-thinning is still taking place in mature stands. Annual variations have been relatively small (0.25 to 0.66 in old-growth) during the observation period although we know that yearly rates in excess of 3.0 percent per annum have been observed in intact Douglas-fir stands during bark beetle epidemics. Surprisingly, mortality is not size specific over most of the size classes present; that is, mortality is proportional to population sizes except for very large trees (>100 cm dbh) where rates drop to half or less (0.25 per annum) of those in smaller size classes. Mortality rates are nearly twice as great on high than on low productivity sites (0.88 vs. 0.51%/yr).

There is a strong regional gradient in both rates and causes of mortality. Rates are highest in coastal Sitka spruce forest (e.g., 3.3%/yr), intermediate in Cascade Range Douglas-fir forests, and lowest in ponderosa pine forests (e.g., 0.15%/yr). Proximate agents of mortality vary drastically with wind responsible for about 80% of the mortality in the coastal forests, grading through 30 to 40% in Cascade forests, to under 20% in ponderosa pine forests. Losses to insects and disease are reversed with high levels in the ponderosa pine and almost none in the Sitka spruce zone.

Vertebrate research accomplishments during LTER I include (1) collaboration with Dr. Larry Harris in his island biogeographic analysis of old-growth forest preservation (Harris 1984), (2) identification of species associated primarily with old-growth, and (3) a comparison of small mammal diversity, density, and habitat use in mature vs. old-growth and in riparian vs. upland forests (Doyle 1985). Vertebrate species diversity is generally highest early in succession, prior to tree canopy closure, lowest in young forests, and intermediate in old-growth forests. Species associated primarily or exclusively with the old-growth forest condition are: hermit warbler, Vaux's swift, brown creeper, northern spotted owl, shrew-mole, northern flying squirrel, red tree vole, Oregon slender salamander, Olympic salamander, tailed frog, and several species of bats. The comparative study of riparian and upland habitats has revealed that 3 species of voles (*Microtus richardsoni*, *Microtus oregoni*, and *Clethrionomys californicus*) are separated into microhabitats probably due to differential selection for food and cover (Doyle 1985). This study has also allowed us to design a minimal sampling scheme to address yearly changes in small mammal diversity and density along a sere.

The substantial accomplishments in invertebrate studies include the establishment of an H.J. Andrews arthropod reference collection and a publication series on the invertebrates of the H.J. Andrews (see publication list). A very large network of taxonomic specialists has collaborated on identification (see Appendix I). One early result of this work has been the recognition of the large number of arthropod predators and parasitoids present in the Douglas-fir forests which may be an important factor in the low levels of forest herbivory. Results from the studies of soil litter arthropods and of herbivorous insects will emerge early in LTER II.

Plans in LTER II. We plan to continue the basic program of terrestrial observations during LTER II with some minor modifications and to establish an experimental gap study. Minor modifications to the measurement program include the addition of fisheye-lens canopy photography on the permanent plots and addition of tree seed-rain measurements. The canopy photography is proving to be of exceptional value in establishing (and permanently documenting) light levels within forest stands. Computerized techniques for analysis of the photographs has minimized the onerous task of scaling light regimes. Additionally, we intend to use the photography to improve our leaf area estimates. Tree seed-rain studies will be initiated in 1985 to measure quantity and quality of seedfall in forest stands representing mature and old-growth Pseudotsuga-Tsuga and Abies-Tsuga. These utilize 10-20 0.2 m^2 systematically located seedtraps per stand.

The gap study will add an experimentation component to a heretofore strictly observational study. The overall objective is to study plant and animal responses to creation of gaps of varying size in mature and old-growth forests. Many hypotheses will be tested using this basic experiment, such as:

Small forest gaps are filled primarily by existing (advance) tree regeneration rather than subsequent tree regeneration.

Tree regeneration subsequent to canopy opening will occur primarily where disturbance to the forest floor has exposed mineral soil or on coarse woody debris.

Understory response to canopy openings will be a function of opening size, once a threshold has been reached. Patterns of response will be a function of their life forms and reproductive strategies, e.g., deciduous shrubs will increase vegetative biomass proportionally more than evergreen shrubs of similar size and the most shade-tolerant species will respond primarily by increased sexual reproduction rather than increased vegetative growth.

Bird responses to openings will consist primarily of cavity-using species and will be strongly affected by size of opening (i.e., number of dead trees).

Gaps up to one tree height in width will not result in changes in shrub and herb diversity.

The plan is to kill standing dominant trees in groups of 2, 4, 8, and 16 individuals; deterioration of the killed trees will be followed as part of the snag decay study outlined in component 5. Trees will be killed by injection with a silvicide. The design utilizes 5 20- to 25-ha stands of each of the 2 age classes. Five sets of 5 matched locations (i.e., comparable stand conditions and environment) will be identified in each stand. The treatments (0, 2, 4, 8, and 16 dead trees) will be randomly assigned. The 16-tree treatment should provide an opening of approximately 1 tree height in diameter, an opening as large as any expected, short of a catastrophic event. At each treatment site soil will be excavated to provide at least 4 m^2 each of pit and mound; this is an effort to replicate the effects of windthrow on the forest floor microhabitat.

Relatively few parameters can be studied under LTER funding: (1) Canopy closure using fisheye photography; (2) Shrub and herb composition, biomass, and fruiting; (3) Tree regeneration by species and substrate types (i.e., undisturbed forest floor, rotting log, soil mound, and soil pit); and (4) Breeding and resident bird population levels. Measurements will be made prior to treatment and at annual to biennial intervals thereafter. The tree seed-rain studies described earlier will include the stands used for the experimental gaps.

We plan to initiate establishment of the experimental gaps in mature forest beginning in 1987 and phase installation over several years. The old-growth segment of the study probably will not be installed during LTER II due to limited resources.

<u>Cooperation</u>. Significant collaboration with other long-term research sites has already begun on aspects of Component 1, such as in use of common sample plot protocols by AEF and Coweeta. As noted later, development of common gap experiments with several other sites, including Coweeta and Duke Forest, are under discussion.

Accomplishments under LTER I have been substantially aided by Forest Service assistance, e.g., in establishment of the permanent plots, mortality checks, and growth remeasurements. This will continue to be the case in LTER II. The degree to which the experimental gap study can be expanded to include other hypotheses and measurements depends upon additional financial support such as from the Forest Service competitive grants program or a regular NSF program. Such grant proposals are already being prepared under the leadership of Dr. Thomas Spies.

Component 2. Nature and Importance of Forest-Stream Interactions

This component addresses the interactions among riparian vegetation, geomorphic structure and processes, habitat, and nutritional resources of stream ecosystems, and how these relationships are affected by disturbance. An important challenge of such work is to understand and quantify attributes of particular system components, such as terrestrial vegetation and geomorphology, in terms relevant to other components, here the stream ecosystem. A second challenge is to design research to provide an appropriate foundation for explaining responses to future disturbances.

Coupled with several complimentary research projects at the Andrews, the LTER studies are examining important aspects of the dynamics of the valley floor landscape in the western Cascade Mountains. A recently completed study of the effects of riparian vegetation on aquatic ecosystems has helped us develop our underlying premise that biological communities in streams respond to the structural and nutritional influences of riparian vegetation. Another pending study is based on the premise that geomorphic processes create and modify a mosaic of stream channel and floodplain surfaces which determine the spatial pattern and successional development of riparian vegetation.

Here we propose to examine the temporal dynamics of forest-stream links at time scales of both forest succession (500-1000 years) and short-term response to disturbance (several decades). Three study approaches are employed: 1) an assessment of stream-forest interactions on a chronosequence of stands from 0 to 500 years of age; 2) a field experiment to separately manipulate (a) structure and (b) quantity and quality of nutritional resources to test hypotheses about the interplay of structural and nutritional effects; 3) design and installation of a sampling program which will allow us to document flood-induced changes in stream ecosystems in relation to levels of control by riparian vegetation. This focus on the coupling of physical and biological change is essential in studies of riparian ecosystems which are characterized by much more frequent low- and high-intensity disturbance than upland areas.

Hypotheses. Our basic premise is that biological communities in streams respond to the structural and nutritional influences of riparian vegetation. Examples include the response of primary production to light; functional groups of macroinvertebrates to quality, quantity, and timing of detrital inputs; and fish and salamander biomass and densities to habitat structure. We examine this premise by testing hypotheses about the conditions and behavior of streams and their associated riparian systems at various stages of succession and in response to disturbance by floods. The following list of hypotheses is far from exhaustive. Clearly, the manipulation and next major flood will stimulate formulation of additional hypotheses.

Disturbances by flooding modify communities of riparian vegetation, and riparian vegetation locally influences both magnitudes and patterns of disturbances.

1. Aquatic systems that are strongly influenced by terrestrial vegetation are more resistant to change from major exogenous events and recover more rapidly when they occur than are streams without the structural controls and food resources of streamside vegetation.

The implications are that stream reaches with riparian vegetation in an early stage of succession have both lower resistance and resiliance to disturbance than reaches influenced by mature or old-growth riparian forests. These resistance-resiliance characteristics can be addressed at the scale of trophic levels.

2a. Primary production in stream ecosystems has low resistance and high resiliance to change by episodic disturbance such as flooding.

2b. Invertebrate communities are intermediate between primary producer and consumer communities in resistant/resiliance characteristics.

2c. Fish communities have high resistance and low resiliance to change by episodic disturbance, a reflection of their dependence on channel structure for habitat.

Riparian vegetation controls food resources and channel structure in an interconnected fashion; the attributes of food resources and channel structure are additive in one direction only.

3. **Food resource limitation only slightly affects available habitat for stream organisms, but removal of macro-habitat structure can affect availability of food resources by reducing the capacity of the channel to retain detrital inputs for sufficient time to allow processing by aquatic organisms.**

Understanding the type and timing of these responses to disturbance is essential to predicting overall effects of natural and management caused disturbances on stream communities.

Recent research by our group and others has recognized the importance of large woody debris in controlling habitat structure in streams.

4. **The spatial arrangement and stability of large woody debris in streams is determined by the size distribution of debris pieces in relation to measures of width and roughness of the channel.**

Once stability relations between wood size distribution and channel characteristics are established for study sites, it will be possible to predict habitat stability in many other systems.

The successional dynamics of riparian vegetation cause the composition and structure to change in ways that have profound significance to the stream ecosystems. Changes in species composition produce shifts in the timing and quality of detritus entering the stream. The increase in height and proportion of evergreen species results in increased shading throughout the year and concomitant decreases in primary production in the stream. The successional dynamics of streamside vegetation are poorly understood, and one of our objectives is to determine the patterns and mechanisms of succession and test hypotheses about these patterns, such as:

5. **While vascular plant species richness remains relatively constant through succession, the diversity of both timing and quality of detrital inputs increases along with the total quantity of inputs.**

6. **At any point in a sere small-scale disturbances increase the diversity of detrital inputs to streams, and large scale disturbances decrease diversity of inputs.**

Several opportunities exist to compare and contrast the patterns and processes in upland systems with riparian systems. Many of the hypotheses presented in component 1 (terrestrial succession) can tested in the riparian, such as patterns of mortality, diversity, and response to disturbance.

Research Design. Five sites representing a chronosequence of streamside stands in and around the H.J. Andrews Experimental Forest were selected on the basis of (1) long-term record of site conditions and (2) high degree of control on future management of the site by researchers. A 10-ha watershed (Watershed 10, clearcut 1975) and an 8-ha clearcut at Mack Creek (clearcut 1964) represent the early successional condition, as will a section of South Fork Hagan Creek to be cut in 1987. Four sites were picked on third-order streams in 450 to 600-ha watersheds. Permanent plots have been established at all sites: a 10-year old stand, a 20-year old stand, paired 100-year old stands and a 450-year old stand.

One of the 100-year old riparian stands (South Fork Hagan Creek) will be experimentally manipulated with three treatments (Figure 1): 1) remove canopy; 2) remove canopy and the structural influence of downed large woody debris; and 3) remove only the large woody debris. A control reach has been established upstream of the manipulated section and a watershed control is the North Fork Hagan Creek within Hagan RNA.

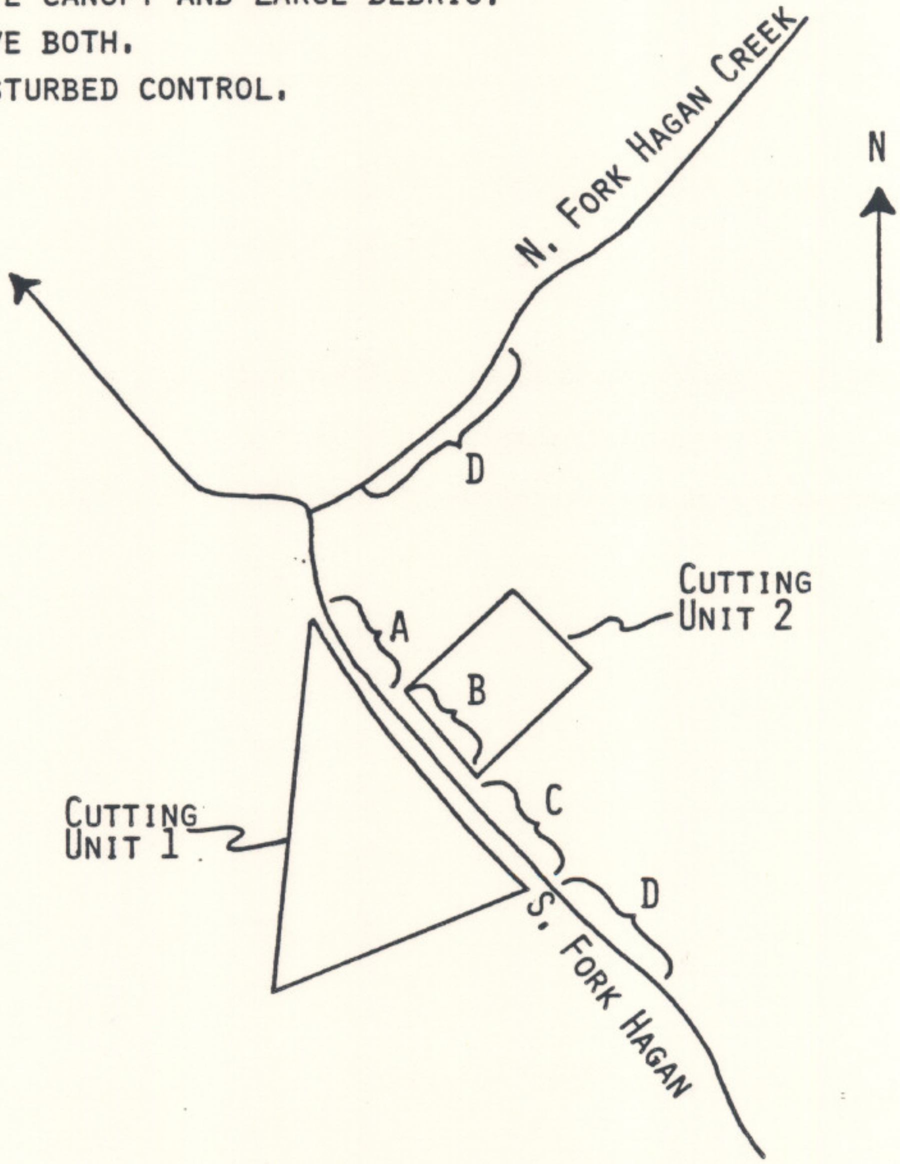
During LTER I we developed a highly integrated approach to examining forest-stream interactions at intensive study sites. Sampling plots at a field site are nested within maps of the stream reaches and adjacent stands. Permanent plots for sampling shrubs and herbs are established within the mapped areas. Light and litterfall are sampled in relation to vegetation strata shown on the vegetation maps. Monumented channel cross sections and sites for sampling aquatic habitat and biology are keyed to the stream maps.

Research at the chronosequence sites is used primarily in examining hypotheses 1, 2, 4, 5, and 6. Hypotheses 1 and 2, the effects of natural disturbances, will be examined

FIGURE 1.

LAYOUT OF HAGAN CREEK EXPERIMENT
WEST HAGAN TIMBER SALE

TREATMENT
A. LEAVE CANOPY, REMOVE LARGE DEBRIS.
B. REMOVE CANOPY AND LARGE DEBRIS.
C. REMOVE BOTH.
D. UNDISTURBED CONTROL.



by resurvey of structural and biological parameters at the intensive research sites where there is a good record of predisturbance conditions. Based on analysis of the response of these sites, we will identify key variables useful in describing the magnitude and consequence of disturbance-induced change. These variables will then be examined at a more extensive array of sites to provide replication. Hypothesis 4 is being examined at the chronosequence and several satellite sites by annual surveys of mapped woody debris in channels. At Mack Creek annual observations of location and orientation of tagged logs provides higher resolution on woody debris dynamics. Tests of hypotheses 5 and 6 will be by comparisons of vegetation composition, structure, and mortality among these intensive sites and at several other sites representing differing stages in succession. A nested sampling design is used with progressively smaller plot sizes for tree, shrub, and herb strata. These plots are mapped and permanently monumented at the intensive study sites and will be resampled at 2 to 3 year intervals. Species specific parameters are measured at that time for biomass estimation.

Hypotheses 2 and 3 will be tested using observations from the manipulation experiments at South Fork Hagan Creek. We are sampling key variables (Table 2) to describe aquatic habitat (pools, backwaters, large woody debris, etc.), processes (retention of particulate organic matter, primary production), and community composition (invertebrates at functional group level, fish). These measurements will be followed through and following manipulation to evaluate initial effects (resistance) and recovery trajectories (resilience) for various components of the system.

Accomplishments During LTER I. Field installations are complete at the chronosequence sites and several years of data have been collected on (a) vegetation structure, composition, and mortality, (b) input and redistribution of coarse woody debris in channels and associated changes in channel geometry, (c) retention of particulate organic matter, and (d) aquatic biology (primary producers, detritus, invertebrates,

Table 2. History of observations at LTER study sites.

Record Type		Mack Creek clearcut	Mack Creek old-growth	Hagan Creek N. Fork	Hagan Creek S. Fork	Watershed 10 old-growth*	Watershed 10 clearcut*
Terrestrial - vegetation							
	Stand map				80		
80	81			74			
	Shrub & herb sampling			77,84	77,82		
	81				77,81,85		
	Perm. veg. transects			77,84	77,82		
83	81,82,83				77,81,85		
	Photo points						
Channel - physical							
	Channel cross sections			79+	79+		
81+	81+			75	76,80		
	Large debris maps			75+	75+		
81+	81+				76		
	Movement of tagged logs			83+	83+		
	Habitat description						
81+	81+						
Hydro - sediment							
	Streamflow			80+	80+		
n.d.	n.d.			67-75	75+		
	Suspended sediment						
n.d.	n.d.			69-75	75+		
	Bedload			n.d.	n.d.		
n.d.	n.d.			73-75	75+		
	Water chemistry			80+	80+		
n.d.	n.d.			69-75	75+		
	(N, P, K, Na, Ca, Mg)						
	Water temperature			81+	81+		
n.d.	n.d.						
Aquatic Ecology							
	Detritus standing crop			81,83	81,83		
81	81			71-75	75-80		
	Detritus retention			83,84	83,84		
84	84						
	Invert. standing crop			81,83	81,83		
81	81			71-75	75-80		
	Fish & salamander			81,83	81,83		
81	81			n.d.	n.d.		
	Algal colonization			81,83	81,83		
81	81			n.d.	79-80		
	Aquatic insect emerg.			81,83	81,83		
81	81			71-73	79-80		

*Old-growth forest clearcut in 1975.

fish populations, and habitat) (Table 2). Relevant additional data have also been collected at key sites, e.g., streamflow and water chemistry at Mack Creek and Watershed 10 and time-lapse photography at Mack and Hagan Creeks.

The dynamics of large woody debris has provided particularly interesting early results from LTER I. Large woody debris input to the Hagan site has been 7 trees/100 m of channel/yr (2 yrs of observation) in contrast to a rate of 0.3/100m/yr (9 yrs) at the old-growth Mack Creek site. The 100-year old Hagan stand is at a critical stage when hardwoods, principally red alder and bigleaf maple, are senescing and providing frequent additions of large woody debris to the channel.

Forest stand and stream conditions are tightly coupled through the dynamics of large woody debris. Stand structure and breakage of woody debris as it is delivered to channels control the size distribution of woody debris entering channels. Relations between size distribution (transportability) of woody debris and channel size and discharge (transport capacity) appear to determine the stability and arrangement of woody debris in streams which strongly control habitat structure and stability in debris-dominated streams of the Pacific Northwest and elsewhere. During 7 to 9 years of observation in 1480 m of first- to fifth-order stream reaches, delivery of large wood has been quite sporadic, averaging about 12 $m^3\ ha^{-1}\ yr^{-1}$, which is comparable to rates reported for adjacent upland stands. Movement in most years has involved less than a few percent of pieces in the channel but in one November flood, more than 50% of pieces in the old-growth reach moved. Despite this movement, the location and major structural units of more than 80 percent of debris accumulations remained unchanged.

To refine such observations in future disturbances we have attached numbered tags to all coarse woody debris (1000 logs) greater than 10 cm in diameter in a 900-m reach of Mack Creek. The location, channel position, decay class, stability, and size of each log is inventoried annually. Less than 5% of the tagged logs have moved over the last three years. During this time we have experienced no unusually high winter flows, pointing to the importance of major flood events in restructuring stream channels.

The periodic resampling of the permanent plots has documented rapid changes of species important in the early successional stages. Interestingly, species richness on a per reach or sample site basis changes very little along the chronosequence. In comparison with upland vegetation, riparian stands have much greater species richness ($\bar{x}$ = 76 species/ha vs. 33 species/ha) in our area. An examination of the chronosequence provided by the intensive and extensive sites suggests that the shrub stratum shows the least total variation through succession in quantity and quality of litter inputs.

Our samples are revealing patterns of associations of vegetation with geomorphic surface. Shrub and herb species richness patterns on different geomorphic surfaces are illustrated along a limited chronosequence sample in Figure 2. The surfaces are arranged from left to right in the figure to show increasing distance from the stream. Herb richness peaks on surfaces nearer the stream than does shrub richness. Old-growth stands such as Mack Creek tend to have greater herb species richness on the near-stream geomorphic surfaces than recent clearcuts, but the clearcuts have much greater (4x) herb biomass. Some plant species are largely confined to certain geomorphic surfaces. Community analyses stratified by geomorphic surface are currently underway.

<u>Plans for LTER II</u>. Our basic design will change little in LTER II. There will be some refinements in planned field experiments and study sites reflecting greatly improved methods of measurement of important variables, especially for retention of leaf and stick litter and dynamics of large woody debris. In addition to the log tagging at Mack Creek, we will tag approximately 1000 logs in lower Lookout Creek to assess input and redistribution of debris pieces with greater resolution. We expect significantly greater movement and lower stability of associated aquatic habitat at lower Lookout, because it is twice as wide as Mack Creek.

One planned addition to our research will be further development and field testing of McIntire's stream ecosystem model (McIntire and Colby, 1978). In the renewal

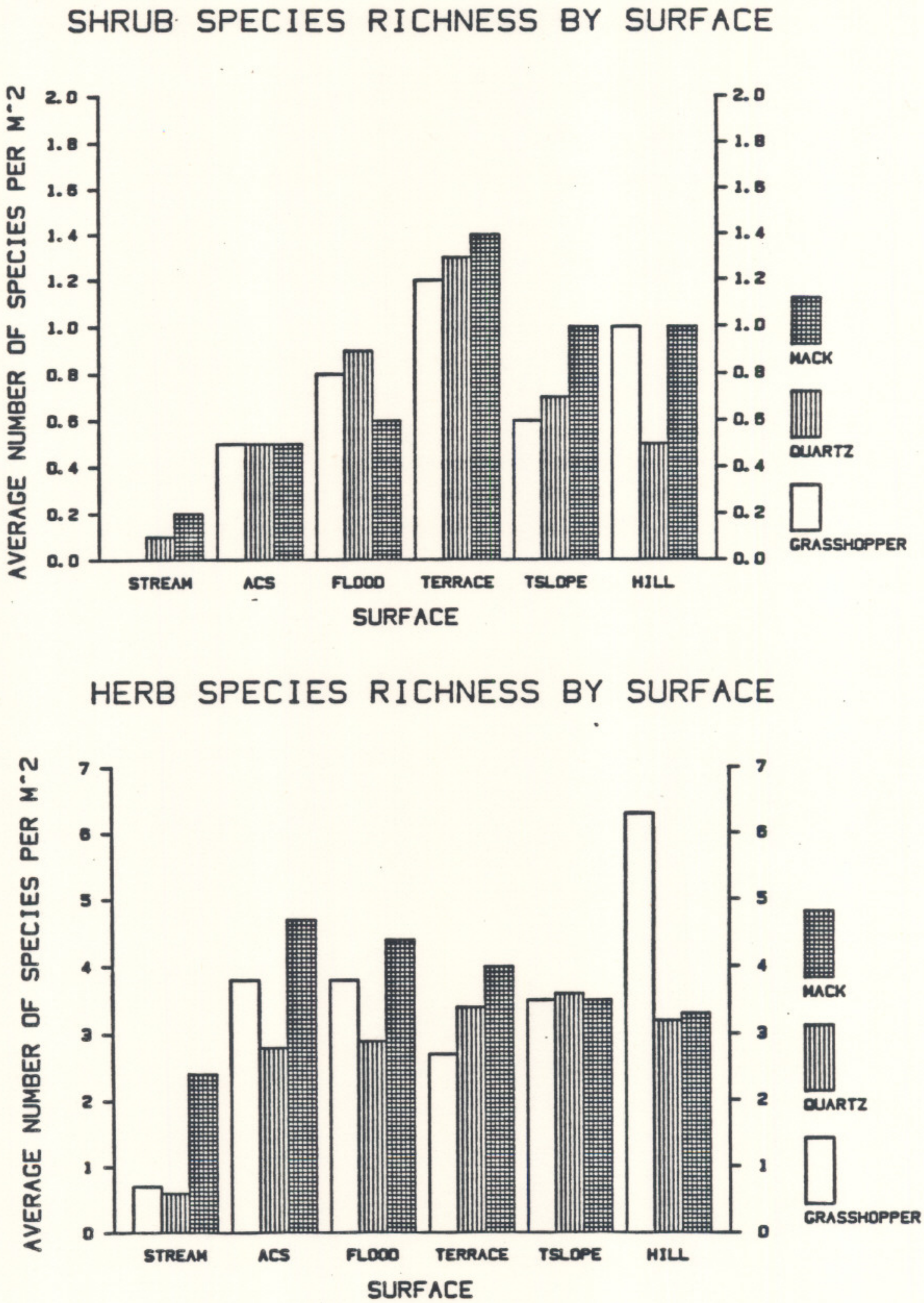


Figure 2. Average number of vascular plant species per square meter by geomorphic surface. Stream = stream channel within summer base flow; ALS = channel surface between summer base and winter base flows; Flood = floodplain; Terrace = higher terraces, often old floodplains; Tslope = toeslope of hillside; Hill = hillside. Grasshopper = recent clearcut, open site; Quartz = 35-year-old alder dominated site; Mack = old-growth forest site.

proposal for our Riparian Project we propose to develop a subroutine which simulates the effects of streamside vegetation on litter and light input to streams, processes that are only input functions in the current model. The field experiment at Hagan Creek would test model predictions of detrital retention, primary production, herbivory, and other processes.

We plan to continue baseline sampling until 1987 when the manipulation on South Fork Hagan Creek is planned. A post-doc will be hired for two years beginning in May 1986 so that he/she can take part in a full-year's cycle of sampling before the manipulation. The post-doc will be the research ramrod for the experiment. The post-doc will also collaborate with senior investigators in preparing publications based on the existing long-term data sets.

A crucial part of future work will be responding to the next major, unscheduled disturbance, particularly a flood, that would give us the opportunity to compare geomorphic, vegetative, and aquatic responses to such an event. Seldom have researchers had good baseline data and been poised to respond when a major natural disturbance occurs. LTER gives us this chance.

<u>Cooperation</u>. Local interactions between LTER and other ecosystem research in the Corvallis group has been critical to accomplishing the broad objectives of LTER component 2. Research on terrestrial-aquatic dynamics under the expired Riparian Grant provided detailed insight into processes regulating aquatic ecosystem conditions in streams bordered with riparian vegetation of differing composition and structure. In a proposal based partially on concepts developed in LTER, Gregory secured NSF support for laboratory experimental studies of relations among light, primary production, and aquatic herbivores. Work on geomorphology of valley floors (G. Grant, Johns Hopkins University) under separate funding provides a broad-scale geomorphic and historical context for interpreting riparian zone dynamics in the LTER study sites. In the pending

Riparian Grant renewal, expanded studies of geomorphic relations to riparian vegetation and stream ecosystems are proposed.

Local support of the Willamette National Forest is essential to the manipulation experiment. It would be impossible financially and logistically to conduct such a massive manipulation of the landscape using research funding.

Component 3. Population Dynamics of Young Forest Stands as Affected by Density and Nutrient Regime

The objective of the "Population Dynamics" component of the AEF LTER research is to investigate the influence of structure on the development of young coniferous forest stands prior to and during self-thinning. In plant populations which are experiencing density-related mortality, the relation between individual plant size and stocking density is expressed with high accuracy by the equation (1):

$$B_I = C\rho^{-x}$$

where B_I = individual plant biomass (or volume),

ρ = stocking density,

C, x = constants.

If a linear relationship between diameter and height is assumed, dimensional analysis can be used to calculate a value of 3/2 for the parameter x (Yoda et al. 1963). For this reason, equation (1) is commonly called the "-3/2 power law of self thinning". Studies have found that, in tree populations, x may in fact vary between 1.2 and 1.9 (Harper 1977 reviews the literature, see also Mohler et al. 1978).

In populations which are not self-thinning, the relation between mean plant size and density is often written (Willey and Heath 1969):

$$\frac{1}{B_I} = B\rho^{\Phi}$$

Equation (2), the reciprocal-yield law, can be derived by substituting equation (1) for K in the integral form of the logistic growth equation (Shimozaki and Kira 1956):

$$B_I = \frac{K}{1 - e^{-rt} + \frac{K}{B_0} e^{-rt}}$$

where K = asymptotic limit on B_I,

r = intrinsic growth rate,

B_0 = B_I at time 0.

Finally, we introduce the generalized logistic equation (here written in the differential form):

$$\frac{dB_I}{dt} = \frac{rB_I}{\alpha} \left(1 - \frac{B_I^{\alpha}}{K^{\alpha}}\right)$$

The parameter expresses the degree of symmetry in the equation. If α equals 1, maximum growth occurs with $B_I/K < 1/2$. One interpretation of this is that crowding effects appear earlier. However, the change in growth rate is less sensitive to increasing B_I/K, thus crowding effects, although perhaps appearing earlier, are not as severe. Growth of at least some forest stands follows a logistic curve with $\alpha < 1$ (Perry and Muscato, unpublished). It is not clear, however, whether this is due to inherent growth properties of individual trees, or merely reflects a distortion of the growth curve due to competition and mortality. In other words, is the nonsymmetric growth curve an organismic response to competition or a population phenomenon?

In this population dynamics component of LTER we are investigating within the context of the above theory, processes of population growth in young coniferous populations prior to, and as they are approaching, the self-thinning state. This may be expressed as the period when

$$\frac{B_I}{K} \ll 1 \quad \rightarrow \quad \frac{B_I}{K} \simeq 1$$

Hypotheses: Where there is little competition for resources, small trees within a stand, because of lower respiratory load, have a greater relative growth rate (RGR) than larger trees. As competition intensifies, small trees, through plastic morphological and physiological adaptations, may increase their photosynthetic efficiency, but eventually the pattern of RGR within the stand reverses and large trees have higher RGR's.

The distribution of RGR's within a stand is a manifestation of "socio-economic" factors -- the availability of resources to the average individual, and how these resources are allocated among individuals of differing social positions. The central premise of our original LTER hypotheses was that the establishment of a dominance hierarchy, as evidenced by reversal of the size-RGR relation, actually reduces the overall level of competition within the stand. In a sense, this process is analogous to that occurring in nonequilibrium thermodynamic systems, where the formation of structure is associated with dissipation of energy (Prigogine 1980); in the nonequilibrium plant population, the development of structure (dominance hierarchy) is linked to dissipation of "competitive tension" -- a term which we purposly leave vaguely defined (Perry 1985). Specific hypotheses are:

(1) In a stand which is not self thinning, mean individual tree growth rate is given by:

$$\frac{dB_I}{dt} = \frac{rB_I}{\alpha} \left(1 - \frac{B_I^{\alpha} \rho^{\alpha x}}{C^{\alpha}}\right)$$

where parameters are as given before. Values for C and x are obtained from self thinning stands. Values for r and α are to be determined.

(2) In a coniferous population which is not self thinning, the relation between mean tree size (B_I) and stocking density (ρ) should asymptotically approach.

$$\frac{1}{B_I} = \frac{\rho^x}{c}$$

where c, x are parameters of the "-3/2 power law", and can be determined on a site specific basis from self thinning stands.

(3) Following disturbance which reduces stand density, the rate at which B_I approaches the postulated relation of hypotheses (2) is a function of r, the "intrinsic growth rate" and α, the parameter measuring sensitivity to competition. This rate may therefore be modified by changing site quality or species.

(4) For a given mean tree size, the stocking density producing maximum-stand growth rate is:

$$\rho = \left[\frac{1}{1 + x\alpha}\right]^{\frac{1}{\alpha x}} \left[\frac{C}{B_I}\right]^{\frac{1}{x}}$$

(5) For a given density, there is a linear relationship between the mean tree size at which density-related mortality begins and the mean-tree size at which maximum-stand growth occurs.

Thus, at the commencement of mortality:

$$\frac{B_I}{K} = \beta \left[\frac{1}{1 + x\alpha}\right]^{\frac{1}{\alpha}}$$

where β = a constant greater than 1. Other parameters as before.

Experimental Design. In order to test these hypotheses it was necessary to alter the size-RGR relation within populations without changing relative density.* To do this, we

---

* "Relative density" refers to stocking density as a proportion of a theoretical maximum defined by the self-thinning line. Throughout we have used Reineke's (1933) self-thinning relation for Douglas-fir as the theoretical maximum size-density line.

took two approaches. First, to flatten the size-RGR curve (distribute growth more evenly throughout the stand), we pruned so that relatively large trees had more leaf area removed than relatively small trees. Second, to increase dominance (i.e., more positive slope of the size-RGR line) we fertilized, the rationale being that dominant trees would increase leaf area and compete even more effectively for light. Pruning plus fertilization would create opposing effects, and thus a response intermediate to either treatment alone. These treatments were superimposed on 3 density levels (control plus 2 degrees of thinning) in each of 4 young Douglas-fir stands on the Andrews.

<u>Accomplishments</u>. The study was essentially installed as designed in LTER I using two stands on south and two on north exposures. Stands were thinned to desired levels (control, 25% of maximum stand density index (SDI), and 15% of maximum SDI) in the spring of 1981. Central measurement plots for each treatment were located to provide 40 to 50 evenly spaced trees. Fertilization and pruning were carried out in 1982; slow release fertilizer spikes were used to avoid difficulties with granular fertilizer.

A progression from stands in which RGR is highest among smaller trees to stands in which RGR is highest among large trees has been clearly established during LTER I (Figure 3, from Perry 1985). Initial relative density in the stand of Figure 3a was relatively low; small trees had clearly superior RGR's, and thinning produced no change in growth pattern within the stand. In contrast, relative densities in the stands of Figures 3c and 3d were high and RGR of small trees was smaller than that of large trees. Response to thinning shows that this reversal of the RGR pattern was due to "one-sided" competition; small trees were affected by large trees, but large trees were unaffected by the presence of small trees.

The most striking thing about treatment responses to date is that, with one exception, they are so inconsistent among stands and density levels as to be almost chaotic. Figure 4 shows within-stand distributions of RGR (basal area) in the first two

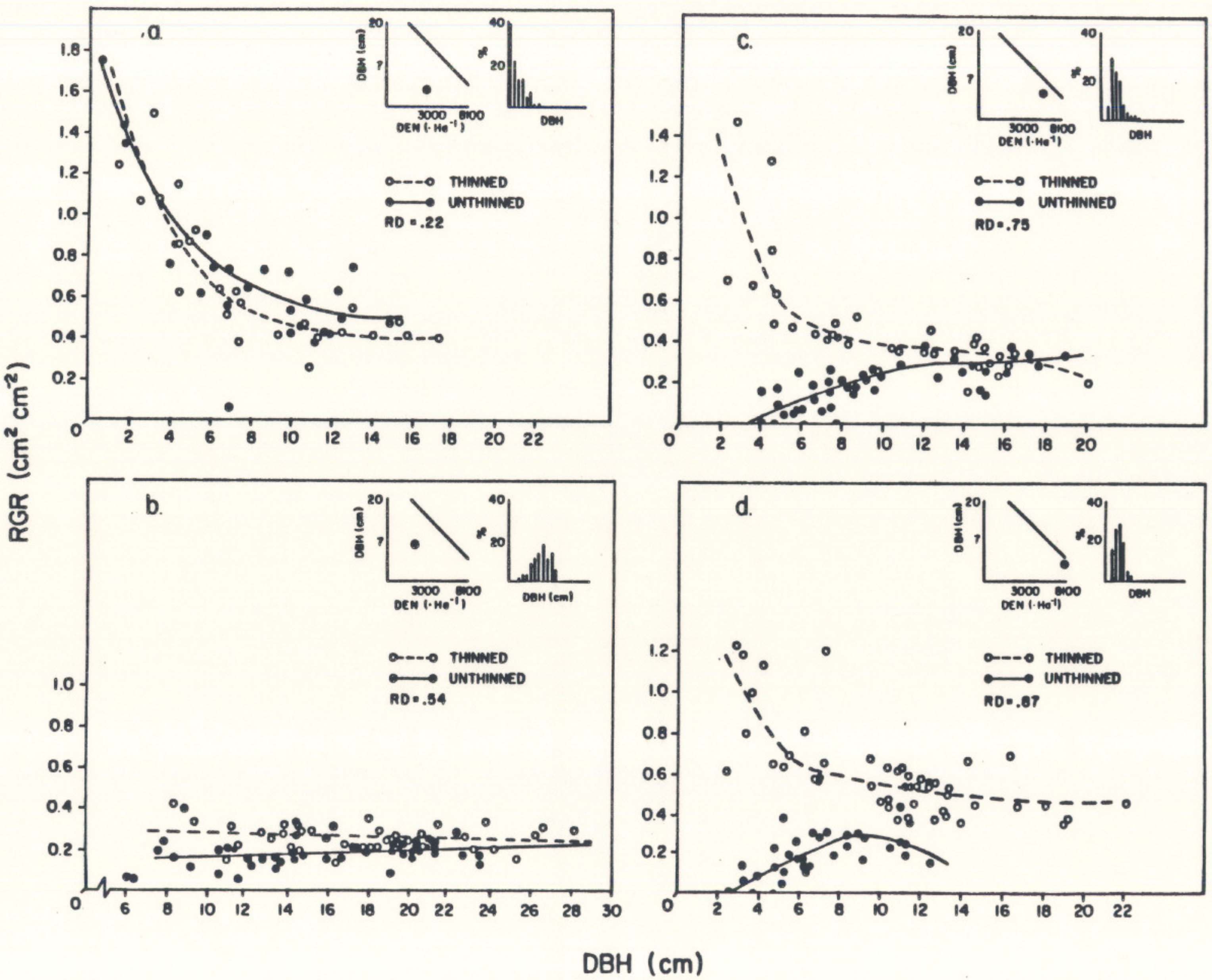


Figure 3. Distribution of relative growth rates (RGR) within young Douglas-fir stands, as influenced by Relative Density and thinning. RGR is measured as 1981 to 1983 basal area growth relative to 1981 basal area. Each pair of curves represent thinned and unthinned plots in the same stand; relative density (RD) of unthinned plots increases from Fig. 3a through Fig. 3d.

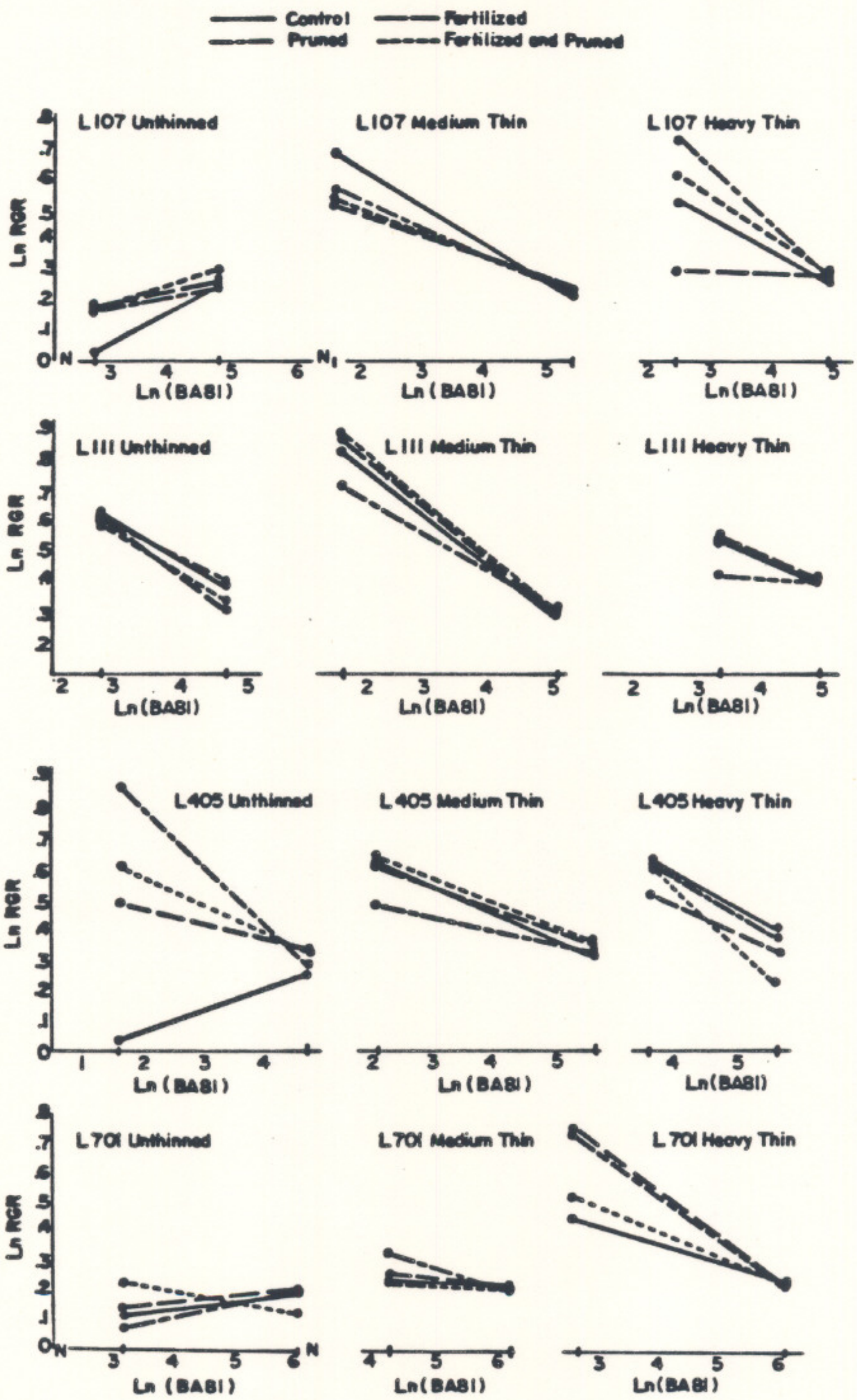


Figure 4. Distribution of RGR (basal area) within four Douglas-fir stands, as influenced by thinning level of fertilization, pruning, or fertilization plus prunning. BA81 is 1981 basal area of individual trees within a plot. Each line is derived from all trees in a single plot. Trees per plot varied from 25 to 50, and averaged 42.

years following treatment of the Andrews LTER Plots (the log-log scale is to linearize the relation). Figure 5 gives slopes and their standard error for the curves of Figure 4. Explanations for the highly variable response suggests analogies with thermodynamic systems. Treatments were applied according to a rigorous protocol* and growth measurements were derived from repeated measurement of the same point on the same trees; experimental error is, therefore, unlikely to account for a significant proportion of the variable response. The 4 treatment curves for each stand-density combinations were derived over the same range of tree sizes, so distortions due to very small or very large individuals within a single plot have been eliminated. We conclude that, as in thermodynamic systems, pertubation of nonequilibrium plant populations (in our case alteration of competitive relations) may produce very different dynamical system behavior, depending on initial conditions which are, as yet, unspecified. This homology between ecological and thermodynamic systems shouldn't be a complete surprise, because we have long recognized mathematical similarities in the underlying structure of the two types of systems (May and Oster 1976, Ulanowicz 1979, Prigogine 1980).

The single consistent feature of our results to date is the remarkable stability of RGR of dominant trees in a stand. This is surprising for 2 reasons: first, since smaller trees sometimes responded to fertilization, it suggests one-sided competition for nutrients (something that, to our knowledge, hasn't been observed before); second, dominant trees in pruned plots had significant amounts of leaf area removed, yet this had no effect on their basal-area growth. Three possible explanations are apparent. First, pruned branches were not contributing to basal-area growth. Second, carbohydrates were diverted from other (non measured) growing points in order to

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*Fertilizer (N-P-K) was applied as slow release tabs in order to reduce volatilization and leaching losses, and minimize uptake by non-target vegetation. The number of tabs applied to each tree was a strict function of tree size. Pruning could not be controlled as precisely as fertilization, but the same crew worked on each plot and tree-size-pruning guidelines were closely adhered to.

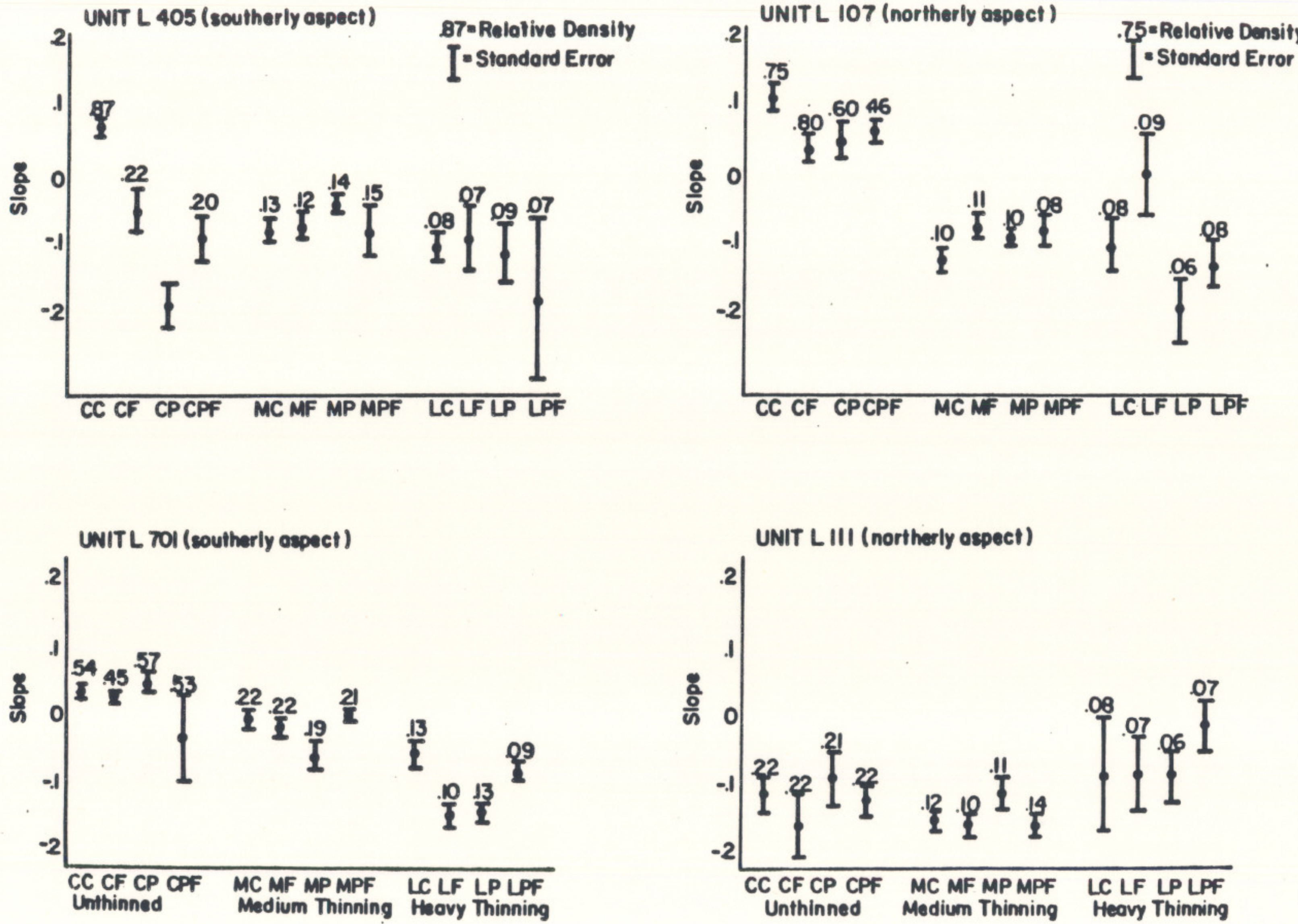


Figure 5. Slopes and their standard errors for lines of Fig. 4. Dominance within a given stand is low with negative and high with positive slopes. The first letter of each plot designation gives thinning level (C = unthinned, M = medium thinning, L = heavy thinning); the second letter represents treatment (C = control, F = fertilized with slow release N,P,K, P = pruned, PF = pruned plus fertilized).

maintain diameter growth. Third, photosynthetic efficiency in remaining foliage was increased sufficiently to make up for the lost leaves. The latter could happen if nutrient and water relations were improved in the residual crown.

Plan in LTER II. The overall design of the experiment is unchanged from the original LTER I study plan; additional research is planned (see cooperation section) from non-LTER funds. We will continue the measurement program and observe development of the study plots as they approach self-thinning. Treatments will be repeated as necessary. The proposed schedule of activities is:

1986 - Repeat fertilization and pruning if necessary.

1987 - Measure height and dbh. Collect increment cores to estimate sapwood area and leaf area.

1988 - Repeat fertilization and pruning if necessary.

1989 - Measure height and dbh. Collect increment cores.

1990 - Repeat fertilization and pruning if necessary.

Growth trends and treatment effects should appear clearly in the next 5 years. This, in turn, will permit us to test a growth model incorporating structural aspects of these tree populations and to conduct initial tests of the hypotheses.

Cooperation. The Willamette National Forest contributed significantly to the installation of this study. Over $25,000 was expended by the Forest Service in identifying the sites; assisting in designation of treatments; and thinning the areas to the designated levels. Additional support was provided by Oregon State University.

Additional studies are proposed for separate NSF or FS funding to expand this population study to an ecosystem level. It exemplifies the potential created by the long-term experiments There are two general objectives. First, measurement of canopy photosynthesis in order to clarify tree growth responses seen in the current LTER study and to develop parameters for a model of plant population dynamics (Perry 1984). Second, to examine relationships between tree growth, understory vegetation, and ungulates. Shrubs and herbs differ in effects on site nutrient and moisture regimes. The nutrient-rich litter of herbaceous species increases mineralization of N and P, favoring growth of suppressed trees relative to dominants. Some woody shrubs also increase mineralization rates (alder, vine maple, ceanothus) but are heavy water users, increasing tree photosynthesis during periods of soil saturation and decreasing it during late summer. The net effect of understory on the tree layer is complex but herbs generally have a more positive influence than shrubs. Shrub cover tends to increase at the expense of herbs, but browsing by elk and deer maintains balance between these 2 understory components and is, therefore, a key factor in tree growth. To test these ideas we would experimentally manipulate portions of the LTER sites by (a) removing all understory, with high quality litter returned to subplots, and (b) excluding ungulates, with artificial grazing of shrubs on subplots.

Component 4: Long-Term Impacts of Nitrogen Fixers on Forest Soils

Woody N-fixing plants, such as _Ceanothus_ spp. and red alder, are important seral forest species in the Pacific Northwest. Their role and importance in the long-term nitrogen balance of forest ecosystems is controversial. While considerable work has been conducted on nitrogen fixation over short periods, almost none has examined the long-term effects of such species on soil physical and chemical properties. On managed sites, where these deciduous shrubs and herbs are viewed as undesireable competitors, the net effect on tree growth or balance between favorable and unfavorable influences is unresolved as is the relative ecological merit of N-fixing plants as compared to inorganic nitrogen additions in fertilization.

In this LTER component we are examining the long-term effect of _Ceanothus velutinus_ (snowbrush), a native N-fixing shrub, on growth of Douglas-fir and on soil chemical and physical properties (especially C and N status). The study will extend at least 60 years, the shortest possible rotation length for Douglas-fir. Ideally, observations would extend over several rotations of Douglas-fir.

Hypotheses. The major hypothesis to be tested is that increases in N availability at sites occupied by *Ceanothus* will increase growth of Douglas-fir. A number of sub-hypotheses concern comparisons of soils at sites with and without N fixers in early successional communities (Figure 6). For example:

> Soil organic matter and carbon will increase during early succession and gradually decline in middle and late succession if N fixers are present in early succession and remain unchanged or decrease gradually throughout succession if N fixers are absent.
>
> Soil total N and N availability will increase during early succession due to rapid N accretion when N-fixers are present and gradually decline in middle and late succession. Total N capital will remain constant or decline slightly when N-fixers are absent, but N availability may increase early in succession and decline gradually thereafter.
>
> Surface and belowground litter N will decompose faster in early successional systems with N-fixers than in those lacking N-fixers due to improved substrate quality and a lower C/N ratio.
>
> Soil structure will improve during early succession on sites with N-fixers but remain constant or decrease slightly throughout succession on sites lacking N-fixers.

The last hypothesis presumes that the increased soil organic matter and soil activity associated with superior litter quality will lower the soil bulk density.

Additional hypotheses are related directly to the role of *Ceanothus* in our northwestern ecosystems. For example:

> *Ceanothus* at intermediate density levels is equivalent to inorganic N fertilizer in its effect on growth rate of conifers, but not in its long-term effect on soil structure and N availability.
>
> *Ceanothus* produces increases in both total and available N in the rooting zone and a smaller increase in total C; hence, the C/N ratio narrows during occupancy of a site by *Ceanothus*.

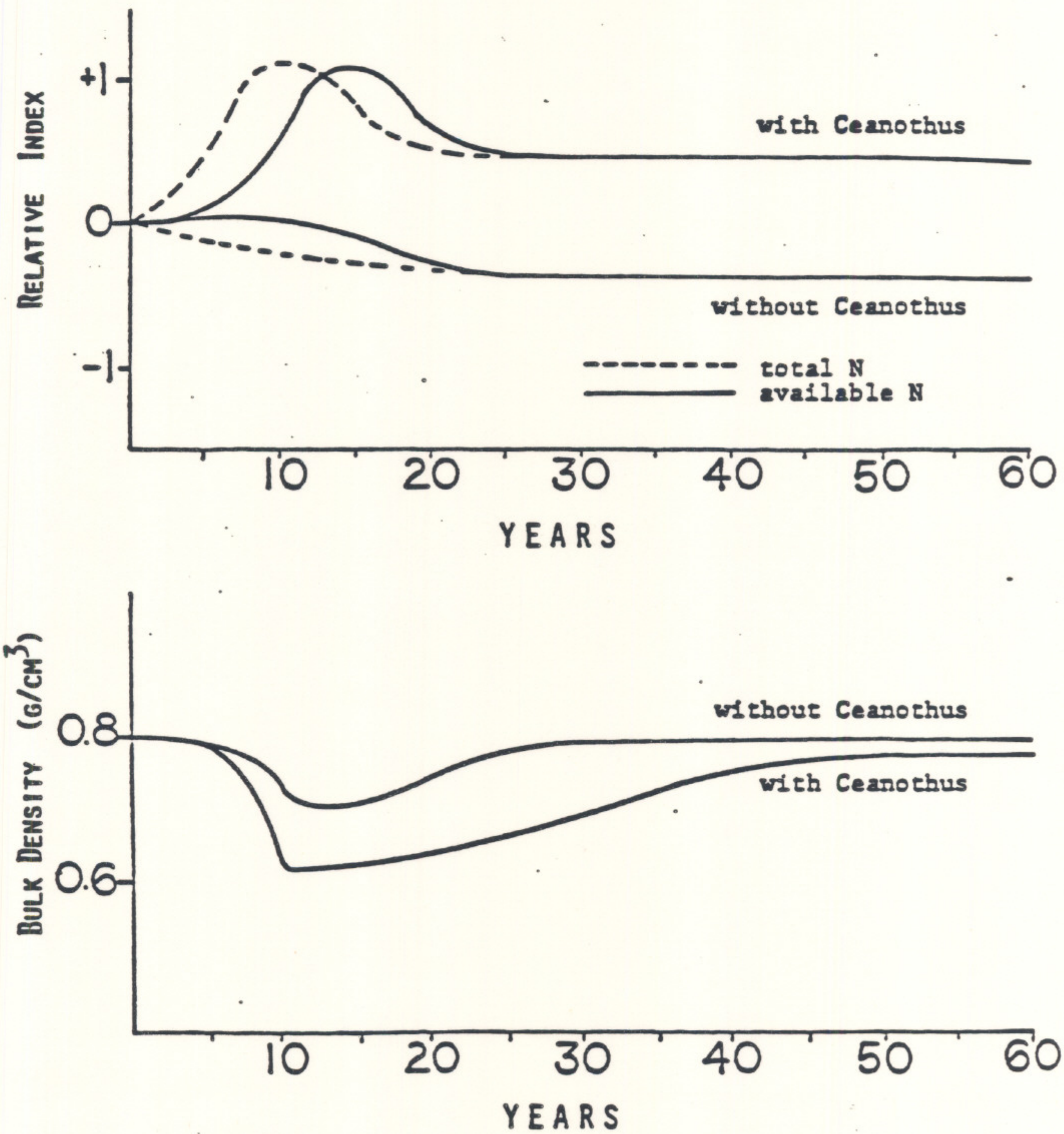


Figure 6. Predicted changes in soil properties during 60 years of secondary succession and stand development.

Conifer growth is initially slower when associated with high densities of Ceanothus than at sites where Ceanothus is absent. However, after 15 to 20 years, conifer growth is greater when associated with Ceanothus and cumulative yields are greater at the end of a rotation.

Conifer volume at the end of a 60-year rotation increases with density of Ceanothus.

This is based on the premise that, even at high Ceanothus densities, initial competition between Ceanothus and seedlings produces highly selective, optimal thinning of conifers. This should produce a vigorous stand well supplied with N in the long run.

A final hypothesis concerns the durability of Ceanothus' influence on soil properties:

Significant differences in total soil nitrogen and soil organic matter content will persist for at least twice the life span of the Ceanothus or, in this case, for 60 years after the elimination of Ceanothus.

Experimental Design. The study design includes 4 replications of 4 treatments on a freshly logged site (Figure 7). The primary variable is Ceanothus density. Three levels are included: zero, 750/ha, and 1500/ha. The fourth treatment is zero Ceanothus, but with annual N fertilization at rates equivalent to rates at which Ceanothus is expected to add N. Approximately 900 Douglas-fir seedlings per hectare were planted over the study area in 1982, approximately 6 months after burning.

Every 5 years beginning with plot establishment we will measure biomass of Ceanothus, biomass and current growth of Douglas-fir, and soil N and C status. Biomass regression equations permit us to estimate biomass from stem diameter.

Soil N and C will be measured in bulk soil and in 2 density fractions of root-free soil. Work to date indicates that these fractions correspond well with turnover time and thus with availability (Spycher et al. 1983, Sollins et al. 1983, 1984). In fractionations of soil from a uniform site at AEF, 4 cores sufficed to reduce the standard error to 10% of the mean (Spycher et al. 1983); more cores are required at the snowbrush site.

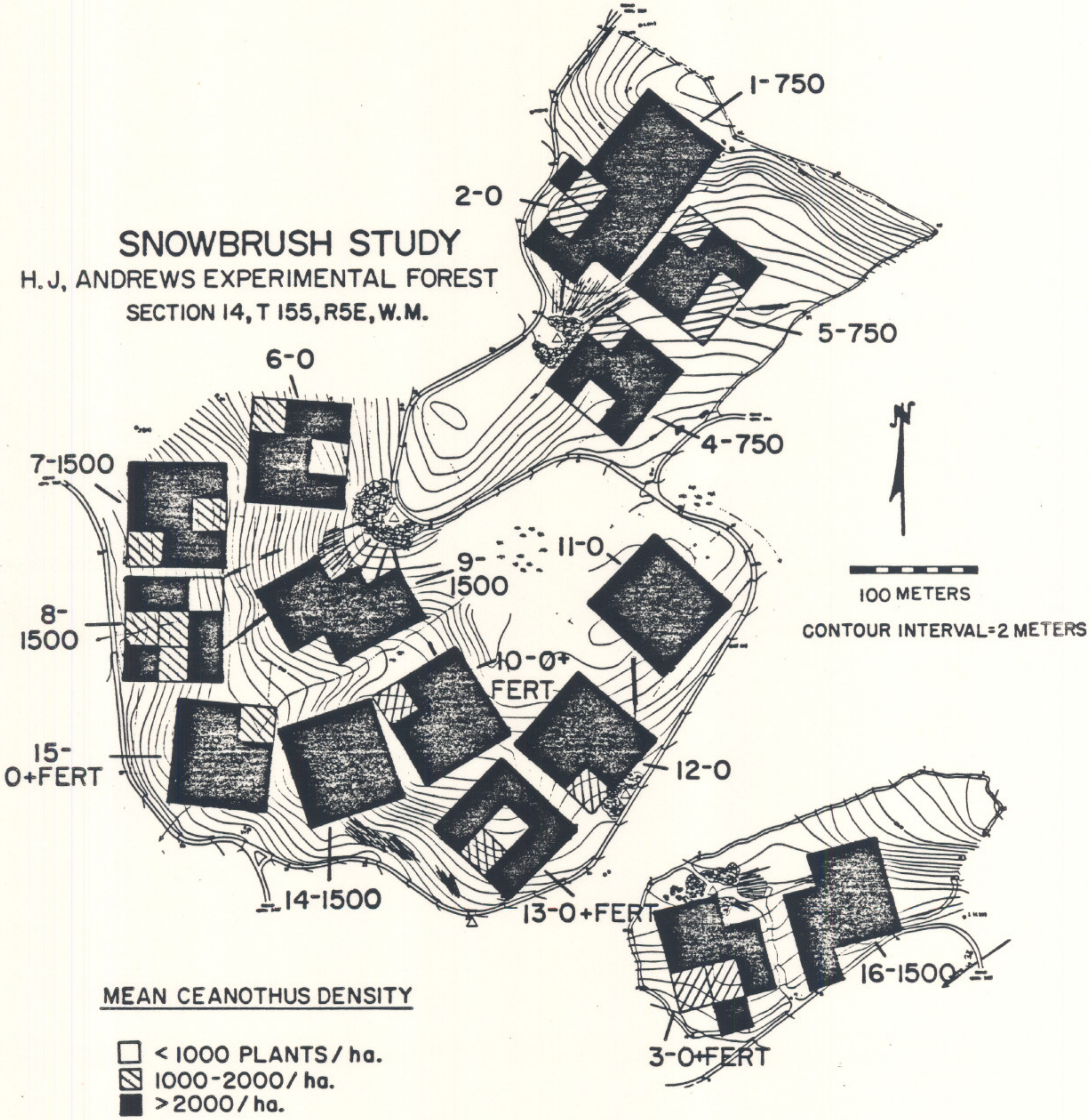


Figure 7. Ceanothus stocking density and treatment assignments at the LTER snowbrush study site.

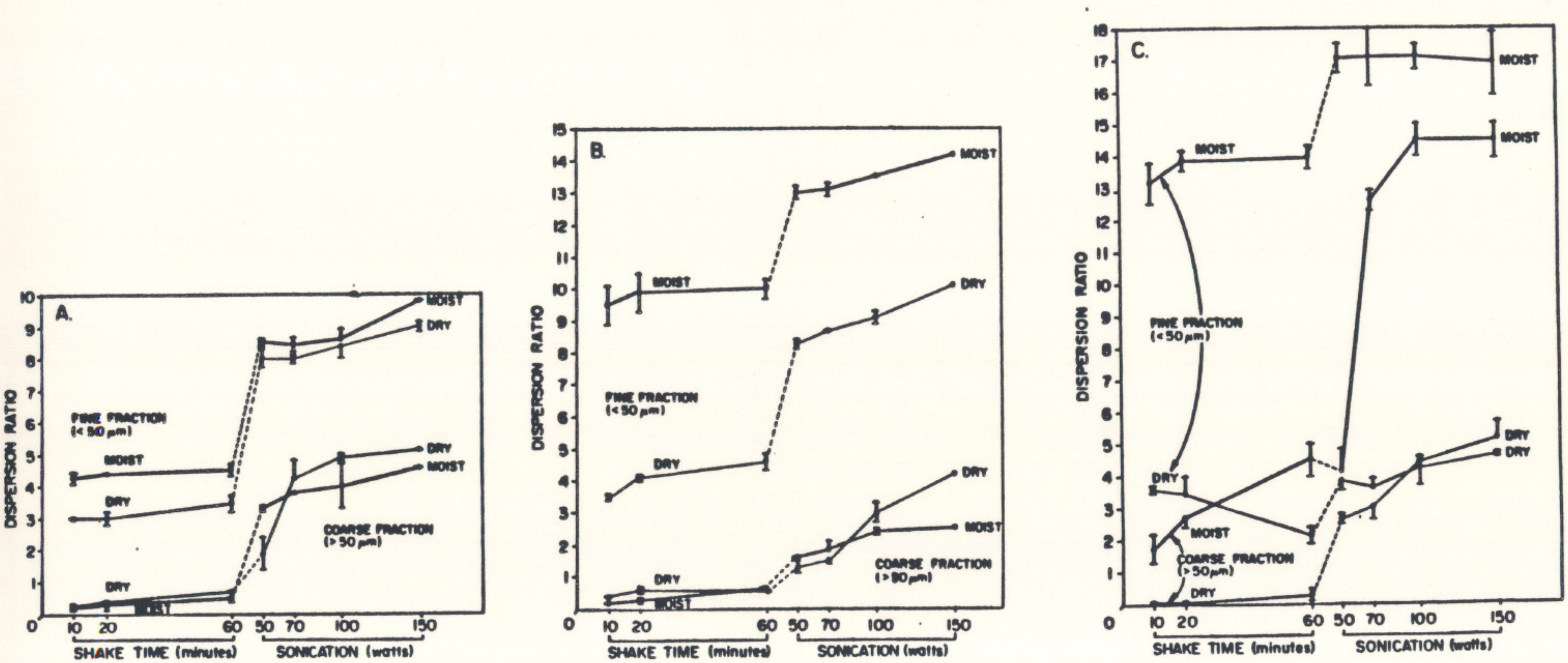
Accomplishments. The study was established essentially as designed despite challenges (Figure 7). Logging problems delayed the project by a year. An intense broadcast slash burn was required in order to stimulate germination of the Ceanothus seed, which exist as a seedbank in the forest floor. This necessitated an expensive mid-summer burn. Next was the suspense associated with emergence and establishment of Ceanothus seedlings; we had ascertained that it was not feasible to establish large numbers of Ceanothus plants by transplanting wildings or nursery-grown seedlings.

Ceanothus seedlings have developed on most of the study plots in sufficient density. Treatments have been randomly assigned and most have more plants than are needed. Ceanothus density will be adjusted to treatment levels in summer 1985 by removing plants (pulling or cutting) and a small amount of transplanting. Douglas-fir seedlings of the indigenous seed source have also been successfully established by planting.

Soil N and C status were measured at 64 locations (4 per plot) in fall 1982 after the clearcut was burned. This data provides the "time 0" value against which later measurements will be compared.

Soil samples gathered during the "time 0" sampling were used in a comparative study of N mineralization from light and heavy soil density fractions (Sollins et al. 1984). Others soils included in the study, all volcanic derived, were from La Selva, Turrialba and Monte Verde (Costa Rica), Cascade Head and Waldo Lake (Oregon), and Wind River (Washington). The Ceanothus soil samples, along with samples from La Selva and from Central Plains Experimental Range LTER site, provided initial comparative data on soil aggregation and aggregate stability (Figure 8). These studies will continue as part of an NSF-funded study of role of soil physical structure in regulating N mineralization to be conducted jointly by P. Sollins (OSU) and D. Schimel (Colorado State Univ.).

Plan in LTER II. Excellent Ceanothus germination (5800/ha) and Douglas-fir seedling survival (95%) have allowed the snowbrush study to get off to a successful start. the



<u>Fig. 8.</u> Effect of air drying (35 C, 24 h) on aggregation and aggregate stability. Composite samples (0-15 cm depth) were wet sieved (50 um), brought to 100 mL volume, shaken or sonicated (5 min) as shown, allowed to settle for 5 min, then assayed for turbidity. Dispersion ratio is the ratio of light absorption (%) to dry weight of the soil fraction.

A. Pachic Argiustoll from C.P.E.R., Colorado (short-grass LTER site).
B. Andic Haplumbrept from H.J. Andrews Exp. Forest (LTER site).
C. Oxic(?) Humitropept from La Selva, Costa Rica (upper-terrace soil).

general approach for the LTER II period will be to track Douglas-fir and _Ceanothus_ growth and soil nutrient status.

Ceanothus in a clearcut adjacent to the study site were checked for N fixation in summer 1982. _Ceanothus_ on the study site will be checked annually beginning summer 1985 and N fertilization initiated at a similar level.

The overall schedule of activities is as follows:

1986 Complete survey of upper soil layer by compositing fifteen 0-15 cm depth cores into 3 samples per cell for a total of 432 samples. The samples will be analyzed for total N, total C, and N mineralization potential (aerobic incubation). A subset will be incubated anaerobically to allow comparison with previous results (Sollins et al. 1984).
Fertilize appropriate plots with 4 kg/ha urea.
Repeat photopoints.

1987 Vegetation survey: For Douglas-fir, measure diameter, height, leader growth, distance to nearest shrub, and animal damage. Estimate biomass and vigor. For _Ceanothus_, measure diameter and height. Estimate cover and biomass.
Survey nodulation and N-fixation.
Fertilization.

1988 Fertilization

1989 Soil survey using both cores and soil pits.
Repeat vegetation survey.
Fertilization.

1990 Fertilization.
Repeat photopoints.

A major value of this experiment will lie in our ability to explain the observed responses which will require detailed information on mechanisms and controlling factors. We will seek additional funds for process studies needed to realize the studies full potential.

Cooperation. The _Ceanothus_ study has been made possible only through the cooperation and large financial contribution of the Willamette National Foest. The operational costs of establishing the study are estimated at around $100,000. The slash burn alone cost in excess of $25,000, a large proportion of the yearly funds available to the Forest for such work. Similarly, the costs of planting the Douglas-fir and adjusting Ceanothus densities have been born by the Forest Service. As important has been the supportive attitudes of responsible Forest Service Administrators.

Component 5. Patterns and Rates of Coarse Woody Debris Decomposition

Coarse woody debris (CWD) serves many important functions within forest ecosystems such as (Harmon et al. 1985): habitat and/or food source; a nutrient pool; site of N-fixation; and influence on geomorphology, animal habitat and movement of nutrients and energy in streams. The functional importance of CWD underscores the need to understand the rate at which CWD is created and lost from ecosystems. Our initial objective was to establish a series of very long-term (200 year) controlled experiments that would examine the effect of log species, log size, and environment on the decay of logs within Douglas-fir-western hemlock ecosystems. Sound logs, cut from green trees and placed at the study sites were to provide the raw material with the "standard log" a 60 cm diameter Douglas-fir 6 m in length. At the end of the first funding cycle, our general objective remains the same, although we have refined the initial hypotheses and study design. We also propose to add studies on snag decay processes, using both freshly killed trees and snags of known age.

Hypotheses. In the following hypotheses we have emphasized log decomposition processes, although we still intend to study plant colonization.

Differences in log decay rates between species correspond to the decay resistance of the heartwood.

Numerous laboratory studies show the decay resistance of heartwood varies markedly between tree species due to differences in phenolic extractives (Hillis 1977, Scheffer and Cowling 1966). Species differences are minor in the nonresistant sapwood and inner bark of trees. Since large logs are mainly heartwood, variations in heartwood decay resistance will strongly influence the decay curve of logs (Figure 9).

Colonization patterns of decomposers introduce a lag-time into log decay curves; although decay starts immediately after tree death, the maximum rate of decay does not occur until logs have been fully colonized by decomposers.

Currently, log decay curves are simulated using a single exponential model (Wieder and Lang 1982). This model predicts that the greatest loss, in absolute terms, occurs early in decay. While this model is appropriate for fine litter, it does not reflect decay processes in large logs (Figure 10). Large logs may not be fully colonized for decades (Buchanan and Englelerth 1940, Kimmey and Furniss 1943).

Invertebrate activity increases the colonization rate of logs by bacteria and fungi and thereby increases the decay rate.

Invertebrates remove little log material in Pacific Northwest forests compared with to losses caused by bacteria and fungi. However, invertebrates allow microbes to more rapidly colonize logs (Leach et al. 1934, 1937). Hence, exclusion of invertebrates should increase the lag-time in log decay curves (Figure 10), but will probably not influence decay once colonization is complete.

Log decay rate is negatively correlated with the diameter.

As log diameter increases, the time required to fully colonize the log crossection increases and this increases the time to fully decompose the piece (Figure 10). Furthermore, the proportion of decay resistant heartwood increases with diameter (Hillis 1977) also decreasing the log decay rate.

The physical processes of abrasion and fragmentation are more important relative to biological processes in streams than in upland environments. However, the residence time of logs is similar in both environments.

Bacterial and fungal respiration is reduced when substrates are either too moist or dry (Kaarik 1974, Griffin 1977). Slow rates of biological decay are therefore expected in streams. Moreover, this activity is restricted to a thin (i.e., < 5 mm) outer shell (Aumen 1985). Physical abrasion by flowing water partially removes this layer. Even with very low rates of physical abrasion (e.g., 1 mm/yr) a 60-cm diameter log would have lost 95% of its mass within 200 years (Figure 11). This residence is comparable to 175

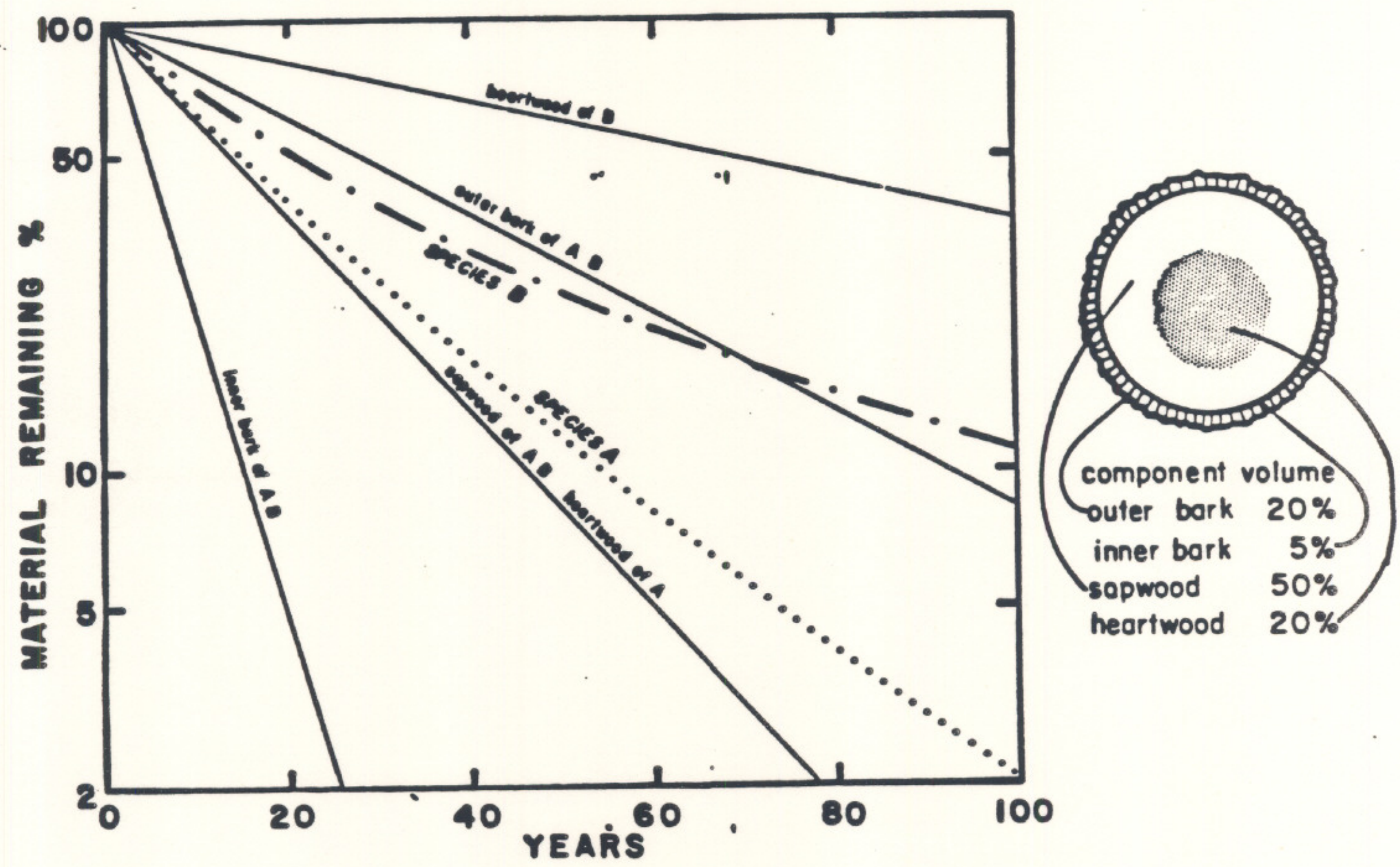


Figure 9. Hypothetical differences between two species of trees when size and proportions of components are constant (see idealized cross-section). The solid lines indicate decay curves for components, while the dashed lines indicate the overall curve for the species. The upwardly concave species curves indicate the slower components (heartwood and outer bark) are dominating the latter stages of the decay curves.

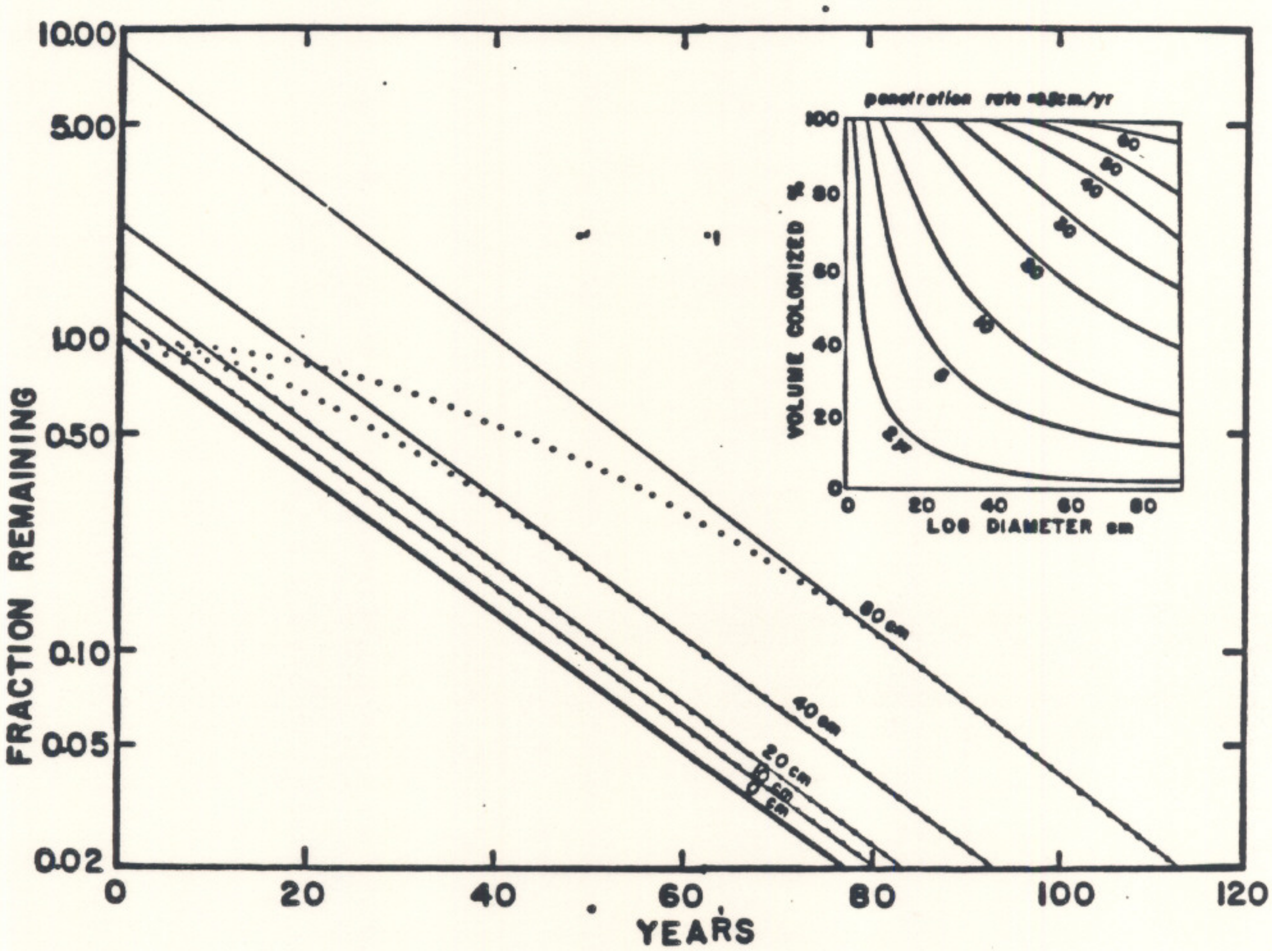


Figure 10. Hypothetical effect of colonization patterns upon log decay curves. The inset illustrates the volume colonized as a function of log diameter and time assuming a radial colonization rate of 0.5 cm yr^{-1}. The larger graph depicts the fraction of log remaining as a function of time and log diameter. In this example, wood has a decay-rate constant of 0.05 yr^{-1}. When a strictly exponential model is followed the curves are linear, and departures from this pattern indicate a lag introduced by colonization patterns.

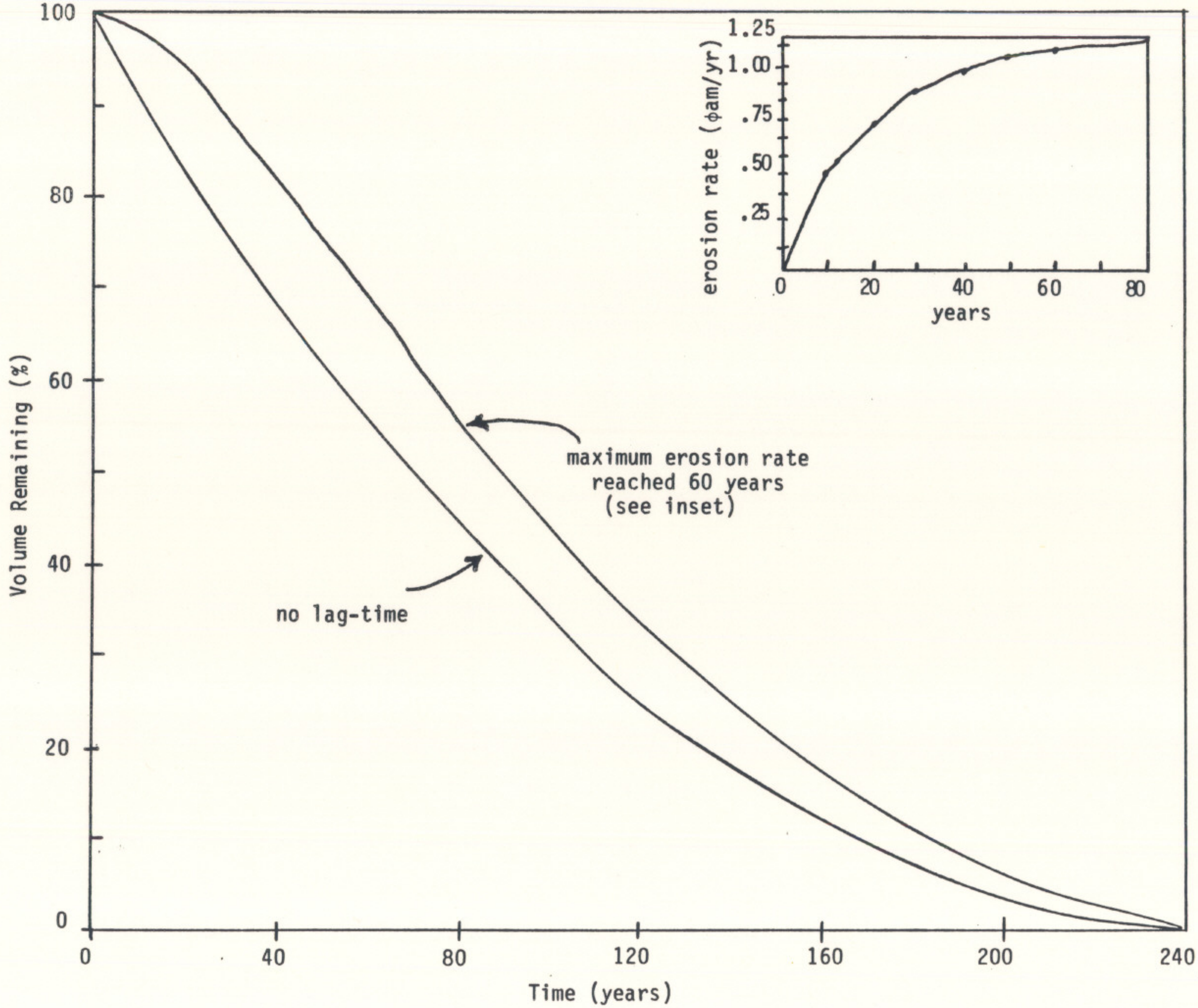


Figure 11. Predictions of the stream abrasion model for a log with an initial diameter of 60 cm.

years calculated (Graham 1982) for 95% loss of a < 65 cm Douglas-fir log in the upland environment.

Experimental Design. The hypotheses concerning heartwood and colonization patterns will be tested by placing green, rot-free, "standard" (45-60 cm diameter and 6 m long) logs into intact forest stands. The basic statistical design of this experiment is a split plot in time with a complete randomized block arrangement of treatments. There are 6 sites or replications of the experiment, each of which represents a block. Four coniferous species -- Pacific silver fir, western hemlock, Douglas-fir, and western redcedar -- are the main plot treatment and represent a gradient of increasing heartwood decay resistance. Substrate types -- outer bark, inner bark, sapwood, and heartwood -- are the sub-plot treatment.

Enough logs will be placed at each site so that 1 log of each species can be removed at 16 different sample interval and dissected. The planned intervals are 1, 2, 3, 4, 5, 6, 8, 16, 24, 32, 60, 90, 120, 150, 180 and 210 years. All the logs will be tagged and mapped as to location. The initial density and volume of the substrates will be sampled within a month of placement during 1985. External log dimensions, as well as cover of bark, bryophytes, lichens and vascular plants will be recorded during the spring of 1986. We will sample the soil under a subsample of logs during the summer of 1986 in order to provide data on initial underlying soil conditions.

At prescribed intervals, randomly selected logs will be dissected at each site to determine the volume of colonized substrate, extent of invertebrate galleries and changes in substrate density. Annual sampling during the first 6 years allows study of microbial colonization patterns and the life history of the earliest invertebrate colonists. A set of logs that is not scheduled for dissection for 60 or more years will be examined biennially for changes in bark, bryophyte, lichen and vascular plant cover.

Exclosures will be used to test the influence of invertebrate activity on microbial colonization and decay of logs. The exclosures will be A-frame tents of 1 mm mesh polyester. Standard sized, green logs will be placed in the exclosures and their decay rates will be compared to the exposed logs described above. The statistical design of this experiment is a split-split plot in time with a complete randomized block arrangement. Western hemlock and Douglas-fir are the main plot treatment. Comparison of controls and exclosures is the sub-plot treatment and the 4 substrate types are the sub-sub-plot treatments. Enough logs will be placed at each of 4 sites to allow dissection of 1 log of each species at 10 sample intervals. We plan to examine logs during each of the first 6 years for comparison with the control logs. Similar measurements of substrate volume and density, decomposer colonization patterns, and bark cover will be made for each of the treatments.

The influence of log diameter will be tested by adding smaller and larger material at the upland experimental sites. Larger diameter material will be added by felling a single old-growth hemlock and Douglas-fir at each site and cutting them into 6 m lengths. Comparisons with the standard sized logs should be possible at 6 separate occasions. At least 5 size classes of small material of 4 species will be removed from fresh clearcuts for comparison with standard sized logs. The size range will be from 1 to 45 cm diameter with sufficient material for 6 comparisons.

Decomposition of logs in streams will be studied by releasing a cohort of tagged, untethered logs into a third-order stream (upper Lookout Creek). Originally, we planned to use tethered logs; however, allowances for natural transport and emplacement of the logs are necessary if a valid upland-stream comparison is to be made. The basic statistical design of this experiment is an analysis of covariance with time as the covariable. Three species -- red alder, Douglas-fir and western hemlock -- will be compared. Logs will be 25-30 cm in diameter and 2 m long. The smaller size is necessary because the logs must be manhandled into the streambed. Enough logs will be placed so that 3 replicates of each species in each environment can be dissected 20 times after placement. The location of the logs in the stream channel and external condition (i.e., bark and bryophyte cover) will be noted annually and destructive samples will be taken every 2 to 3 years.

Accomplishments During LTER I. The majority of the work to date has been planning the study, preliminary field work, and reviewing the literature (Harmon et al. 1985). Planning with the Willamette National Forest personnel has been extensive (Figure 12). Essentially all experiments will be in place by the end of October, 1985 although the logistical problems of placing over 700 logs during 2 months will doubtless strain the Forest Service, timber contractor, and scientific staff at AEF. The review paper on the behavior and function of coarse woody debris in temperate ecosystems (Harmon et al. 1985) represents a major synthesis effort by our group.

Plan in LTER II. During LTER II we will first complete installation activities including log mapping, and sampling of log surfaces for cover of plants and bark, data entry, and preparation of an establishment report.

During each year of LTER II a randomly selected set of logs will be dissected at each of the upland sites to measure heterotroph colonization patterns and density decreases in the substrates. A set of logs will also be examined biennially to measure changes in cover of bark, lichens, bryophytes and vascular plants. The position and condition of untethered logs within Lookout Creek will be examined annually and dissections of selected logs will be made biennially.

Snag Fragmentation. During LTER I we ignored snags, yet rates and paths of snag decomposition contrast sharply with those of logs. At AEF snags disappear at 2 to 4 times the rate of logs of comparable size and species. In LTER II we intend to extend our work to snags.

A number of the hypotheses being tested for logs apply to snags as well, such as effects of decay-resistant heartwood. We would like to specifically test the following hypothesis in LTER II:

CRITICAL PATH - LOG DECOMP. PROJECT 1/17/85

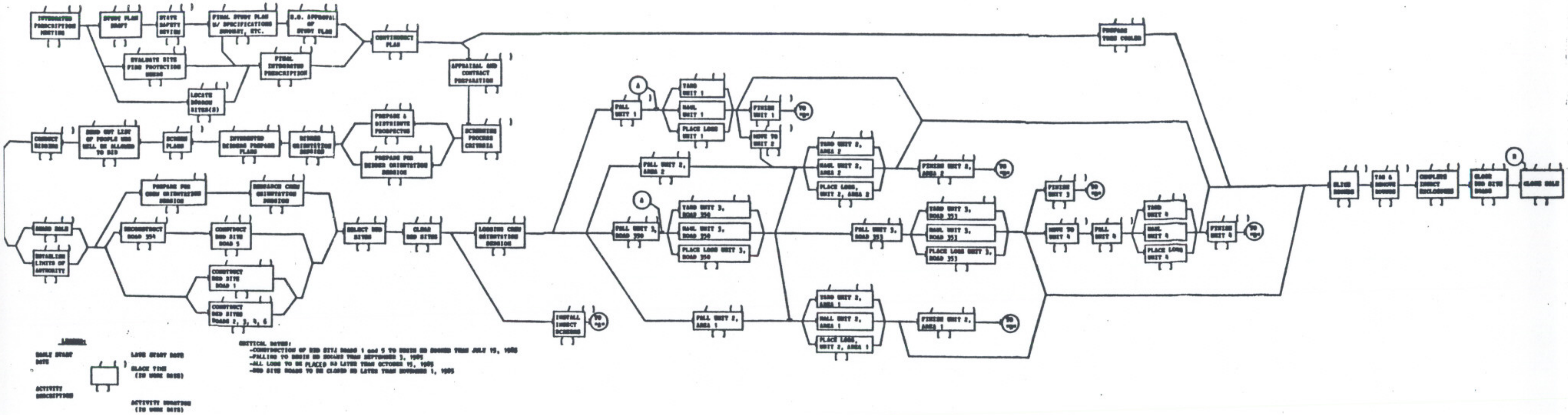


Figure 12. Critical path analysis for installation of the log decomposition experiment.

Respiration losses from snags and logs are roughly equivalent, whereas snag fragmentation is faster and begins sooner than in logs.

The relative importance of snag fragmentation in adding CWD to the forest floor is controlled by the form of mortality. In coastal Sitka spruce forests snag input is very low relative to logs because most trees are killed by wind throw. Snag input is very important in ponderosa pine and white fir forests where most trees die standing.

We will use 2 approaches in the snag fragmentation research. First, we will create new snag cohorts by killing trees of desired species and dimensions using an appropriate silvicide. This will be done in conjunction with the experimental gap study. Our eventual goal is to establish these cohorts in mature and in old-growth forest although we may be limited to mature stands in LTER II. Species selected are: Douglas-fir, western hemlock, western redcedar (old-growth only), and noble fir (mature only). An optical dendrometer will be used to provide the initial and repeat measurements of volume and total height. Other variables for measurement are bark cover, presence of twigs, small branches, and large branches, and nesting cavities. This approach has already been tested on freshly fire-killed sugar pine and white fir snags at Sequoia N.P.

The second approach will be to periodically examine snags in reference stands and other plots with good records of mortality. This follows our National Committee's suggestion that we find ways to reduce the long time periods necessary for definitive results by judicious use of existing data and plots. Dead trees will be stratified by age, species, size, and forest type. Dependent variables to be measured are as outlined previously.

Cooperation. We have activly solicited participation in the log decomposition experiment both locally and nationally. During 1984, a grant proposal was submitted to NSF by Dr. Tim Schowalter to study the invertebrates colonizing the logs during the first three years of decay. The research would also examine changes in substrate quality in terms of carbon chemistry (i.e., lignin, cellulose, sugars, phenolics) and nutrients during decay and how these influence insect life cycles and feeding preferences. There are plans to submit another proposal by Dr. Kermit Cromack Jr to examine changes in soil chemistry caused by the presence of logs and the role of CWD in trapping litter and sediments in upland sites.

The extensive contributions of the Forest Service to establishment of this study have already been mentioned. Cost equivalents of materials, personnel, equipment, etc., are estimated to exceed $250,000.

Component 6. Factors Controlling Long-Term Site Productivity

Objectives. The overall objective of this new component is to identify factors controlling long-term forest productivity using the case of coniferous forests in the Cascade Range. The major hypothesis to be tested is:

> Long-term yield is controlled by nitrogen (N) availability which is roughly proportional to system nitrogen stores. Other factors will be important but will manifest themselves mainly through their effects on N availability.

The experimental design consists of plots on which treatments will be imposed that affect rates of production and accumulation of soil organic matter and therefore long-term patterns of N availability. Proposed treatments consist of a broad range of forestry site preparation practices as well as research treatments which should drastically alter N availability in the soil. The experiment will also provide a framework for testing hypotheses related to treatment effects on soil biology, chemistry, and physical structure, and the role of early seral shrubs and herbs in nutrient retention and cycling.

Justification and Overall Design. Tree growth at our sites is thought to be limited by N availability and also by moisture, the latter only during late summer (Waring & Franklin 1979). Light is generally thought not to limit growth except where competition from seral shrubs is intense. Phosphorus is abundant because the young soils still contain large amounts of unweathered primary minerals and is believed to not be limiting (Radwan and Shumway 1983).

We hypothesize that N availability is the limiting factor for several reasons. Douglas-fir responds to N fertilizer over a wide area of the Cascade Range (Peterson and Gessel 1983), especially where available N (anaerobic mineralization potential) is <50 ppm (Shumway and Atkinson 1978). At some sites where Douglas-fir and red alder are grown together, Douglas-fir growth correlates with N availability (anaerobic mineralization potential) (Binkley 1983). Growth of seedlings in pots correlates with N availability (anaerobic mineralization potential) under different site preparation practices in the Rocky Mountains and Pacific Northwest (Perry et al. 1982, Schoenberger and Perry 1982, Perry and Rose in press).

Site preparation practices affect N stores and N availability. Biomass removal, whether by utilization or site preparation, greatly decreases total N stores (Leaf 1979, Perry 1984). Worldwide, there is evidence that at some sites continued burning or intensive biomass utilization has drawn down the N supply and therefore slowed tree growth (Ballard and Gessel 1983), but simply calculating removal as a proportion of the total system N stores indicates little about effect on tree growth. The forest, unlike a car, is not able to run at full speed until its gas tank runs dry. Moreover, some site preparation practices positively affect system N stores. Burning, for example, may stimulate regrowth of N fixers, offseting N removal by fire.

Because of our interest in the effects of management activities, the overall experiment is designed around a set of site preparation treatments that we expect to produce different long-term effects on N availability. The treatments may also affect availability of other nutrient elements, soil organic matter, and moisture and may have indirect effects on all of these by controlling the species composition of the regrowth and of the soil microflora. We hypothesize, however, that these factors will manifest themselves primarily by affecting N availability. The treatments are:

1. Control with standard utilization levels and in which logging slash is left unburned but scattered evenly over the plots;

2. Stems-only harvest with all residue >20 cm diameter and >2 m length removed (semi-clean harvest);

3. Whole-tree harvest with all residue >5 cm diameter and >30 cm length removed (clean harvest);

4. Broadcast burn in which the site is logged as in #2 (semi-clean), then burned.

The treatments span a range of possible management practices while creating plots at which N availability and other fators should differ substantially, thus providing a range of sites at which to study processes of N input, loss, and transformation.

The research tratments, to be superimposed on 3 of the site prep treatments in a partial split-plot design, are intended to alter the factors controlling N availability as severely and quickly as possible. Proposed treatments and their objectives are:

1. Continual removal of all vegetation to hasten soil organic matter (SOM) decomposition and thus draw down total N stores;

2. Continued removal of all understory vegetation to alter the C:N ratio and lignin content of the leaf and root litter and thus the balance between N mineralization and N immobilization;

3. Continued removal of all vegetation coupled with periodic ammendment with sugar or sawdust to immobilize N and decrease its availability;

4. Continued removal of all vegetaion coupled with periodic ammendment with a nitrification inhibitor in order to draw down soil organic matter levels without increasing N leaching and lowering pH;

5. Periodic ammendment with wood ash to simulate part but not all of the effects of burning on N availability;

6. Trenching to prevent root turnover and N uptake by roots and raking to eliminate litter as a source of soil N and C (these two will be done separately on small areas within intact second-growth forest so that litterfall, in the first case, and root turnover, in the second case, will not be affected).

The choice of treatments is tentative and will be reviewed and probably modified during the first 2 years of LTER II as a detailed study plan is prepared.

The experiment will be integrated and coordinated with a modelling effort in order to quantitatively assess the importance of particular processes and parameters to tree growth. We have taken FORCYTE, a computer model developed at the University of British

Columbia that projects long-term effects of silvicultural practices on N availability, adapted it to predict growth of Cascade Range Douglas-fir and implemented it on a microcomputer. We will continue to develop the model, incorporating results of process research and eventually comparing model predictions with observed long-term behavior of the systems. Other models will also be examined (e.g., Aber et al. 1978, 1979). We will use results of other long-term studies such as the Northwest Regional Forest Fertilization Program, to calibrate and interpret the models.

Process-Level Research. The treatments proposed here will allow us to test hypotheses about factors regulating processes in 3 areas:

1. Long-term system inputs and outputs of N;
2. Pathways and processes by which N is converted from organic to inorganic form available for uptake by vegetation; and
3. Effect of N status of the trees and understory vegetation on their growth.

Space does not permit a thorough review of background information so relevant references are provided for each part of the following hypotheses.

Treatments will affect rates of N input to the system mainly where patterns of vegetation regrowth are altered (Isaac 1940, Morris 1970) such that the density of symbiotic N fixers is increased (Dunn and Poth 1979, Egeland 1985).

Revegetation by N fixers will be stimulated by burning because Ceanothus seed requires scarification. Asymbiotic fixation in the rhizosphere will be important and will be roughly proportional to NPP by ectomycorrhizal species (Li and Trappe unpublished). Fixation in woody debris and litter will be predictable simply from amounts of each substrate (Jorgensen and Wells 1971, Spano et al. 1982, Silvester et al. 1982, Jorgensen et al. 1984, Heath 1985).

Amount of soil organic N will be determined by the amount of SOM (constant C/N ratio). The exception will be where return in litter continues inputting dissolved N but return in root death is stopped (trenched plots with continuing input of litter), in which case C:N will narrow through time.

SOM derives mainly from fine roots, not from leaf litter; therefore, amounts of SOM will be affected by rate of root turnover (predictable in part from net primary productivity)

(Keyes & Grier 1981, McClaugherty et al. 1982, Persson 1983), by content of lignin and other polyphenolics in the root litter (see Aber and Melillo 1982, Melillo et al. 1982, Gill and Lavender 1983), and by soil temperature (a function mainly of plant cover). Temperature effects will only be important on plots where vegetation regrowth is partly or totally prevented. Root lignin content will affect SOM levels mainly where regrowth of understory vegetation is totally prevented resulting in dominance by conifer roots with higher lignin content, and, therefore, slower decay rate. Differences in understory composition resulting from site prep treatments will have smaller but still important effects on litter lignin content and C:N ratio and thus SOM levels.

N mineralization potential will be proportional to total N stores except where the ratio of light- to heavy-fraction organic matter or the C:N ratio of the light fraction is altered.

Large amounts of wide C:N light fraction material will depress N mineralization potential (Sollins et al. 1984, Vitousek and Matson 1984). Fire on the other hand, may preferentially consume the high C:N (woody) material resulting in increased net N mineralization. Burning will also release base cations and P in large amounts which will speed decomposition and increase pH, both of which will increase rates of net N mineralization (Woodmansee and Wallach 1981). Chemical composition and degree of physical protection of the heavy-fraction organic N will be little affected by treatment except where SOM stores are reduced substantially. Where SOM stores decline (e.g., long-term devegetation), recalcitrant residues will predominate thus depressing N mineralization potential (Van Veen and Paul 1981, Cambell and Souster 1982), but restricted aeration and root growth will decrease aggregation (Tisdall and Oades 1982) thus increasing mineralization potential.

N uptake by plants wll have a dominant effect on solution nitrate and ammonium levels.

Site prep treatments will affect amounts of vegetation and their uptake efficiency (Boring and Monk 1981). Burning will particularly result in revegetation by plants and mycosymbionts adapted to efficient nitrate utilization. Preferential and efficient nitrate use will be tested for by plant bioassay. In general, changes in net mineralization will not greatly affect solution N levels because the plants will correspondingly increase their rate of uptake from solution. Nitrification will be regulated mainly by levels of solution and exchanged ammonium (Vitousek et al. 1982), thus mainly by rates of uptake by the vegetation. However, burning will also stimulate nitrification by increasing availability of P and cations.

Amount of inorganic N leached from the system will depend mostly on amount in solution.

(It will actually correlate better with N mineralization potential because of difficulties in representatively sampling the soil solution (Haines et al. 1982, Russell and Ewel 1985)). Water flux will not be affected much by the treatments unless leaf area changes enough to affect E-T. Rainfall is high, however, and only about 30% of the precip exits via E-T (Fredriksen 1972, Sollins et al. 1980); thus, large effects on soil water flux are not expected. Soil cation exchange capacity and base saturation will not change enough to affect ammonium export except where SOM stores are severely depleted (long-term devegetation). Soil anion exchange capacity (AEC) will remain small unless regrowth is prevented for many years in which case declines in SOM will raise the PZC (point of zero charge) close to the soil pH thus increasing AEC (Gast 1977, Sposito 1984).

Export of dissolved organic N from the system will change little with treatment because it is controlled mostly by rate of adsorption onto soil and subsoil mineral surfaces, and much less by rate of soil organic matter decomposition (Sollins et al. 1980, McDowell and Wood 1984).

Differences among plots in biomass of new foliage produced annually will be predictable from the amount of foliar N and the age and vertical distribution of foliage through the canopy (Jarvis et al. 1976, Linder and Troeng 1980, Agren 1983). Overall, N availability will affect yield mainly by influencing total leaf area and average needle retention, less by influencing photosynthesis per unit area of foliage (Brix and Ebell 1968).

Experimental Design. Each site preparation treatment will be replicated 5 times on plots of about 1 ha. A 30x30 m bare fallow subplot will be established within each site prep treatment -- control, semi-clean yarded, clean-yarded, and burned. The research treatments involving ammendments will be nested within each of the bare, fallow subplots. Thus each bare, fallow subplot will have 4 sub-sub-plots: ammendment with high C:N material, ammendment with wood ash, ammendment with nitrification inhibitor and no ammendment.

In order to test hypotheses about litterfall and root death as sources of soil organic carbon and nitrogen, small plots will be set up within otherwise intact second-growth or old-growth forest adjacent to the site prep plots. Understory vegetation will be clipped by hand. Litter will be raked periodically from half of each plot; the other half will be trenched to prevent root in-growth but litter will not be removed.

Treatments will be assigned to plots in a blocked design based on N mineralization potential (aerobic incubation). The entire area will be gridded at 20 m and block kriged to map spatial variability in N mineralization potential (Vierra et al. 1983, Burgess and Webster 1980).

Tree height and diameter will be measured periodically so that biomass and productivity can be calculated. Room will be allocated within site prep treatment plots for destructive sampling of the trees since allometric relations are known to change with nutritional status (e.g. Satoo 1970, Koerper and Richardson 1980). Accurate values for canopy nitrogen content will be needed; regression equations may have to be established between leaf area or mass and appropriate independent variables (diameter, height, sapwood area, competition factor). Foliar and root nutrient concentrations will be monitored at all plots; litterfall, throughfall, and root turnover will be monitored only at selected plots (see below) because of the expense.

Soil properties to be monitored are N mineralization and nitrification potential (aerobic incubation), denitrification potential and asymbiotic N fixation rate (acetylene addition to intact cores), total N and C (Leco), pH, effective CEC (Uehara and Gillman 1981), and PZC (Van Rai and Peech 1972). These will be measured before and after the stand is logged, immediately after site prep, and then periodically at increasing intervals. Ideally, soil variables would be sampled to 1 m depth (the active rooting zone). The surface soil (0-20 cm) can be sampled with a corer; the deeper samples may require soil pits which are labor intensive and destructive.

At most plots, amounts and nutrient content of litter and coarse woody debris will be measured before and after site preparation and then only once more during the 5-yr study unless differences in litter acumulation between treatments are much larger than expected. Hypotheses about the role of understory vegetation in controlling litter quality require that litterfall and accumulation by monitored carefully and compared with areas from which understory vegetation is not excluded. This will be done on some but not all of the site prep treatment plots as funding permits.

Ideally, leaching would be measured at all plots but the methods available (tension and tension-free lysimeters, resin bags) leave serious doubts as to just what is being measured especially in our soils where much of the water flows through macropores. Sollins and his post-doc are currently testing and improving these methods at La Selva. We will defer our decision on whether and how to measure leaching.

Schedule. The experimental treatments are planned for 1989 in order to phase in with the other Andrews LTER projects. The site pretreatments require advance planning and coordination with the USFS. Sites will be selected and contracts written during 1986 and 1987. In 1988 a post-doctoral researcher with a soil microbiology background will be hired and the simulation model will be updated to incorporate as much existing data as possible. Some treatments in intact forest stands will also be established. Logging is planned for 1989 with a spring broadcast burn in 1990. Plot establishment on clearcuts and large scale soil sampling will also take place in 1990.

Coordination with Other Projects. Work proposed here complements two of the existing Andrews LTER projects. The experiment on -3/2 power law thinning attempts to alter soil N status with slow-release fertilizer. The *Ceanothus* study, like the site-prep study described here, is concerned with input and transformation of N and effects of N availability on tree growth. Density of N fixing plants is controlled in the *Ceanothus* study whereas changes in N-fixer density will be largely unpredictable in the site-prep study.

The site-prep project will parallel a long-term manipulated plot study initiated at La Selva, Costa Rica. Soils at La Selva and at the Andrews are similar in that both (1) have weathered from volcanic-flow materials under a wet moisture regime, (2) are strongly influenced by amorphous weathering products and variable-charge clays, and (3) are extremely well aggregated. Consequently, techniques developed at La Selva for measuring microbiological activity, soil spatial variability and soil chemistry should be directly adaptable to soils at AEF.

The U.S. Forest Service will cooperate extensively in setting up the project described here. The Blue River Ranger District will take overall responsibility for the site-preparation treatments. The Pacific Northwest Forest Experiment Station (PNW) will to help with growth measurements and soil sampling; this study is coordinated with the PNW Residue Management Program.

To realize the full potential of this experiment, 2 other components are needed. First, additional funds must be secured since only a small fraction of the potential process research can be conducted with LTER funding. Second, replicates are needed at other locations in the PNW if regional responses are to be adequately defined. We will cooperate with the Forest Service, Bureau of Land Management, and forest industries in creating replicates at other locations.

Publications and Information Synthesis

Five years is relatively early in the life of a purported long-term ecological research program. Nonetheless, publications are beginning to appear which have had significant support from LTER funding and which address LTER hypotheses. One major factor contributing to early production has been the legacy of experiments, permanent plots and other installations, and baseline data sets provided by earlier NSF and Forest Service research projects at AEF. A few products are strictly LTER efforts, most notably a review paper for Advances in Ecological Research on coarse woody debris in forest and stream ecosystems (Harmon et al. 1985) and the data management papers by Stafford and her staff. LTER research also contributed substantially to the ecosystem textbook written by Waring and Schlesinger (1985).

We expect publications from the LTER program to increase rapidly during LTER II. The largest single product will be an effort to synthesize our understanding of western coniferous forest ecosystems based upon the Andrews experience. Franklin will take the lead in development of this synthesis volume during a sabbatical leave at Harvard Forest although chapters will be individually authored and involve a dozen or more of Andrews scientists. The Springer-Verlag Ecological Series is the anticipated outlet.

A list of publications based on LTER research is provided in Appendix II. It is divided into publications and theses (32), published abstracts (20), and manuscripts in review (3). The abstracts are included to suggest the type and level of scientific activity that is underway but has not yet made it into the literature.

DESCRIPTION OF THE H.J. ANDREWS EXPERIMENTAL FOREST

The LTER Program at Oregon State University is centered at the H.J. Andrews Experimental Forest (Figure 13) which is located on the western slope of the Cascade Range approximately 80 km east of Eugene, OR. The AEF occupies the entire 6400 ha

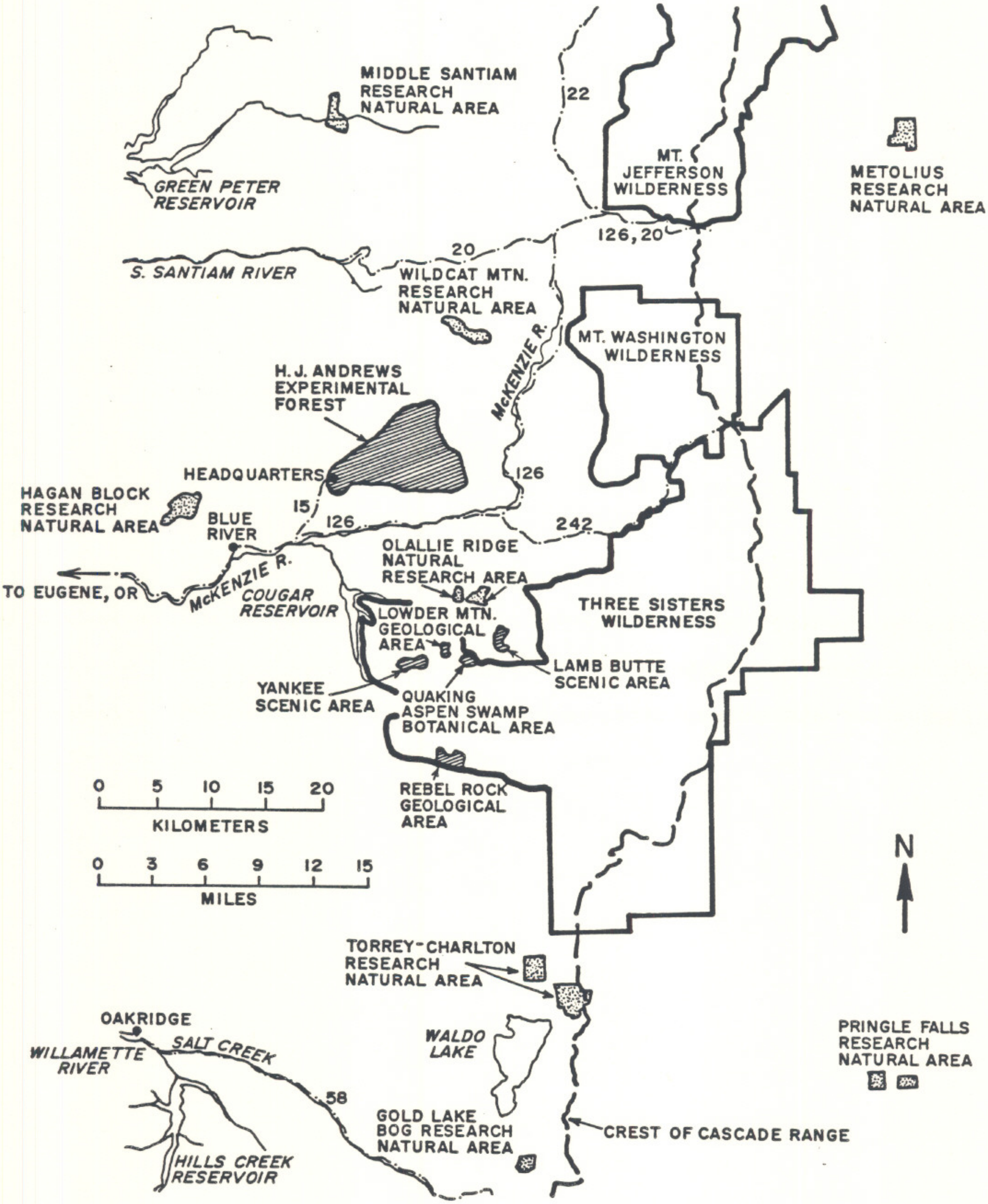


Figure 13. Location of the H.J. Andrews Experimental Forest, the Headquarters Site, nearby Research Natural Areas and other areas of special scientific interest.

Lookout Creek watershed, and ranges from 410 m to 1,630 m in elevation. It is broadly representative of the forests and rugged landscapes of the Pacific Northwest. The dense coniferous forests are dominated by species such as Douglas-fir (Pseudotsuga menziesii), western hemlock (Tsuga heterophylla), and Pacific silver fir (Abies amabilis). Several Research Natural Areas (RNA's) compliment AEF (Figure 13) and are frequently used in LTER research.

The AEF and 4 RNA's are geologically situated in the Western Cascade province. The geologically younger High Cascades province to the east forms the Cascade crest. Both Western and High Cascades are underlain by volcanic materials of Tertiary or more recent age. Pleistocene and post-Pleistocene volcanic activity have produced the relatively gentle topography of the High Cascades. The older Western Cascades are characterized by steep topography with deeply incised, dendritic drainages, the result of extended erosional processes.

A maritime climate prevails with wet, relatively mild winters and dry, cool summers. January means are near 1° C, and July means near 20° C over most of the area. Temperature extremes range from -20° C to 40° C. The precipitation is strongly seasonal with 72% occurring in November through March. The 25-year annual average at a low-elevation station is close to 2,500 mm.

First to fifth order streams are the major aquatic habitat on the AEF and associated RNA's, although there are several lakes and ponds in one RNA (Torrey-Charlton). Streamflow tracks precipitation closely; winter maximum flow is typically three orders of magnitude greater than the summer minimum. Stream water has low concentrations of cations and anions and a pH near neutral. Summer stream temperatures approach 15° C, winter temperatures are around 1° C to 4° C. First and second order streams are strongly influenced by large amounts of litter and coarse woody debris, which provide the major energy source and create habitat for the aquatic organisms. Larger streams have increasing amounts of net primary productivity, but processed carbon from the small tributaries is still important. Aquatic organisms adapted to debris-dominated habitats are particularly well represented. Cutthroat (Salmo clarkii) and the Pacific giant salamander (Dicamptodon ensatus) are the top carnivores in the aquatic system.

Dense conifer forests cover most of the AEF and RNA's, although good examples of nonforested ecosystems, such as talus slopes, shrub thickets, bogs, ferns, and herbaceous meadows, are present. Forests below 1,000 m are generally dominated by Douglas-fir, western hemlock, and western redcedar. Upper elevation forests are typically dominated by true firs (Abies sp.) and, at the highest elevations, mountain hemlock (Tsuga mertensiana). The natural stands generally are either old-growth, with dominants in excess of 400 years, or mature, with dominants of 100 to 135 years. The AEF, however, contains a variety of secondary succession communities on areas logged within the last 35 years. Old-growth stands are massive, with individuals commonly exceeding 60 m in height and 125 cm dbh. Above-ground biomass values in excess of 1,000 mt/ha are not uncommon. Leaf areas range up to 20 m^2/m^2 (although 9 to 14 are more common values) and basal areas average about 80 m^2/ha, but can exceed 100 m^2/ha.

The diversity of terrestrial communities found on the AEF provides for a rich fauna which is broadly representative of the Pacific Northwest. Species dependent upon old-growth forests are especially well represented.

FACILITIES ASSOCIATED WITH LTER PROGRAM AT THE ANDREWS FOREST

Field facilities at AEF are substantial, largely due to improvements over the past 5 years. We currently have 6,100 ft^2 of bunkhouse space with overnight accommodations for 55 researchers, and 3,400 ft^2 of laboratory/office space. A grant from NSF's Biological Research Resources Program (BRR) financed development of a headquarters site (Figure 14). This low elevation location is centrally located with regard to the LTER study sites. Trailers were obtained from the Willamette National Forest, PNW Forest and Range Experiment Station, and Environmental Protection Agency and installed with other trailers from Oregon State University (Figure 14).

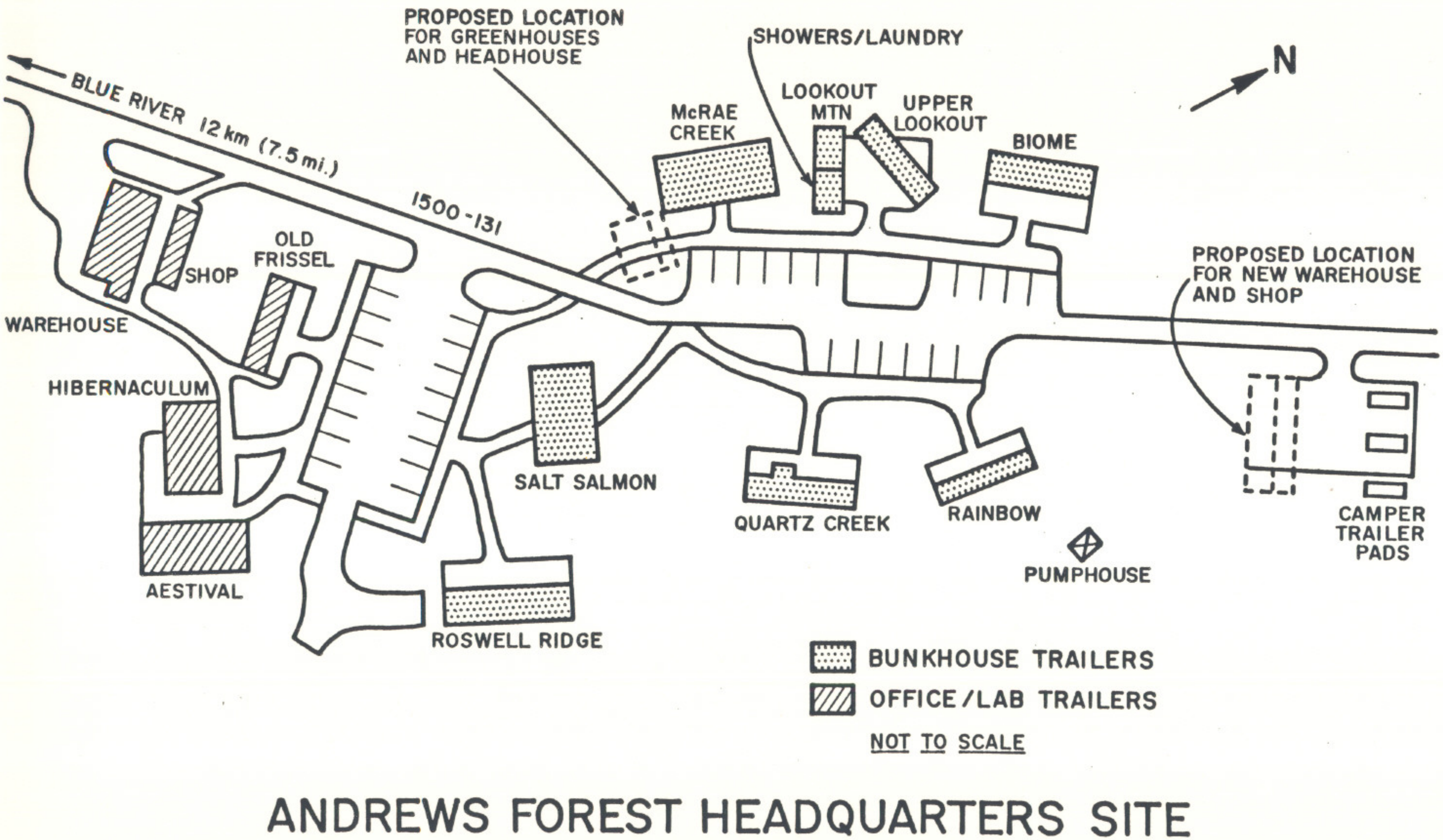


Figure 14. The Headquarters Site at the H.J. Andrews Experimental Forest showing locations of bunkhouse facilities and the office and laboratory facilities.

Most trailers arrived as empty shells. Funds from the PNW and a grant from BRR were used for remodelling and construction of roof shelters over 4 double-wide trailers; the shelters are convertible to permanent buildings.

Two laboratories have been created. One is equipped as a sample preparation and soils laboratory. The other is equipped with a hood and available for installation of chemical analytical equipment. One trailer has been remodelled to house an herbarium and insect collections and another to provide a library and conference room.

The AEF and RNA's have numerous field installations. The meteorological network consists of a primary meteorological station at headquarters, 25 thermograph stations, and 21 precipitation stations. Snow courses are run at these sites. We participate in the National Atmospheric Deposition Program; the wet-fall/dry-fall sampler is located at the primary meteorological station.

Permanent facilities for hydrologic and geologic research include 10 gauged watersheds, 7 with stream chemistry samplers. Permanent stream cross-sections and photo-point systems exist along reaches of 3 gauged watersheds and at 4 other stream sites. A snowmelt lysimeter and a deep-seated soil movement measurement system have existed for 9 years. Surface soil erosion is under study on 2 clearcut and 2 control watersheds, and 5 watersheds have sediment basins.

AEF currently has a microcomputer with a magnetic tape reader/writer, digitizer, line printer and 300 BOD modem for a direct link with the OSU Computer Center. These provide us with on-site capability to reduce the central meteorological station data tapes, thermograph and precipitation charts and provide hard copy of reduced data. The computer is available for entry of data sets, on-site analysis of data, and word processing. Its use in the summer is nearly constant. A network of similar, compatible microcomputers exists at OSU. People working on various projects bring magnetic disc copies of their data along to AEF and work on it there in the evening. This flexibility from compatibility is very valuable.

On-campus facilities at OSU are well suited for LTER research. The College of Forestry's Forest Science Department shares space with the PNW Station in the Forestry Sciences Laboratory. The 2 organizations support the Central Chemical Analytical Laboratory and Quantitative Sciences Group (see section on data management). Other chemical labs are available for special needs. A variety of computing facilities are available from portable micros to the campus mainframe. The LTER scientists are from several different departments: Entomology, Botany and Plant Pathology, Fisheries and Wildlife, Statistics, Geology, Forest Management, Engineering, Forest Science, and Zoology. For example, the Systematic Entomology Laboratory (Dept. of Entomology), containing about 2.5 million specimens, is responsiable for the H.J. Andrews Arthropod Collection. The size and diversity of the cross-campus network means that most OSU resources are available as needed.

SITE AND PROGRAM MANAGEMENT

Administration of Andrews

The Andrews Forest is administered jointly by Oregon State University, the Pacific Northwest Forest and Range Experiment Station, and Willamette National Forest. These institutions have entered into long-term agreements on operation and management of the site.

The overall objectives for the Andrews Forest are:

1. Enhance the Andrews Forest in its established role as a major site for basic research on structure, function and composition of coniferous forest and stream ecosystems under natural and disturbed conditions.

2. Establish the Andrews Forest as a major center of applied research on the management of young forests, with emphasis on using basic research to identify and solve management problems, and on integrating ecological and management effects at the drainage level.

3. Develop the potential of the Andrews Forest for education and training in environmental sciences and land management.

There are several important principles or premises that guide management decisions to accomplish the above objectives:

1. Management direction will be to retain all current research opportunities and develop new opportunities by (a) creating a greater diversity of situations/environments/ecosystems, (b) developing additional data bases, and (c) providing improved field, laboratory, and living facilities, and additional equipment.

2. Decisions that involve major or irrevocable commitments of facilities, data, and ecosystems will be subject to review by the National Advisory Committee.

3. All research projects compatible with existing programs will be encouraged. Priorities in use of facilities for basic research will go to ecosystem-level activities and to use of the site for regional and national comparisons.

4. Strong, continuing efforts will be made to encourage use by scientists and students from outside the local institutions.

The current administrative structure of the Andrews Forest is shown in Figure 15. J.F. Franklin and A. McKee are the site co-directors having been delegated the responsibility for developing and operating AEF by the PNW Station and OSU, respectively. Arthur McKee is also the site manager and has responsibility for day-to-day operation of the reserve. McKee supervises three full-time technicians, a full-time silviculturist and a varying number of part-time assistants in carrying out the responsibilites.

The Site Management and Policy Committee is an advisory body of 10 to 12 people intimately involved in research and management on the site. This committee develops the research and management plan, reviews and approves timber sale and similar activities, selects parameters for monitoring and decides on allocation of resources including space and national funding. Formal procedures exist for approval of a research project at the Andrews Forest and are the same, regardless of supporting institution. An assessment of impacts on facilities and compatibility with current research projects are primary in the review. It is AEF policy to accommodate all research proposals compatible with the basic objectives of the site with preference to ecosystem-oriented work when a rare conflict arises.

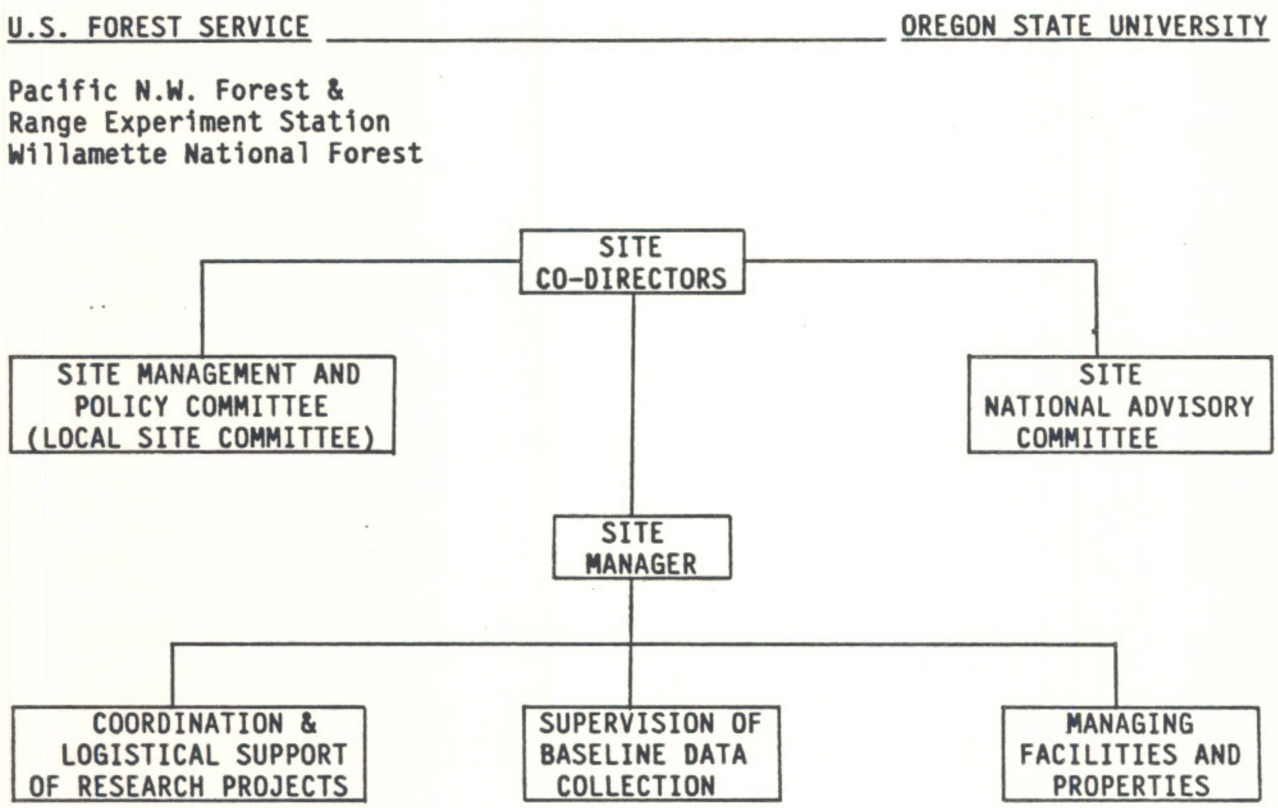


Figure 15. Administrative structure of the H.J. Andrews Experimental Forest.

Management of LTER Program

Overall management of the AEF LTER is a collective responsibility of the principal scientists involved in the program. The Site Management Committee is the forum for administrative matters and generally meets monthly.

J. Franklin has overall administrative responsibility for the LTER grant. Franklin will be on sabbatical at Harvard forest from late August, 1985 through May 1986. During this time F. Swanson will be Principal Investigator.

Each component of the AER LTER program has an identified and committed leader (Table 3). Most components have several other established scientists associated with them. It is our objective to provide in-depth leadership for program components so as to minimize risk-to-program from loss of a particular individual.

Senior investigators, funded from non-LTER sources, carry most of the responsibility. Most are tenured and attempts are being made to change status of those who are not (Sollins, Gregory). Postdoctorates play important roles: Harmon will continue as leader of the woody debris component; postdoctorates will be employed during the major experiments in stream-forest interactions (at Hagan Creek) and in factors controlling long-term site productivity. Finances necessitated phasing these positions and the experiments.

Data Management

Th AEF LTER considers data management and other documentation procedures to be of the highest priority and about a fourth of our resources is dedicated to these activities. Adequate documentation of the LTER studies is absolutely critical to achieving the long-term potential; this includes everything from field marking of plots to archiving of clean data sets. Data management is also critical to achieving more immediate goals of data analysis and publication of research by LTER and other scientists.

Table 3. Major scientific personnel associated with AEF LTER program components; first listed individual is the leader of that activity. Status: T = tenured or tenure track, S = nontenured.

Person	Specialty	Status	Funding
Component 1			
Jerry Franklin	Succession, mortality	T	USFS
Jack Lattin	Invertebrates	T	OSU
Tim Schowalter	Invertebrates	T	OSU
Robert Anthony	Vertebrates	T	OSU
Mark Wilson	Tree seedlings	T	OSU
Thomas Spies	Experimental gaps	S	OSU
Art McKee	Succession	T	OSU
Component 2			
Fred Swanson	Geomorphology	T	USFS
Stan Gregory	Aquatic biology	S	OSU
Jim Hall	Fish ecology	T	OSU
Art McKee	Riparian vegetation	T	OSU
Postdoctorate (1986-88)	Limnology	S	LTER
Component 3			
Dave Perry	Population processes	T	OSU
Component 4			
Phil Sollins	Nutrient cycling	S	OSU
Dave Perry	Nutrient cycling	T	OSU
Component 5			
Mark Harmon	Ecology of woody debris	S	LTER
Jerry Franklin	Necromass, inputs	T	USFS
Stan Gregory	Stream wood	S	OSU
Tim Schowalter	Insect interactions	T	OSU
Kermit Cromack, Jr.	Decomposition	T	OSU
Component 6			
Phil Sollins	Nutrient cycling	S	OSU
Dave Perry	Production processes	T	OSU
Joe Means	Nutrient cycling	T	USFS
Postdoctorate (1988-90)	Soil microbiology	S	LTER
Data Management			
Susan Stafford	Data management	T	OSU
Site Management			
Art McKee	Site management	T	OSU

Progress During LTER I. The major accomplishment of the Forest Science Quantitative Sciences Group (QSG) during LTER I was to reorganize staff and procedures to meet the newly stated goals of LTER and Forest Science Department for data entry, archiving, documentation and analysis. Staff with background in ecology and data management were recruited to insure practical, user-oriented system. During the first year a new system for data documentation and management was developed for the Forest Science Data Bank (FSDB), and all extant data were carefully cataloged, including some not yet computerized. A major effort was improvement of the overall level of data documentation.

During the last 4 years we have implemented virtually all major elements of the database envisioned at the beginning of the grant, including a formal procedure for ensuring that all new data come in with high quality documentation and adequate error checking and validation. The overall, systematic approach to data management and data analysis from problem conception to published results is illustrated in Appendix III.

Our data management example has helped other LTER sites, field stations, and other institutions. We helped organize the first general data management symposium at the Kellogg Biological Station in Michigan (Gorenz and Lauff 1984), took a lead role in organizing 3 annual LTER data management conferences which culminated in the Research Data Management Symposium at the Baruch Institute (Klopsch and Stafford 1985, Stafford et al. 1984a, b, c).

LTER data sets have had top priority for data documentation. Older data sets have been documented as required. We now have available both on computer and in book form a complete description of data abstracts, file organization, and variable documentation for all data sets associated with the LTER program at AEF. Organization and variable descriptions exist for all data sets in the data bank. For all studies initiated during LTER complete documentation of study methods, objectives, etc. is also available. Abstracts are available for many older studies. An annotated and completed set of the documentation forms that we have developed and use are provided in Appendix IV. These forms illustrate the various types of information recorded as well as the research study abstract providing an overview of each study.

In all, over 430 data sets are maintained by the FSDB, including over 1500 data files. This has doubled since 1980. In addition we have planned equipment and software so as to increase researcher productivity and decrease time for analysis and data entry. A microcomputer-based data entry system has been instituted using double entry vertification. Communications between microcomputers, their myriad periferals, and the mainframe computers have been developed. The LTER program now has a full host of microcomputers at AEF , and the Departments of Fisheries and Wildlife and of Forest Science. These are fitted to a general plan for meeting the computational needs of LTER.

Data Management for LTER II. The LTER data management needs will continue to be handled through the QSG and data housed in the FSDB. We have two main objectives:

1. Facilitate expedient data analysis, documentation, and retrieval with continued focus on "results".

2. Anticipate future data analysis and computational needs. Plan and coordinate hardware and software acquisitions accordingly.

Data management is viewed as a means to an end, not an end in itself. We recognize as paramount maintainence of FSDB standards in documentation and cataloging on all LTER datasets. We will continue to strive to make this essential process personnel-independent so that personnel changes do not compromise the long-term value of these data.

In terms of our second objective, we are adapting to a changing computational environment -- from centralized operations to distributed processing. With more microcomputers, PI's and graduate students are doing more of their own analysis and data managment. QSG support will be needed more as facilitation. QSG will be asked upon to help solve more advanced analysis questions and to resolve equipment and technology problems; for example, how to network micros, share data, and send results among LTER sites.

In February, 1985, the QSG and FSDB conducted a critical self-evaluation focusing on strengths and areas of improvement. The improvements needed include: improved equipment compatibility; improved access to SAS (Statistical Analysis Systems) software package; better hardware and software for modelling; and the need to maintain adequate levels of documentation on current LTER data sets, to insure utility of data is not dependent upon presence of associated PI's. Short-term goals will be: (1) establishment of a local area network for improved efficiency in equipment use; (2) additional availability of general use microcomputors; (3) improved software support; (4) local availability of SAS; and (5) improved programming language. High on the list of long-term goals is acquisition of a supermicro or minicomputor to handle modelling activities, wide distribution of microcomputors, additional graphics capability, mass storage capabilities, and a geographic information system.

<u>National Advisory Committee</u>

We have had a National Advisory Committee (NAC) for AEF since 1977. It's original purpose was to review and advise OSU and the Forest Service on major decisions regarding operation and utilization of AEF and to monitor the performance of the 2 organizations in fulfilling the objectives outlined earlier. Review and advice on the content and conduct of the LTER program has been an added responsibility of the NAC during the last 5 years.

The NAC meets yearly to review the AEF and LTER. Specific responsibilities include review of any proposed action which would: (1) significantly alter more than 10 acres of the AEF; (2) commit 20 percent or more of the research, living, or working facilities; or (3) otherwise have a significant impact on the long-term value of AEF as a national facility. The NAC also reviews all study plans for LTER research. The NAC prepares a report following each meeting on its findings and recommendations; complete copies of these reports are provided to NSF.

The Andrews program has profited greatly from NAC advice. Their recommendations are invariably accepted. Recent examples were their strong direction to proceed with preparation of a synthesis volume and general advice on insuring the continuity of the baseline data gathering program.

The current NAC consists of five members and last met on February 26 and 27, 1985:

Dr. Mel Dyer (Chairman), Oak Ridge National Laboratory
Dr. Larry Bliss, Chairman, Botany Dept., Univ. Washington
Mr. John Butruille, Deputy Regional Forester, U.S. Forest Service
Dr. Richard Marzolf, Kansas State Univ.
Dr. Gordon Wollman, Chairman, Geography Dept., Johns Hopkins Univ.

INTERACTIONS WITH OTHER SCIENTISTS AND PROGRAMS

The interactions between the Andrews LTER and other scientific programs are extensive. In this section we outline (1) collaborations with other sites and programs involved in long-term ecological research and (2) relationships between the Andrews LTER and other programs utilizing the site.

Collaborations with Other Long-Term Ecological Research Sites

The Andrews LTER group believes strongly in the merits of collaboration with other sites and groups involved in long-term ecological research. This is based on a belief that comparative analyses -- parallel and reciprocal examination of processes, structures, and ecosystem behavior -- are critical elements in developing robust ecological theory. Exchanges can also provide dramatic efficiencies in time and dollars as expertise or data or both are shared. AEF scientists participated enthusiastically in intersite activities during LTER I and will do so more extensively during LTER II.

We do wish to underline our belief that collaborations must extend to sites and programs engaged in long-term ecological research but outside of the 11-site LTER program. We have operated in this mode during LTER I and will do so in LTER II. We also recognize the special responsibility that we have to the LTER system and its success and that future support for long-term ecological research is especially dependent upon the success of this high profile program.

During LTER I Andrews scientists have been leaders in various collaborative activities as well as participants in multi-site research projects. Major leadership roles have been:

Franklin	Chairman, LTER Coordinating Committee
Swanson	Co-chairman, Workshop on Disturbance Regimes
Gregory/Cummins	Co-chariman, Workshops on Streams Research I & II
Stafford & staff	Main participants, Data Management Committee & Symposium
McKee	Leader, Meteorology Committee
Cromack	Leader, Decomposition Workshop
Lattin	Leader, Litter-Humus Invertebrate Workshop
Lattin & Stanton	Leaders, Workshop on Collaborative Research Between Ecologists and Systematists of Soil Organisms

Collaborative research ventures have included the following:

Subject	Person	Site
Soil nitrogen and organic matter	Sollins	Central Plains ER
		La Selva
Establishment of reference stands	Klopsch	Coweeta
	Team	Sequoia NP
	Team	Olympic NP
Design of experimental gap studies	Team	Duke Forest
Exchange of woody debris samples	Harmon	Coweeta
Assist in design of wood studies	Harmon	Illinois River
Data exchange on coarse woody debris	Harmon	Hubbard Brook
Natural variation in meteorological parameters	Mckee	Jornada
Ecological implications of hydrologic regimes	Gregory	Konza
Establishment of stream & riparian refer. areas	Team	Sequoia NP

Collaborative efforts by Andrews scientists during LTER II will take a variety of forms including data exchanges, development of joint research projects, and exchanges of personnel, sometimes for extended periods (Table 4). As reflected in the table, our approach is to initiate intersite work on topics of special interest to our group -- woody debris, riparian zones, stream retention characteristics, forest demography, and role of disturbances, including gaps. Reciprocally, we will cooperate wherever possible with initiatives by other lter groups as with the stream invertebrate-transport research of Wallace, wood dynamics studies of Blood, and analyses of subalpine meadow processes with Webber. One objective during Franklin's sabbatical will be to exchange data and

Table 4. Collaborative ventures with other long-term research sites during LTER II.

Topic	Site	Year	SMs[1]	Leader
Tree demography and dynamics of woody debris	Sequoia NP, Olympic NP	1986–1990	3	Franklin
Exchange and synthesis of data on forest structure & woody debris	Hubbard Brook	1986	3	Franklin
Establishment of reference stands & plots for woody debris	Hubbard Brook & other NE sites	1986–7	2	Franklin–McKee
Establishment of plots for tree demography & woody debris	Niwot	1986	8	Franklin + team
Analysis of invertebrate communities in early successional vegetation	Coweeta	1986–1990		Schowalter
Exchange of site directors	Hubbard Brook	1986–7	4 1/2	McKee
Riparian vegetation composition and function	Niwot	1986	4	McKee + team
Examination of riparian vegetation successional dynamics	Hubbard Brook	1986–7	4 1/2	McKee & Swanson
Retention characteristics of stream ecosystems	Konza, North Inlet, Niwot, Coweeta	1986–9	6	Gregory & associates
Wood dynamics in aquatic ecosystems	North Inlet Coweeta			Gregory
Study of soil N and organic matter	Central Plains La Selva	1986–7		Sollins
Study of factors controlling long-term site productivity	La Selva	1986–8		Sollins
Collection of data on standing crops & dynamics of woody debris	Coweeta, Great Smoky MNP, North Inlet?, Cedar Creek?	1987–9	3	Harmon
Reciprocal wood decay study	Coweeta Duke?	1987	1/2	Harmon
Snag fragmentation processes	Sequoia NP Coweeta? Niwot?	1986	1/2	Harmon
Forest gap workshop	Coweeta, Duke, and others	1986 or	1	Spies
Experimental forest gap study	Duke Coweeta? Other sites?	1988	12	Spies
Landscape as a dynamic template	Niwot	1986	2	Swanson

[1]SMs = months of scientist, student, and technician time.

establish collaborative programs on coarse woody debris, mortality, and forest structure with Hubbard Brook and other northeastern research groups; McKee will followup during 1986-7 on riparian topics.

One collaboration well underway is an analysis of the landscape as a dynamic template by Swanson (AEF) and Caine (Niwot). A manuscript is in preparation comparing landscape dynamics at the 2 sites and analyzing implications for ecosystem structure, function, and patchiness. Both sites have diverse disturbance regimes but large differences in vegetation stature, disturbance types, and climate should force interesting generalizations and issues of scale.

It is obviously impossible to identify all of the cooperative ventures at this time, but the projects identified (Table 4) exemplify the type and level of effort. Team efforts or "pulses" will be an element of our intersite program. Much collaboration will be by individuals that are not salaried by LTER; however, the monetary contribution substantially exceeds 15% of the LTER grant. The tabular presentation does not take account of most of the numerous workshops (including leadership roles), short term exchanges of personnel, and individual data exchanges that will take place during LTER II. It also cannot take account of the topics identified for interbiome synthesis efforts by the upcoming LTER senior scientist brain-storming session (May 1985).

Cooperation With Other Resarch Programs at the Andrews Forest

The research program at AEF includes over 100 separate projects (Appendices 5 and 6) and is characterized by an active spirit of cooperation. This spirit of cooperation was fostered during the 1970's when the Andrews Forest was an intensive study site for the U.S.I.B.P./Coniferous Forest Biome. The experience gained by the group of scientists involved in that multidisciplinary effort convinced the participants of the value of cooperative research. Many of these projects are directly related to LTER, and include activities such as riparian research (Gregory; Swanson and Franklin, co-investigators), entomological research (Lattin; Schowalter, investigators), erosion budget and sediment routing work (Swanson), modelling of long-term productivity (Sollins), and stream channel geomorphology (Wolman and Grant, co-investigators). These are a few examples of separately funded and related research that is the result of the coordinated efforts of the scientists.

It is the stated management policy at the Andrews Forest to encourage multidisciplinary use of research manipulations. Notices have been placed in the Bulletin of the Ecological Society to encourage use of the research sites and facilities by any interested party. This is in addition to examining possible cooperation and collaboration among the scientists at the site. It is our experience that the synergy derived from cooperative efforts often yields the benefits of additional insight into the problems being studied.

Cooperation with other agencies is extensive. Both EPA and NASA are using AEF for data and ground truthing. EPA is considering the site for installation of a prototype dry deposition sampler. NASA will be testing several types of remote sensing equipment designed to measure micrometeorological parameters.

The greatest integration is with the U.S. Forest Service. Several key hydrologic and nutrient-cycling monitoring activities are maintained by Research Work Unit 1653 of the PNW Station. There is very extensive collaboration with the Old-Growth Wildlife Habitat Research Program on the vertebrate research, as already mentioned, and this work will continue for at least the next 5 years. Other cooperative ventures include the erosion, stream and riparian research. LTER work is also of direct interest and supported by the administrative branch of the Forest Service which created and funds the position of silviculturist at the Andrews Forest to assist scientists in their research.