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CHAPTER 4. INFORMATION ON THE H. J. ANDREWS EXPERIMENTAL FOREST, WESTERN OREGON CASCADE RANGE

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Abstract. This paper reviews the historical development of watershed experiments on the H. J. Andrews Experimental Forest, Oregon, and gives site characteristics and background information on current programs. The site is a Biosphere Reserve and has an active program on Long-Term Ecological Research program funded by NSF. H. J. Andrews represents one of the world's most productive forest ecosystems, and its integrated research base includes the land-water interface.

INTRODUCTION

The H. J. Andrews Experimental Forest (HJA) was established in 1948 by the USDA Forest Service from a part of the Willamette National Forest, Oregon. The primary objective was to provide a site for research and education on old-growth Douglas-fir-western hemlock forests and their conversion to managed stands (see Franklin and Waring 1979).

The HJA consists of the 6000 ha drainage of Lookout Creek and is located in the rugged topography of the Western Cascades approximately 44°N latitude 122°W longitude. Elevations range from 450 to 1650 m. Bedrock consists entirely of volcanic materials--tuffs, breccias, and andesitic flows of Miocene and Pliocene age. The climate is maritime in character with cool, very wet winters and warm, relatively dry summers; very little precipitation occurs during the period of June through September. There are strong orographic influences on precipitation and on the proportion which falls as snow. At higher elevations, winter snowpacks may reach depths of 5 m and persist for 8 months of the year. Because of the mild, wet winters a great deal of the biological activity, such as photosynthesis, goes on during the fall and winter months, even at higher elevations.

Aquatic ecosystems consist almost entirely of streams which range up to fifth order in size (Lookout Creek). Low flows are in late summer and early fall, while maximum flows are associated with winter storms. Ratio of low to high flow is about 1:1000 for the smaller streams.

Forests on the HJA are strongly dominated by conifers, and forest conditions vary markedly along environmental gradients of temperature and moisture. In the low-elevation temperate forest (Western Hemlock) zone characteristic species are: Douglas-fir (Pseudotsuga menziesii), western hemlock (Tsuga heterophylla), western redcedar (Thuja plicata), western yew (Taxus brevifolia), sugar pine (Pinus lambertiana), incense-cedar (Calcocedrus decurrens), and bigleaf maple (Acer macrophyllum). At higher elevations (above about 1000 m) subalpine forests (Pacific Silver Fir Zone) occur. Characteristic species are Pacific silver fir (Abies amabilis), noble fir (Abies procera), mountain hemlock (Tsuga mertensiana), and western white pine (Pinus monticola).

The bulk of the forests at HJA are old-growth stands of about 500-years age, although substantial acreages of young-conifer forests have been created by clearcutting since 1950. Dominance of old-growth forests was a primary reason for the original selection of HJA as an experimental forest. Approximately 80% of the original acreage was in old growth, mostly of 500-year age but with a significant amount of the 275-year-old forest at higher elevations. The other important age class in the primeval landscape was mature forest, which originated following wildfires in the mid-1800s; these forests are generally around 135 years of age today. Approximately 20% of HJA has been clearcut since 1950, resulting in a highly dispersed series of young stands of 10- to 20-ha size.

Both existing and potential natural vegetation (habitat types) have been mapped on the experimental forest. Standing crop biomass values are large, averaging approximately 868 t/ha in the old-growth forests. Leaf area index (LAI) values are among the highest in the world, reaching maximum levels of above 12 $m^{-2} \cdot m^{-2}$ (Franklin and Waring 1979, Marshall and Waring 1986).

PAST, PRESENT, AND PROPOSED RESEARCH

Research at HJA has gone through a series of phases: pre-1950--Corps of Engineers Willamette Basin Snow Laboratory; 1950-1960--timber management research primarily on cutting methods and regeneration; 1960-1970--watershed management research using small watersheds to study effects of logging and roads on water yields, erosion, and nutrient cycling; 1970-1980--ecosystem research as part of the International Biological Program's (IBP) Coniferous Forest Biome, with emphasis on carbon and nutrient cycling; and 1980s--balanced program of basic ecological and ecosystem research and applied forest, wildlife, and watershed management research.

Early Research Program

The early research program at HJA covers the period from 1948 to 1968. During the first decade, the emphasis was on development of the staggered setting approach to clearcutting Douglas fir--development of forest logging and road plans, natural and artificial regeneration, salvage logging, and other similar projects. During the second decade, emphasis was on watershed management and included the first experimental watershed treatments in the region and broad surveys of soil stability problems.

Regeneration and Cutting Methods. HJA was the site for majority of research on effectiveness of staggered setting clearcutting (Timberman 1957). The original concept was to utilize natural regeneration. Research at HJA showed that natural regeneration was not dependable because of (1) infrequent seed crops and (2) severe micro-environmental conditions on many clearcuts. This was one of the major factors in the shift to artificial regeneration, now practiced widely in the Pacific Northwest.

The location of first shelterwood and strip clearcutting in the Region was at HJA (Franklin 1963). This work demonstrated the effectiveness of shelterwoods for regeneration and that well-selected trees would survive exposure and wind. The development of shelterwood cutting in the region also evolved largely from the HJA experiences. The HJA was the location of research on windthrow associated with staggered setting cutting systems (Gratkowski 1956).

Many individual studies were conducted on artificial regeneration (stock size, stock type, season of planting, planting site amelioration, fertilization, and etc.). This was the first location where importance of dry ravel in burying seedlings was recognized.

Watershed Management. Watersheds 1 to 3 were the first experimental watersheds in the region and demonstrated the extreme importance of roads and of mass movements in causing soil erosion. Watershed 1 was completely logged without roads using a skyline crane, while Watershed 3 was 1/3 logged in patch clearcuts using a road system. Erosion losses during the first 5 years were approximately in the ratios of 1:4:100 (control:WS1:WS3). The soil losses in WS#3 occurred as a large pulse soon after treatment with subsequent stabilization while losses in WS#1, while lower, have continued at elevated levels.

Watershed research showed that nutrient losses were generally low following clearcutting in the Douglas-fir region. They did not follow the Hubbard Brook Experimental Forest model of high losses following cutting because, among other factors, nitrification was limited during the summer due to drought and during the winter due to low temperature.

Research throughout the HJA site and surrounding regions showed the extreme slope and road stability problems associated with particular geological formations and soil types (such as hydrothermally altered tuffs and breccias). In effect, a small percentage of the landscape contributes a highly disproportionate part of the mass movements.

General Forest Management. The basic concept of comprehensive forestry logging plans and of parallel (contour) road systems was developed and demonstrated at HJA and Cascade Head (Timberman 1957). The system of salvage logging in mature and old-growth timber using mobile yarder-loader was developed and demonstrated at HJA.

The first west-side habitat type classification was developed in and around HJA and has been used widely in management programs including identification of regeneration problem sites. Two habitat types have been identified as nitrogen deficient sites which should be good candidates for fertilization (Hemlock / Chinkapin and Hemlock / Rhododentron / Salal types).

Each of these phases of research contributed certain facilities, installations, or data bases to HJA. There is a headquarters site with living, office, laboratory, and shop facilities. This is also the location of the central meteorological station which provides continuous records of temperature, wind, precipitation, dewpoint, and radiation. A National Atmospheric Deposition Program sampling site for chemistry of wetfall and dryfall is also maintained at the station. There is also a geographically extensive sampling network throughout the HJA for precipitation, in-forest air and soil temperatures, and stream temperatures.

One of the most important field installations is the series of gauged small watersheds. The first of these sets was installed in the 1950s and was treated in the 1960s. There are three sets of small gauged watersheds:

Watersheds 1, 2, and 3. Acreage 60 to 100 ha. Watershed 1 was clearcut without roads, Watershed 3 was 1/3 clearcut using roads, and Watershed 2 is the control. Stream flow, temperature, and suspended sediment and bedloads are monitored on all three watersheds, and Watershed 2 is continuously monitored for nutrient content.

Watersheds 6, 7, and 8. Acreage 10 to 15 ha. Watershed 6 was clearcut, Watershed 7 shelterwood cut, and Watershed 8 is control.

Watersheds 9 and 10. Acreage approx. 10 ha. Watershed 10 was clearcut in 1975 (part of IBP experiments) and Watershed 9 is control. Continual nutrient as well as hydrologic monitoring is conducted on both.

In addition to these sets of experimental watersheds, the 800-ha drainage of Mack Creek is gauged for continuous records of streamflow and continuously sampled for nutrient content. Stream gauges also exist near the mouth of Lookout Creek and on a comparably size portion of the adjacent Blue River drainage.

A large body of data on forest productivity, biomass and structure, and nutrient budgets has accumulated at HJA as a result of the IBP and subsequent ecosystem research programs. This includes the development of the allometric equations essential for estimation of various ecosystem parameters such as biomass, leaf mass, root mass, leaf area, etc. A variety of specialized studies have also been conducted, including work on root productivity and turnover and detailed tree canopy studies which involved nondestructive sampling of physical, chemical, and biological parameters using climbing techniques.

The forest stands, particularly the old-growth forests, are massive and present significant problems in developing the essential ecological data. Old-growth Douglas-firs are often 100 to 200 cm in diameter and 60 to 80 m in height. Most estimates of biomass and productivity have been done on permanent sample plots (Franklin and Waring 1979) (Table 1). A distinctive feature of these forests is very high levels of biomass ranging to an excess of 100 m^2/ha of basal area and 1000 mt/ha of aboveground biomass. There is also a very high level of necromass, or dead organic matter, in these stands in the form of standing dead trees or snags and of down trees or logs. Typical necromass levels are 150 mt/ha in old-growth forests. A substantial body of information has been developed on this dead woody material or 'coarse woody debris' as it is commonly known.

The permanent plot system at HJA and on associated Research Natural Areas is one of the major research resources. There are several series of such plots. The most extensive set is a series of reference stands which are generally 1-ha permanent sample plots established in mature and old-growth forests representing a wide variety of environmental (and productivity) conditions. There are about 30 of these reference stands with additional, comparable plots at Olympic, Mt. Rainier, and Sequoia National Parks and at the Cascade Head Experimental Forest on the Oregon Coast. Two extensive series of systematically spaced 1/10-ha circular sample plots (Long-Term Ecological Research [LTER] plots) have been established in the old-growth forests of the 100-ha Watershed No. 2 and the mature forests (100-year-old) of the 400-ha North Fork Hagan Creek watershed. In both the reference stands and the LTER plots all trees over 5-cm diameter are monitored, are checked annually for mortality, and are remeasured for growth and recruitment at approximately 5-year intervals.

Two other major sets of permanent sample plots have been established to follow development of early successional vegetation following cuttings of Watersheds Nos. 1 and 3 and No. 10. The Watershed 1 and 3 plots now provide a record of development over 20 years following cutting. The plots on Watershed 10 are now 10 years old. Data are taken on herb and shrub cover and biomass as well as individual trees, once they have attained 1.4 m height. Vegetational changes are occurring very rapidly in these young stands.

Current and Proposed Research

Current research strongly emphasizes the establishment of long-term field experiments with the support of the National Science Foundation's (NSF) LTER program. Experiments installed to date include: a 100-year study of effects of a nitrogen-fixing shrub, <u>Ceanothus velutinus</u>, on soil properties and growth of associated Douglas-fir; a 100-year test of the -3/2 thinning law in young Douglas-fir forests with various densities, pruning, and nutritional treatments; and a 200-year study of log decomposition processes in terrestrial and aquatic environments using freshly cut logs placed in a forest or stream system. A major study of the effects of management practices of long-term site productivity is planned for the next 5 years. All of these experiments involve replicated field designs with installations at the scale of at least 10's of meters.

The research group at the HJA makes extensive use of other research sites in the Pacific Northwest and has developed data bases and permanent plots at these other sites. Major efforts are under way at Olympic National Park (includes plots and exclosures in alluvial rain forests); at Cascade Head Experimental Forest near Lincoln City, OR (includes 1/10 to 1 ha permanent plots, some of

Table 1. Data sources for biomass and leaf area in stands in the Pacific Northwest. From Franklin and Waring (1979).

Dominant species	Stand age	Basal area	Aboveground biomass Total	Wood[a]	Foliage	Projected leaf area	Source and plot identification[b]
Douglas-fir	70	60	422	406	16	8.1	Santantonio (Dry)
Douglas-fir	110	63	661	650	11	5.6	Fujimori et al. 1976
Douglas-fir	100	56	478	466	12	6.1	Franklin (RS 24)
Douglas-fir	120	72	531	509	22	11.2	Santantonio (Wet)
Douglas-fir	125	54	449	437	12	6.1	Gholz 1979 (III)
Douglas-fir	130	90	792	772	20	10.2	Franklin (RS 26)
Douglas-fir	150	72	527	509	18	9.2	Gholz 1979 (IV)
Douglas-fir	150	84	865	849	16	7.4	Gholz 1979 (II)
Douglas-fir	150	90	786	762	24	12.2	Franklin (MR 13)
Douglas-fir	170	72	532	510	22	10.2	Santantonio (Modal)
Group average		71	604	585	19	9.7	
Noble fir	130	98	880	862	18	9.9	Fujimori et al. 1976
Sitka spruce/hemlock	121	100	916	908	8	5.1	Grier 1976 (Plot 12)
Sitka spruce/hemlock	130	118	1,080	1,057	23	14.1	Gholz 1979 (IA)
Sitka spruce/hemlock	140	111	1,492	1,460	22[c]	15[c]	Gholz 1979 (IB)
Group average		110	1,163	1,142	21	13.4	
Western hemlock	26	49	192	171	21	13.4	Fujimori 1971
Douglas-fir/hemlock	250	106	1,117	1,094	23	11.7	Franklin (MR 1)
Douglas-fir/hemlock	250	99	991	968	23	11.7	Franklin (Bagby)
Douglas-fir/hemlock	450	68	715	701	14	7.1	Franklin (RS 1)
Douglas-fir/hemlock	450	84	911	893	18	9.2	Franklin (RS 2)
Douglas-fir/hemlock	450	92	826	801	25	12.7	Franklin (RS 3)
Douglas-fir/hemlock	450	99	1,223	1,203	20	10.2	Franklin (RS 28)
Douglas-fir/hemlock	450	118	1,237	1,208	29	14.7	Franklin (RS 29)
Douglas-fir/hemlock	450	116	1,137	1,107	30	15.2	Franklin (RS 30)
Douglas-fir/hemlock	450	92	1,039	1,018	21	10.7	Franklin (RS 31)
Douglas-fir/hemlock	450	129	1,423	1,392	30	15.2	Franklin (RS 27)
Douglas-fir/hemlock	500	50	317	303	14	7.1	Franklin (MR 6)
Douglas-fir/hemlock	500	81	590	567	23	11.7	Franklin (MR 5)
Douglas-fir/hemlock	500	76	585	559	26	13.2	Franklin (MR 8)
Douglas-fir/hemlock	500	65	606	586	19	9.7	Franklin (MR 4)
Douglas-fir/hemlock	500	89	957	933	24	12.2	Franklin (MR 11)
Douglas-fir/hemlock	750	79	927	908	18	9.2	Franklin (Squaw)
Douglas-fir/hemlock	1,000	69	541	520	21	10.7	Franklin (MR 2)
Douglas-fir/hemlock	1,000	98	789	760	29	14.7	Franklin (MR 3)
Douglas-fir/hemlock	1,000	74	563	539	24	12.2	Franklin (MR 14)
Group Average		89	868	845	23	11.7	

[a]Bole, bark, and branches.

[b]Daniel Santantonio: personal communication; stands located on wet, modal, and dry sites in McKenzie River drainage of Oregon Cascade Range. J. F. Franklin: data on file at Forestry Sciences Laboratory, Corvallis, Oregon. "RS" plots are hectare reference stands or permanent sample plots located at elevations between 360 and 1,200 m on the H. J. Andrews Experimental Ecological Reserve in the Western Cascades of Oregon. "Bagby" is a plot in the Bagby Research Natural Area, Mount Hood National Forest, Oregon. "Squaw" is located in the Squaw Creek drainage, a tributary of the South Fork of the Santiam River, Willamette National Forest, Oregon. "MR" plots are hectare reference stands or permanent sample plots located at elevations below 1,200 m in Mount Rainier National Park, Washington.

[c]Adjusted by R. Waring on basis of additional information.

which were established in the 1930s); Wind River Experimental Forest near Carson, WA (includes permanent plots in mature forests which go back to 1910 and a grid of plots in an old-growth Research Natural Area which goes back to 1948); Mount Rainier National Park; and several areas in the ponderosa pine forests of eastern Oregon.

Current and proposed applied research programs include: (1) specific studies focused on current management problems (e.g., regeneration of the vanillaleaf habitat type) or topics expected to be of major concern in the future (e.g., early commercial thinning) and (2) research based upon application of findings from the basic research programs (e.g., management strategies for riparian zones and for down logs and snags). These are obviously not mutually exclusive; in fact, almost all major basic research projects at the HJA have proved to have management applications, even though the funding source is typically the National Science Foundation.

Regeneration. Major studies are in progress or planned for comparison of silvicultural methods (shelterwood vs clearcutting, various planting treatments, etc.) on the most serious upper-slope and dry-site problem sites. The study of regeneration on the Vanillaleaf habitat type is most advanced and will be followed by similar studies of Xeric (dry, lithosolic) and Beargrass habitat types. The vanillaleaf study will isolate the effects of gophers and competing vegetation.

Long-term effects of snowbrush on Douglas-fir stand development and on soil properties is being established under NSF auspices designed to study effects throughout the rotation. Some short-term research is being carried out on snowbrush X tree interactions. This research should provide a definitive answer to balance between positive and negative effects of snowbrush for at least one major transition zone habitat type. Replication on other habitat types would be highly desirable.

Thinning. A matrix of stands representing different species and stand densities on important habitat types is being established to study effects on stand yields.

Intensive, long-term study of effects of stand density, crown length, and nutrient status on tree growth has been established using NSF funds. This research should provide some very basic information on tree and stand growth response for use in developing stocking level criteria. It also serves to help investigate how individual trees compete differentially for resources.

Research on methods, responses, and problems associated with very early commerical thinnings planned as oldest regeneration stands reach minimal size during the next 5 years. Work of this type is already under way at Cascade Head with a replicated test of commercial thinning in 14" average dbh western hemlock. Treatments were regular thinning to 18- and 24-foot spacings and strip thinning.

Growth and Yield. Several projects have been developed recently. Permanent sample plots for growth and yield studies in young Douglas-fir stands have been established on experimental watersheds.

Permanent sample plots for growth and yield information have been established in several 70- to 130-year-old noble fir stands.

Site index curves for Douglas-fir in dry sites on the Willamette National Forest are currently being developed, using data primarily from stem-dissected trees collected from Blue River south. Site index curves for mountain hemlock are currently being developed using data from Oregon and southern Washington Cascades. Site index curves have been developed for upper-slope Douglas-fir and for noble fir based, in part, on Andrews trees. This research was the first to show the dramatic difference between upper-slope height growth patterns and the McArdle Douglas-fir curves. Upper-slope trees start more slowly but have significant height growth, generally through the second century. A similar pattern exists for trees on hot, dry sites.

Wildlife Habitat. Extensive study is underway of structure and composition of young, mature, and old-growth forest stands with objective or providing quantitative definition of each stage and identification of the major animal species associated with each.

Studies of the ecology of spotted owl have and continue to heavily utilize Andrews as a base site due to large numbers of breeding pairs. Dispersal of fledglings has been wide, but survival has been very poor.

Extensive research has been conducted on the amounts, patterns and rates of decay, and functional roles of snags and logs in forests and streams. Down logs persist much longer than snags of the same size and species; even very large snags will not persist for a rotation, while logs may persist for 200 years or more if not mechanically disturbed. Species, size, and location are all important factors in determining rates of disappearance.

A very long-term study of log decomposition is being established to determine factors affecting rates of decay and log disappearance including size and species. This experiment will provide more controlled conditions than can be obtained by looking at naturally-created down logs. A similar long-term study of types, rates, and factors in snag decay is planned.

General Silvicultural Systems. Long-term site productivity and how it is affected by various management alternatives is planned as major research topic in next 5-year period. The specific plan is to establish long-term study of effects of several residue disposal treatments (including burning vs no burning) on site productivity.

Establishment of areas demonstrating various management alternatives for young stands (e.g., high density/intensive tending vs wider initial spacings) is planned.

Trials of silvicultural approaches for incorporating old-growth and other ecological features (such as snags and down logs) in intensively managed commercial forests are planned.

Watershed and Erosion. Studies are currently under way on factors affecting movement of landslide areas. H. J. Andrews continues to be a benchmark location for full-range erosion research (earthflows, shallow rapid slides, ravel, root throw, etc.) including management impacts and revegetation processes. Data have been incorporated in planning on the Willamette National Forest.

Stream and riparian zones are under intensive study from a variety of viewpoints including fish production, overall biological productivity, streambank stability, and water quality. Riparian areas are proving to be very complex ecosystems. Stable woody debris is an important component of all streams and small rivers in terms of both physical stability and biological productivity. Source areas for woody debris and persistence of woody debris of various sizes, species, and decay states is under way in a variety of stream sizes and forest types. Studies of the dynamics of woody debris in streams are designed to provide criteria for judging stability and planning debris management.

Streamside vegetation provides a rich variety of food sources and ameliorative functions (e.g., cover, temperature control, and erosion reduction). In forested reaches, litter inputs are almost the sole source of energy for the entire stream food chain. The mixture of coniferous trees, deciduous shrubs and trees, and herbaceous riparian growth provides a desirable mixture of energy sources of varying food quality (e.g., red alder (*Alnus rubra*) and devilsclub are very high) and speed of decomposition (e.g., Douglas-fir needles are slow). As a result of variation in the quantity, quality, and timing of litterfall, a microbially prepared substrate is available for invertebrates and other stream organisms throughout the year.

Research has shown that the ability of a stream to retain material within a reach is very important, partly so food sources can be held until processed and ready for use by stream organisms. Woody debris is one of the most effective ways in which streams retain resources and stability.

Research at HJA and in the Olympics and Coast Ranges is showing that woody debris is also important in larger streams and rivers; removal of materials can result in undesirable loss of aquatic habitat diversity. Logs attached to rootwads anchored in banks are particularly desirable structures in many stream and small river systems.

Streams in clearcuts may be most productive of small fish (provided water quality is maintained) because of better food supply. Streams in young stands are generally least productive, while old-growth streams are intermediate in production but harbor the larger sized fish in pools created from large woody debris.

Integrated Research. One of the major keys to successful research programs at Andrews has been the existence of an integrated research team which includes a variety of disciplines (geomorphologist, plant ecologist, physiologist, soil scientist, entomologist, etc.) involved in a mix of basic and applied research. The most significant research results appear to occur in interdisciplinary areas as a consequence of collaborations in field and data analysis. Many of the most challenging management problems also appear to be interdisciplinary— for example, cumulative effects, timber and wildlife interactions, and riparian zone management.

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