AN ABSTRACT OF THE DISSERTATION OF

Kenneth R. Carloni for the degree of Doctor of Philosophy in Forest Science presented on May 20, 2005.

Title: The Ecological Legacy of Indian Burning Practices in Southwestern Oregon

Abstract Approved:

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David A. Perry

Two research questions are posed: (1) How have ecosystem conditions changed through time in southwestern Oregon? (2) How have culture-driven and climate-driven processes contributed to ecosystem change in southwestern Oregon? A brief introduction to the Little River study area is followed by a cultural and ecological history of the watershed. Historical, ecological and archaeological data are used to describe shifts in landscape structure, stand structure and fire behavior. Changes in corridor/patch/matrix relationships, increases in stand densities, and changes in stand age and species structure are documented, and changes in fire dynamics from frequent to infrequent, and small to large are corroborated with descriptive statistics from the nearby 2002 Umpqua Fires. Hypotheses are then proposed to test the relative influence of humans vs. climate on landscape change during Aboriginal (<1820) vs. Euro-agrarian (1850-1950) cultural phases. While precipitation shows no correlation with fire frequency or tree recruitment before 1820, significant associations are observed from 1850 to 1950. Moreover, a significant correlation exists between fire frequency and subsequent tree recruitment after 1850, but is not observed during aboriginal times. This suggests that indigenous management fires may have obscured precipitation influences that become apparent only after 1850. In order to test spatial hypotheses concerning the associations between indigenous

humans and the landscape, archaeological sites were digitized into a GIS, and ergonomic pathways were modeled between them. These maps are then compared to historically fire-maintained upland meadows interpreted from 1946 aerial photos. A significant spatial correlation was found between archaeological sites and historic meadows, and a highly significant spatial correlation was found between modeled travel networks and historic meadows. The close spatial association between cultural features and fire-maintained habitats again suggests active landscape management by local Indians. These associations are corroborated with historical records. After summarizing the shifts in ecological conditions and describing current conditions, I argue that while restoring the landscape to aboriginal conditions is no longer possible, emulating those conditions within the framework of the Little River Adaptive Management Area Plan can improve the resilience and productivity of the Little River watershed.

The Ecological Legacy of Indian Burning Practices in Southwestern Oregon

by

Kenneth R. Carloni

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Kenneth R. Carloni, Author

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PREFACE: FIRE ON THE MOUNTAIN

In the hot, parched summer of 2002, a combination of lightning and arson touched off some of the largest wildfires the western United States had witnessed since Euro-American settlement. All told, 88,458 fires burned in the western states, encompassing nearly 7 million acres (2,832,000 ha). Arizona, Colorado and Oregon experienced the largest wildfires since Euro-American resettlement (NASA, 2003). When the smoke cleared, government agencies had spent over $1.6 billion on technology, fuel and muscle in attempts to confine them. Ultimately, the last flames were not extinguished until the snow fell that winter.

Before the last embers faded, however, they ignited a hot debate that quickly spread across the political landscape. Images of infernos raging on television screens across America awoke deep fears in a culture raised on "Smokey the Bear'". Alarmed by the emotional stories of property owners who lost their homes, the stark images of charred forests, and the huge cost of fighting the fires, citizens demanded action from their elected officials.

The heat quickly spread from the political arena to academia, where research foresters and fire scientists were asked to inform policy makers. Many pointed to the vast accumulation of highly flammable fuels in most forest stands. Soon agency officials and timber industry leaders were using terms like "uncharacteristic" and "unnatural" to describe the extent and intensity of the recent fires (e.g. Mealy and Thomas, 2003; Wells 2003), and many began promoting "fuels reduction" programs as the antidote.

While most stakeholders agree that the increased flammability of modern forests is an issue, advocates from the timber industry and the conservation community are at odds over the causes of the problem, and are polarized over the goals and strategies proposed to solve it. Government land management agencies are often gridlocked on how to serve multiple publics with apparently mutually exclusive goals.

President George W. Bush's program for federal forest lands dubbed the "Healthy Forest Restoration Act" has recently been passed by congress, but its implementation is still being actively debated. The title of this act, however, begs an important question: *To what set of conditions should we "restore" forests?* If forests are indeed in an "unhealthy" state at present, then what were the "natural" native forests of southwestern Oregon like and what forces kept these ecosystems "healthy" in the past? What changes in forest structure now cause them to spawn "uncharacteristic" fires? And most pragmatically, what can studies of current and past fire and forest patterns contribute to future management decisions?

In this dissertation, I attempt to shed light on these broad questions by using a multi-scale, multi-disciplinary approach to analyze historical, archaeological and ecological data at the region, landscape and stand levels. I will focus on changes in the landscape dynamics of the Little River watershed in the Umpqua National Forest in southwestern Oregon -- an area that also experienced its largest fires in recorded history in 2002.

CHAPTER 1. INTRODUCTION

Until the mid 20th century, fire of varying frequency, intensity and extent had been the preeminent disturbance process shaping American forests (Pyne, 1982; Bonnicksen, 2000; Wells and Anzinger, 2001), particularly those of the western US (Agee, 1993). Stands of forests, savannas and prairies were continually reshaped by fires that commonly burned in the late summers as fuel and weather allowed. Since the intensity and behavior of landscape fires is largely dependent on the flammability and arrangement of the biomass it burns, complex forests generate complex fire patterns (Pyne, 2004). While severe, high mortality fires can trigger secondary succession and the establishment of an entirely different biotic assemblage (Agee, 1993), the structural diversity created by “patchy” fire behavior reinforces biotic diversity (Perry, 1994) which in turn influences future fire behavior.

The ignition sources for landscape fires – *humans* and *lightning* -- haven’t changed since the arrival of Paleoindians to the Pacific Northwest in the early Holocene. Intentionally or not, humans have been initiators of broadcast burning in nearly every habitat they have encountered worldwide (Pyne, 2001), and there is a long local history of burning for agro-ecological purposes in southwestern Oregon. While the amounts and types of deliberately burned lands have changed with the dominant culture, systematic fires were set by Indians (Lewis, 1990), by the Euro-American settlers who replaced them, (Pyne, 1982; Agee, 1993; Bonnicksen, 2000), and by industrial era land managers up to the present time. On the other hand, lightning is seasonal, weather-driven, and therefore less predictable in its annual frequency, patterns, and vegetation responses than human-set fires (Lewis and Ferguson, 1999).

Mechanized logging introduced a new agent of change into forested ecosystems in the mid 1900s. Industrial technology made large scale clearcutting feasible, causing landscape patterns in western forests to change dramatically (see

Chapter 2). As complex, fire resistant primary forests were replaced with highly flammable even-aged plantations (Wildfire Effects Evaluation Project (WEEP) Report, 2003; Spies and Pabst, 2004), wildfire can now spread more rapidly across the landscape. Uncharacteristic patterns and distributions of even-aged stands created by industrial silviculture practices (Little River Watershed Analysis, 1995) have combined with high fuel loads from fire suppression programs to spawn unusually intense fires. Or as Pyne (2004) puts it, "Messed-up forests will only yield messed-up fires."

But just how "messed up" are the forests of southwestern Oregon, and by what measures can the pattern and extent of the changes that have occurred since historic times be assessed? Broad, qualitative questions such as these need rigorous, quantitative answers if policy makers and land managers hope to be able to apply an understanding of the past into our planning for the future.

In efforts to reconstruct historic ecosystem dynamics, landscape ecologists have employed the concept of *Historic Range of Variation* to try to understand present ecological patterns and processes in context with those of the past (see Morgan et al., 1994; Swanson et al., 1994). Baseline ecosystem reference conditions can be reconstructed through the analysis of numerous forms of historical, ecological and cultural data (Cronon, 1983; Russel, 1997; Egan and Howell, 2001) and compared to both the average and the extremes of each parameter through time.

Because good resource planning requires a multi-scale approach (Lindenmayer and Franklin, 2002), characteristics that describe key spatial and temporal aspects of ecosystem structure and disturbance behavior at multiple spatial scales should be selected to serve as reference conditions against which to compare current forest patterns and disturbance processes.

1.1 RESEARCH QUESTION AND OBJECTIVES

In human occupied landscapes, local resource management practices interact with seasonal weather patterns to influence feedbacks between ecosystem patterns and disturbance processes (Pyne, 1993). Euro-Americans, however, were apparently not the first land managers in the western US. A growing body of evidence documents the influence of Native Americans on their landscapes through the use of systematic landscape fire (Pyne, 1982; Boyd, 1986; Lewis, 1990; Robbins, 1997; LaLande and Pullen, 1999; Lewis and Ferguson, 1999; Williams, 2001; and other references in Chapter 3 and 4).

While acknowledging the use of broadcast fire by Indians in the western US, other researchers, however, suggest that the effects of Native American burning practices were localized to small areas near villages and were insignificant relative to the influences of climate (Vale, 2002; Whitlock and Knox, 2002).

This controversy has important implications for the current culture: Untangling the relative impacts of human activity versus climate on local and regional forest dynamics will give resource managers a stronger understanding of the consequences of past and future management activities.

To provide a framework for investigating the relationships among people, climate, fire and the forests of southwestern Oregon, I developed the following research questions:

> ***1) How have ecosystem conditions changed through time in southwestern Oregon?***
>
> ***2) How have culture-driven and climate-driven processes contributed to ecosystem change in southwestern Oregon?***

The following objectives were generated to facilitate the construction of testable hypotheses:

Objective 1: To compile a multi-scale, geographic and historic database on human activity, vegetation structure, precipitation, and fire occurrence in southwest Oregon, focused on the Little River watershed.

Objective 2: To document shifts in ecosystem reference parameters from aboriginal times through Euro-American settlement and into the period of industrial forestry.

Objective 3: To test hypotheses concerning relative influences of humans and climate on forest dynamics by comparing precipitation, tree regeneration and fire frequency during different cultural phases in the Little River watershed.

Objective 4: To map archaeological features and model the land use patterns of the Indians of the Little River watershed.

Objective 5: To test for spatial correlations between Indian land-use patterns, forest structure, and fire occurrence.

1.2 OVERVIEW

In the chapters that follow, historic maps and photos, government and private documents, ethnographic records and ecological and archaeological data are used to investigate the links between fire behavior, human cultures, and forest patterns during the past four centuries in southwestern Oregon.

Chapter 2 introduces the Little River study area and addresses Objectives 1 and 2 by discussing the historical, archaeological and ecological data used in reconstructing the environmental history of the area, and by providing a brief cultural and ecological history of the Little River watershed, emphasizing the changes in fires and forests over the last 400 years. Past fire behavior is then compared to the aftermath of the 2002 Umpqua Fires.

The effects of precipitation and culture on fire and tree recruitment (Objective 3) are analyzed in Chapter 3. Fire history data and precipitation history derived from tree rings are used to look for relationships between precipitation and fire scar frequency, precipitation and tree recruitment, and fire scar frequency and tree recruitment in the Little River watershed during two different cultural phases.

Chapter 4 first reviews the historical literature on local and regional Indian burning practices. After mapping known archaeological sites and modeling the most ergonomic pathways between them (Objective 4), I then address Objective 5 by analyzing the spatial relationships between archaeological sites, pathway models and historic meadows.

The findings of previous chapters are summarized in Chapter 5, and management applications are discussed.

CHAPTER 2. THE LITTLE RIVER WATERSHED THROUGH TIME: HUMANS, FIRE AND THE NATIVE LANDSCAPE

2.1 INTRODUCTION

The record area of land burned and the severity of the wildfires of 2002 have been described as “uncharacteristic” and “unnatural” (Mealy and Thomas, 2003; Wells, 2003), but the causes of this apparently aberrant fire behavior are being hotly debated. Although global warming has undoubtedly exacerbated the problem (Pierce et al., 2004), increases in timber harvesting, livestock grazing, and fire suppression since Euro-American resettlement have also contributed to stand and landscape scale changes in the types, densities, and distributions of fuels (Harris, 1983; Savage and Swetnam, 1990; Ripple, 1994; Belsky and Blumenthal, 1997; Covington et al., 1997; Spies and Pabst, 2004).

Charged with the mandate of “restoring” the nation’s forests, current land managers face enormous challenges. Among the first and most important of these is to provide benchmarks for future restoration efforts by reconstructing historic forest dynamics. In addition to quantifying changes in ecosystem patterns and processes through time, determining the roles that climate and human cultures – past and present – have played in shaping forest structures and fire patterns will provide resource managers with critical information necessary for robust planning.

Toward that end, this chapter documents changes in pattern and process in the forests of the Little River watershed in southwestern Oregon. I first discuss the ecological parameters used in this analysis, and then provide a description of the geographic and environmental setting of the Little River watershed and the data sources available from this area. I then focus on the histories of culture, landscape, and fire that have culminated in the current ecological conditions of the watershed. The 2002 Umpqua Fires are then examined, and their effects will be evaluated based on the history of the forests they burned.

2.2 CHARACTERIZING MULTI-SCALE ECOSYSTEM CONDITIONS

Only when accurate historic baselines of ecosystem conditions are established can our current culture begin to build consensus around plans to restore ecosystems. But any restoration attempt must begin by determining the parameters that characterize historic forest structures and fire behaviors in order to assess the “naturalness” of current stands and landscapes. The following is a description of the forest structure and fire pattern reference parameters used to characterize ecosystem conditions in this dissertation.

2.2.1 Landscape Level Reference Parameters

Patch, corridor and matrix configuration: I will use these terms as defined by Forman and Godron (1984), and refined by Malanson (1993), Perry (1994), Foreman (1995), Lewis and Ferguson (1999), Lindenmayer and Franklin (2002), and others in the emerging field of landscape ecology. Matrix refers to the dominant community type in which all other elements are embedded. In the Little River area, matrix was historically dominated by White Fir/Hemlock and Mixed Conifer forests (Franklin and Dyrness, 1973). Patches are less common communities or landforms embedded in matrix lands (e.g. wetlands, savannas, unique habitats embedded in woodland). This term may also refer to areas that contrast structurally with the surrounding vegetation such as old-growth vs. tree plantation, etc. (often referred to as “stands” in the forester’s lexicon). Corridors are long and sinuous structures or biotic communities (e.g. roads and riparian strips). Changes in the sizes, shapes and configurations of these landscape elements may be documented by comparing historic maps and photographs with recent air photos and satellite images.

Tree species proportions: Changes in climatic conditions and/or disturbance processes are likely to result in changes in forest species composition. The characteristics of bark and other aspects of a tree's structure that affect its ability to survive fire vary considerably among tree species (Agee, 1993). Therefore, changes in fire regimes over time will likely be reflected in the recruitment ratios of species based on their level of fire tolerance.

Annual tree recruitment: This is simply the number of trees in a dataset entered for each calendar year (e.g. Fig. 2.21). These data are derived from tree ring counts of varying precision, often from nonrandom samples. If data limitations are taken into account, useful comparisons with other environmental parameters can be made. For example, years of high or low tree establishment success may reflect a landscape level shift in climate and/or human activity.

Annual proportion of trees scarred by firer: Fire scar records are also derived from tree ring analyses (e.g. Fig. 2.5). Because the cumulative number of trees in the dataset increases each year, more scars are likely to be found in years closest to the present. Therefore, comparing the proportion of scars counted in a given year to the cumulative number of trees in the dataset for that year (e.g. Fig. 3.1) gives a more accurate representation of the *relative* amount of fire recorded that year than the simple number of scars per year.

Fire patterns: While modern fires have been precisely mapped (Fig. 2.26), historic fire patterns must be inferred from historical records and images, as well as from current landscape conditions. For example, mapping historic meadows and other fire-generated plant communities from early air photos allows spatial comparisons with landforms and cultural features, while demographic and fire scar data from associated stands help corroborate observed spatial trends.

2.2.2 Stand Level Reference Parameters

Stand demographics: Tree ring data may also be used at the stand level to investigate tree age structures and stand densities. For example, stand demographics and tree ring analyses were used in recent studies from the Oregon Coast Range, the central Oregon Cascades, and the Southern Cascade/Siskiyou Mountains. that report significant changes in forest densities since Euro-American resettlement (Tappeiner et al., 1997; Poage, 2000; Sensenig, 2002).

Fire intensity: While the intensity of modern fires can be accurately measured with aircraft and satellites (Fig. 2.26), historic fire intensities can only be inferred. However, because fire history is reflected in surviving trees, rough reconstructions of fire effects can be made from fire scar and stand demography. High-intensity fires are likely to cause high-severity (high-mortality) events which trigger secondary succession leading to even-aged patches. Intermediate to low-intensity fires, however, generate intermediate disturbance processes that lead to multi-aged stands with high structural and biotic diversity (Perry, 1994; Lindenmayer and Franklin, 2002)

Fire frequency: Although many recent studies attempt to use fire scar data to quantify fire return intervals, these calculations are based on data with inherent biases and inaccuracies (see Chapter 3). For example, Baker and Ehle (2001) present interpretations from ponderosa pine forests that suggest “fire-history data have uncertainties and biases when used to estimate the population mean fire interval (FI) or other parameters of the fire regime". Therefore, I have not attempted to characterize fire cycles in a quantitative way; I instead simply identify fire frequency trends from historic to current conditions.

2.3 STUDY AREA AND DATA SOURCES

To investigate the interactions of humans, fire and climate in southwestern Oregon, I chose to study the historic patterns of fires and forests in the Little River watershed southeast of Glide, Oregon on the west slope of the southwestern Oregon Cascades (Fig. 2.1). This major tributary of the North Umpqua River drains a highly diverse landscape that includes parts of 3 different ecological provinces (Franklin and Dyrness, 1973).

The 131,853 acre (53,360 ha) drainage comprises a patchwork of public and private ownerships (Fig. 2.2.). Currently, 37% of the watershed is privately owned, about three quarters of which are managed as industrial timberland. Public lands are managed by the Umpqua National Forest of the US Forest Service (USDA) and the Roseburg District Bureau of Land Management (USDI). The 83,377 acres (33,742 ha) of public lands have been designated as one of ten Adaptive Management Areas (AMAs) under the Northwest Forest Plan (NWFP, 1994).

AMAs were established with the objective of "learning how to manage on an ecosystem basis in terms of both technical and social challenges, and in a manner consistent with applicable laws." (Little River Adaptive Management Area Plan, 1997). The specific goal of the Little River AMA is the “development and testing of approaches to integration of intensive timber production with restoration and maintenance of high quality riparian habitat." (NWFP, 1994). The status of the majority of this drainage as an AMA makes data readily available in the public domain and provides a framework for sharing data and other resources among public and private entities.

The Little River Watershed Analysis (LRWA) was completed in 1995 by the Umpqua National Forest and the Roseburg District BLM as part of the 1994

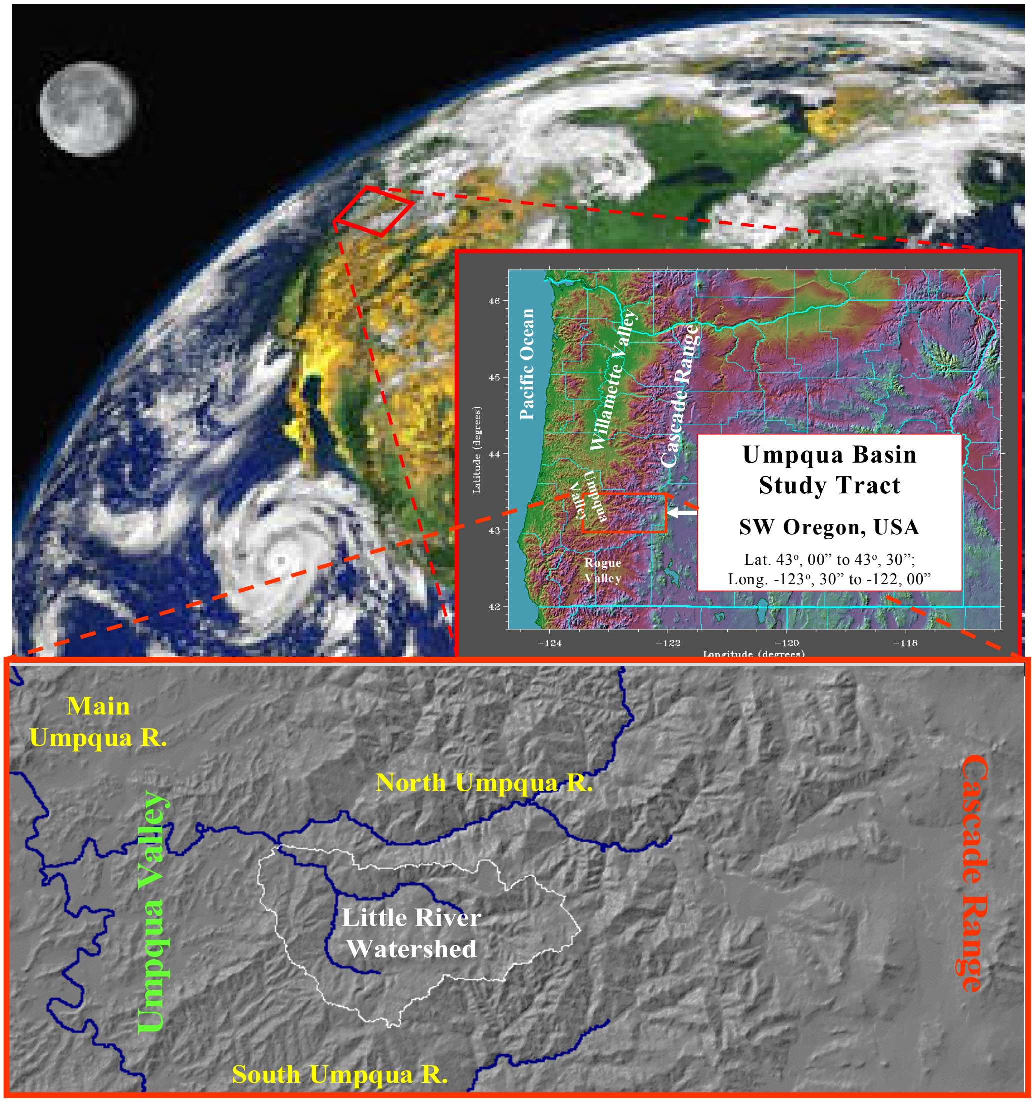


Figure 2.1: The Little River Watershed in Geographic Context.
The top image locates Oregon in western North America, while the rectangle at the bottom outlines the map window used in the GIS analyses presented in subsequent chapters. The Little River watershed is outlined in white with major geomorphology features of the surrounding area labeled.

Northwest Forest Plan (NWFP). The LRWA was designed to provide baseline information to be used by agency resource managers to assess the consistency of proposed management activities with the goals of the Northwest Forest Plan's Aquatic Conservation Strategy (ACS). One of the cornerstones of the Northwest Forest Plan, the ACS "was developed to restore and maintain the ecological health of watersheds and the aquatic ecosystems contained within them on public lands." (NWFP, 1994). The watershed analysis conducted by agency specialists in the Little River drainage contains assessments of current conditions, and provides important data and valuable insights into the ecological history of the area.

In addition to the studies conducted during the Little River Watershed Analysis, a number of other well designed ecological studies were conducted in the watershed in the late 1990s, and substantial archaeological data documenting Indian activity in this area are also available.

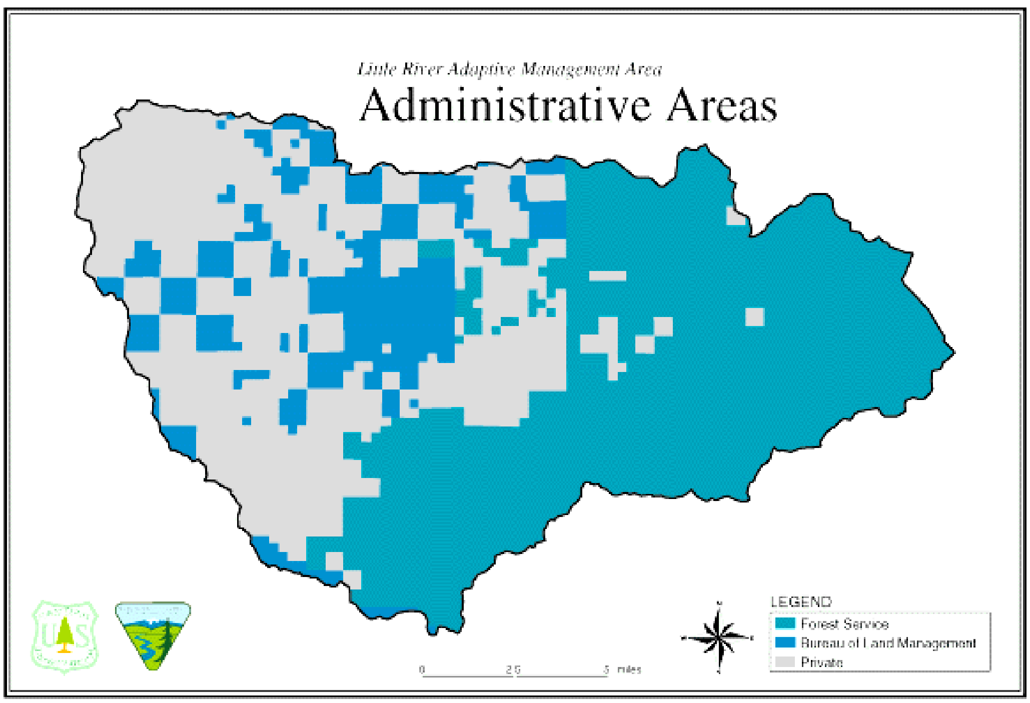


Figure 2.2: Current Ownership Pattern of the Little River Watershed. *Gray* areas represent private lands, *blue* areas represent public lands managed by the USDI Bureau of Land Management, and *blue-green* areas represent public lands managed by the USDA Forest Service. (Source: USDA/USDI)

2.3.1 Geographic and Environmental Context

The Little River watershed is located near the geographic center of the Umpqua Basin (Fig. 2.1) and is one of the largest tributaries of the North Umpqua River. It ranges in elevation from 730 ft (220 m) at its western edge to 5720 ft. (1743 m) in the eastern uplands. Lands to the north drain into the North Umpqua River while lands to the south deliver water to the South Umpqua River. The easternmost point of the Little River watershed joins a long ridge that forms the Umpqua Divide, which separates the two major river systems.

The upper Umpqua drainage is a transition zone between the forests to the north (the Willamette forests dominated by western hemlock/white fir climax forests) and to the south (the Rogue and Siskiyou forests dominated by Douglas-fir/mixed conifer forests) (Franklin and Dyrness, 1973). The change in forest types is most strongly observed at the Umpqua Divide between the North and South Umpqua drainages beginning at the eastern edge of the Little River watershed.

Forest series in the Umpqua basin include (in descending order by area covered) western hemlock (*Tsuga heterophylla*), white fir (*Abies concolor*), Douglas-fir (*Pseudotsuga menziezii*), mountain hemlock (*Tsuga mertensiana*), Shasta red fir (*Abies magnifica shastensis*), lodgepole pine (*Pinus contorta latifolia*), Pacific silver fir (*Abies amabilis*) and western red cedar (*Thuja plicata*) (Atzet and McCrimmon, 1990). In addition, islands of meadow, oak savanna (*Quercus garryana* and *Q. kellogii*), and pine (*Pinus ponderosa* and *P. lambertiana*) stands are scattered throughout the area.

The western side of the Little River watershed is a mix of the valley oak savanna and meadow communities that gradually grade to a patchy margin of oak, madrone, ponderosa pine and big leaf maple dominated woodlands with Douglas-fir stands in the draws and north slopes. These give way to the east and upland to diverse, conifer dominated forests.

2.3.2 Climate and Precipitation History

Climatic conditions and landforms affect the initiation and spread of wildfire in the Western Cascades. High evapotranspiration in the late summer and fall may create fuel moisture conditions that are highly conducive to fire spread, and periodic east wind events can bring dry, warm air from the high desert east of the Cascade Range into the Umpqua basin (Agee, 1993). Steep, rugged topography can cause local convective winds that can also promote wildfire spread (Morrison and Swanson, 1990) (see Fig. 2.28).

The present climate of the Umpqua Basin is characterized by wet, mild winters and warm, dry summers. The majority of the 35 to 75+ inches (90-200 cm) of precipitation falls between November and March. July, August and September may be entirely dry, but electrical storms that generate abundant lightning with little precipitation are common during this time. The upper elevations of the drainage maintain a winter snowpack that feeds the creeks and rivers during the seasonal summer dry period.

Historic precipitation fluctuations in the Pacific Northwest have been successfully correlated to tree ring widths (Graumlich, 1985). Since stands near mountain peaks are more protected from local processes that can affect growth, tree ring widths from these stands tend to more accurately reflect that year's relative rainfall. By comparing the width of annual rings from 41 such sites to rainfall records dating back to 1899, Graumlich was able to create a precipitation index for the region that she extrapolated back into the 1500s.

Figure 2.3 presents portions of Graumlich's data at the regional and landscape levels. These reconstructions "…do not reveal long-term changes in mean conditions" from the mid 1600s to the present (Graumlich, 1985). This is noteworthy considering that the Little Ice Age abruptly ended during the span of Graumlich's study and an ongoing warming trend began in the mid 1800s. The

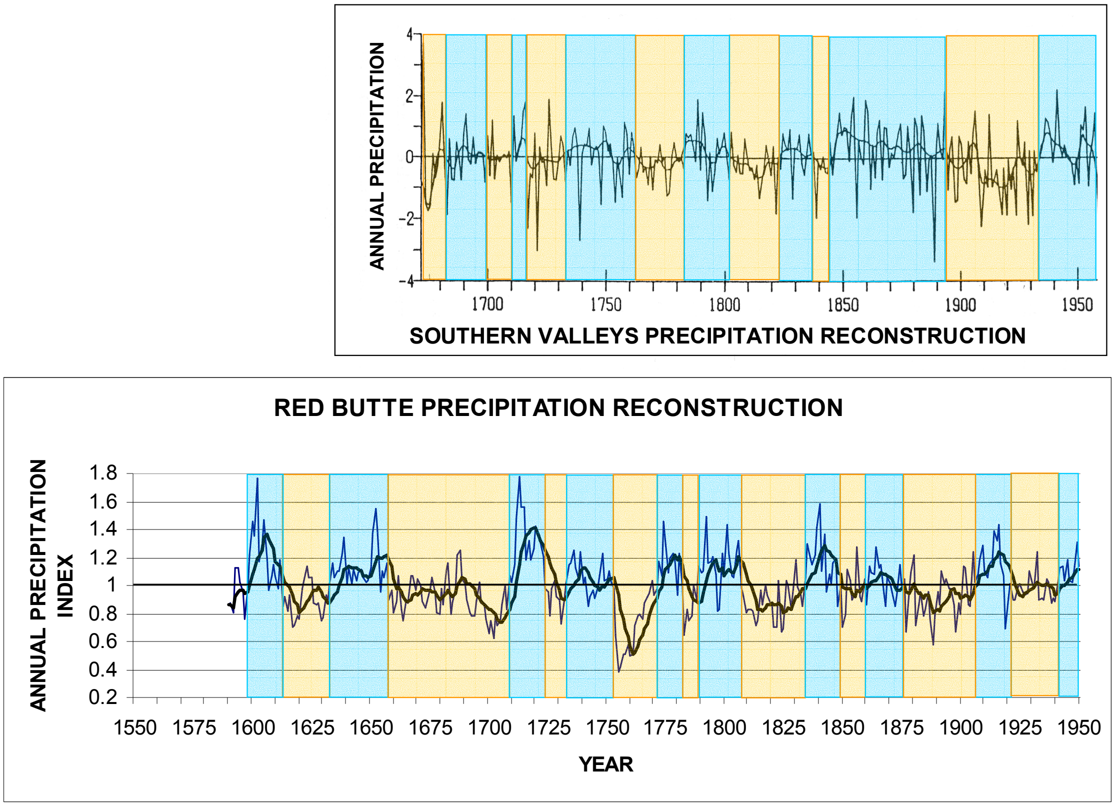


Figure 2.3: Regional and Landscape Level Precipitation Reconstructions. Lisa Graumlich's data (1985) for the Southern Valleys region of southern Oregon and Northern California (top) and for the Red Butte site in the Little River watershed. Blue represents periods of above average precipitation, yellow represents below average periods. Five year moving average lines are also displayed.

increase in temperature, however, apparently had little or no effect on precipitation averages in southwest Oregon. Note the somewhat cyclical pattern of precipitation, especially in the plot-level data from Red Butte. The variation in precipitation over time, and its effects on forest dynamics, will be discussed in detail in Chapter3.

2.3.3 Agents of Ecosystem Change

The concept of ecological disturbance is useful in characterizing the agents of change in forest structure and species composition (Botkin, 1990; Lindenmayer and Franklin, 2002), but the term itself is open to varying interpretations (Botkin, 2003). Lindenmayer and Franklin (2002) define *natural disturbances* as "…discrete events that are not primarily of human origin and which alter ecosystem structure and resource availability." In subsequent discussions, I include human-caused agents of ecosystem change (e.g. clearcut logging, road building) in the definition of disturbance. Aside from the industrial forestry practices of the past several decades, fire (both lightning-caused and of human origin) has historically been the predominant agent of ecosystem disturbance in southwestern Oregon (Agee, 1993).

Wildfire (as we currently think of it) and anthropogenic fire used by humans for agro-ecological purposes may have quite different effects on forest structure. A high intensity, episodic disturbance (Lindenmayer and Franklin, 2002) tends to dramatically change the state of the ecosystem in terms of structure and biota, and usually triggers the establishment of early seral communities. On the other hand, chronic, low to intermediate intensity disturbance tends to increased structural -- and therefore biotic -- diversity (Perry, 1994). Because historic Indian-set fires tended toward higher frequencies and lower intensities with regular intervals separating them relative to lightning sparked fires (Boyd, 1999; Lewis and Ferguson, 1999; Williams, 2001), these chronic disturbance patterns tended to increase biotic diversity. On the other hand, high-severity wildfires and the fires set by modern managers for logging slash removal both tend to reduce biotic diversity.

Disturbance agents often have significant interactions. For example, the effects of wildfire can be intensified in areas with large amounts of insect and/or disease killed timber (Agee, 1993), but mitigated by moist conditions surrounding beaver ponds. The Little River Watershed Analysis (1995) states that

> Since the late 1940s, fire suppression, timber harvest, and the lack of prescribed fire in unmanaged stands [have] influenced how fire interacts with the landscape. Insects, disease, and windthrow are

> disturbance processes that all function at a smaller scale and fire, providing pockets of disturbance at the stand level. These combined processes, working simultaneously, determined landscape vegetation patterns, and have influenced wildlife populations and aquatic habitat for centuries.

2.3.4 Local and Regional Data for Reconstructing Historic Conditions: Strengths and Limitations

A number of local and regional data sources are available for reconstructing historic conditions in the Little River watershed and the surrounding area (Fig. 2.4), but the historic time frame for this investigation is constrained by the available data. Since the ecological datasets from Little River only record events of the last several centuries, and since the accuracy of those data diminish with time, I can reliably document the historic landscape patterns and fire history of Little River only about as far back as the late 1500s.

In order to compare disparate sources of data for reconstructing landscapes, I have adopted standards for assessing data quality developed by the EPA (1996) to evaluate the strengths and weaknesses of available data sources:

Precision: How well do repeated measurements agree?

Accuracy: How confident are we that the data collected actually measure what we think it's measuring?

Representativeness: Has sampling been done in the right places?

Completeness: Are there enough samples to provide valid inference?

Comparability: How well do data from one set compare to others that purport to measure the same parameter?

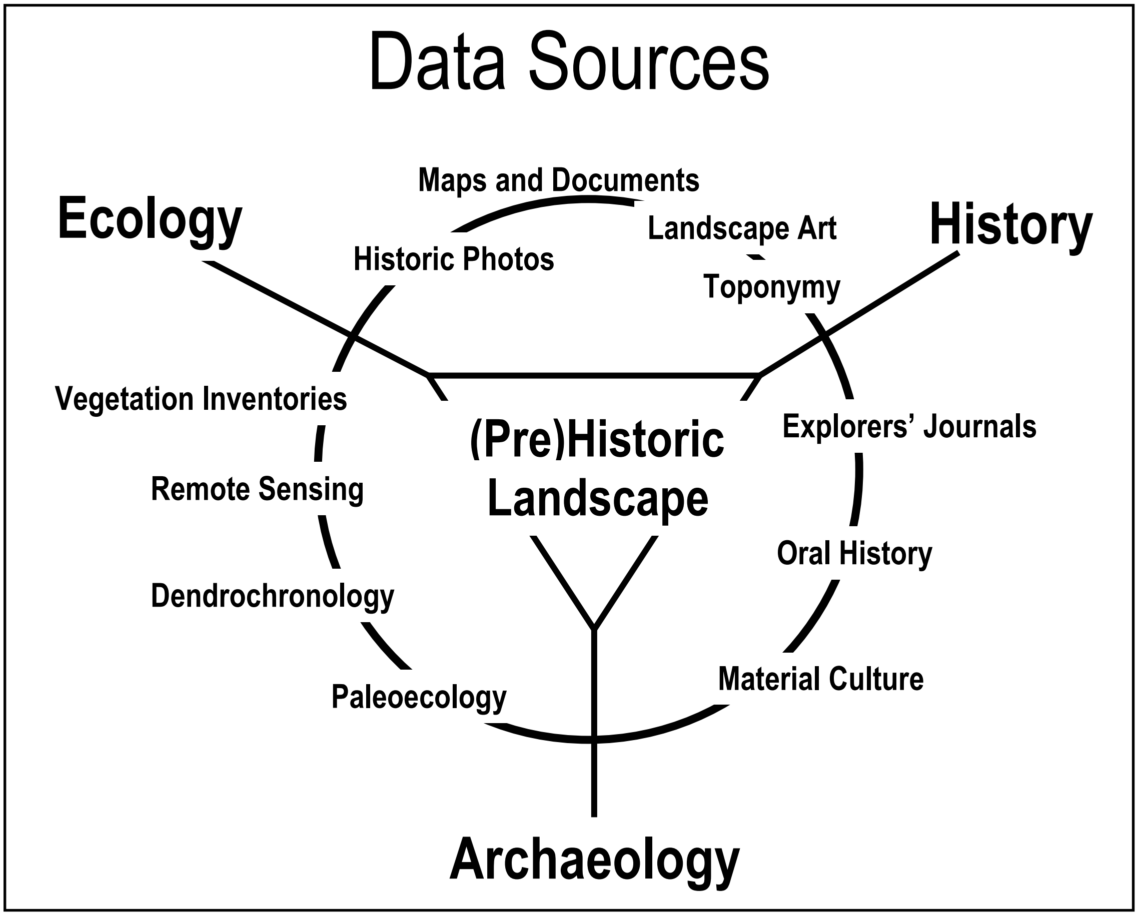


Figure 2.4: Sources of Data for Ecological Reconstructions in the Little River Watershed.
Data sources are arranged in relation to their historical, archaeological and ecological content. All of these data types are used in the following chapters to reconstruct historic conditions in the Little River watershed.

Historical data sources such as Government Land Office Survey Notes and USGS maps tend to rate highly in all of these standards. Many other sources (e.g. historic sketches and journal entries) are often detailed but their accuracy may be impacted by cultural biases. One must be mindful of the protocols used and reporters' cultural milieu, and should always look for congruence with other data (Cronon, 1983; Russell, 1997; Egan and Howell, 2001).

Archaeological data (Fig. 2.5) are fragmentary and often highly degraded. Depredations by physical forces and looters have made clues to past material cultures highly incomplete, while precision and accuracy vary from low to moderate. Completeness and representativeness are largely a function of the time and effort spent on archaeological surveys – cultural resource surveys have only been routinely conducted on federal lands for the past few decades, and are often initiated by impending management activities rather than by research goals. This leaves a frustratingly sketchy picture of past conditions that is open to numerous interpretations. However, the fact that their georeferencing is highly reliable gives archaeological data excellent comparability.

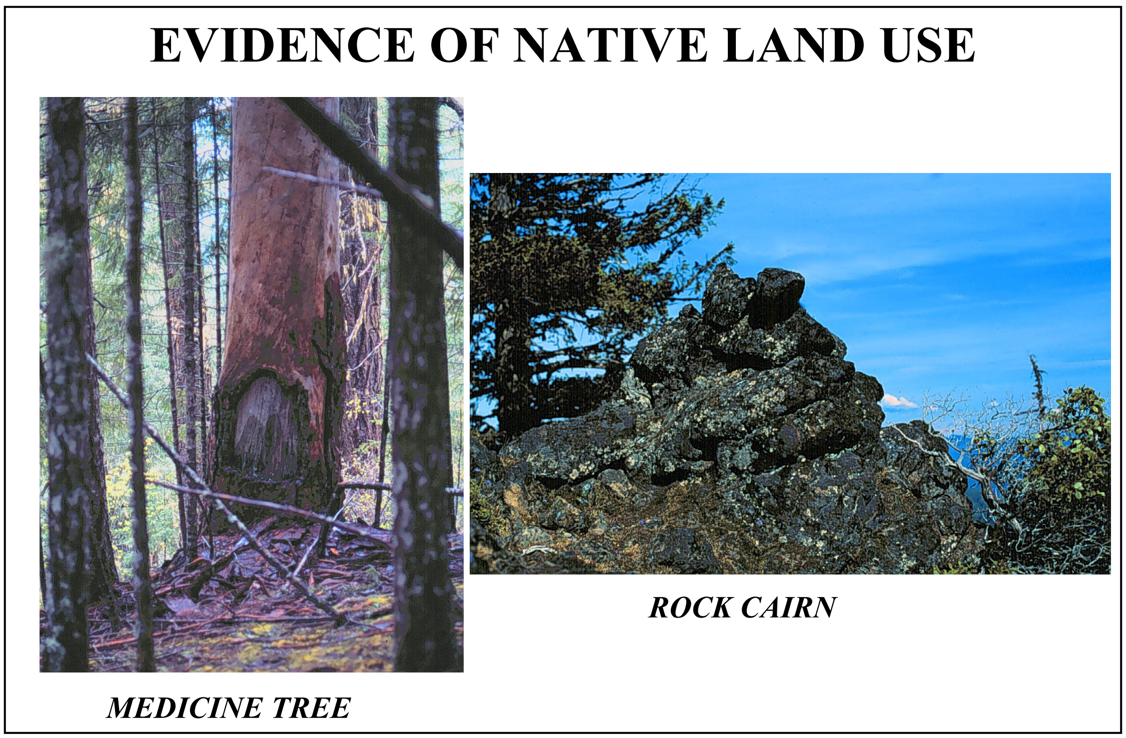


Figure 2.5: Archaeological Evidence of Ancient Human Activity.
The image on the left is a "medicine tree" (now dead) showing characteristic scarring from having its inner bark peeled by Indians as a source of food or medicine. The rock cairn on the right was photographed in 1996, but is clearly visible in a 1933 Osborn panorama. Its thick incrustation of slow growing lichens indicates that they have been undisturbed for centuries. (Photos by the author.)

Data on the locations and interpreted uses of 80 archaeological sites in and around the Little River watershed have been made available to me by local agency archaeologists (Isaac and Debra Barner, agency archaeologists, pers. com., 2000).

The quality of ecological data is constrained by the protocols under which they are collected. Although a tremendous effort by the scientific community in the late 20th century to gather and analyze ecological data produced a wealth of public domain databases, they were collected under many different sampling schemes driven by distinct objectives. When the limitations in each experimental design are taken into account, however, these data are extremely useful in reconstructing ecological histories.

Ecological datasets are usually very complete, but may vary in other qualities. For example, data collected from tree ring counts in harvest units are often biased toward steep slopes because gentle ground that was harvested so long enough ago that the stumps have rotted are not represented. As with other types of records, confidence in reconstructions using ecological data can be increased by narrowing the inference of conclusions based on them, and by corroboration with historical and/or other sources of evidence.

Ground fires that are intense enough to injure the cambium but not severe enough to kill the tree leave characteristic scars (Fig. 2.6) that can be closely dated by ring counts. A great deal of recent fire history research has been based on tree ring data collected from stumps in recently logged units (see Chapter 3). These data are routinely used to (1) date fire scars for reconstructing stand and landscape fire histories, (2) establish tree ages for reconstructing forest stand demographics, and (3) infer past precipitation over large regions.

Although the age structures of stands can be accurately determined by simply counting tree rings, the reconstruction of fire histories presents a greater challenge. Most fire history reconstructions are based on data collected in ways that can severely limit the strength of some inferences that are drawn from them

(Weisberg, 1998; Baker and Ehle, 2001). Of the three stand demography datasets and two fire history datasets collected in the Little River basin in the mid to late 1990s (Current Vegetation Survey, 1995; Van Norman, 1998; and Little River Watershed Analysis, 1995), all used different sampling schemes and data recording protocols. Their use in subsequent analyses is accompanied by discussions of their values and limitations.

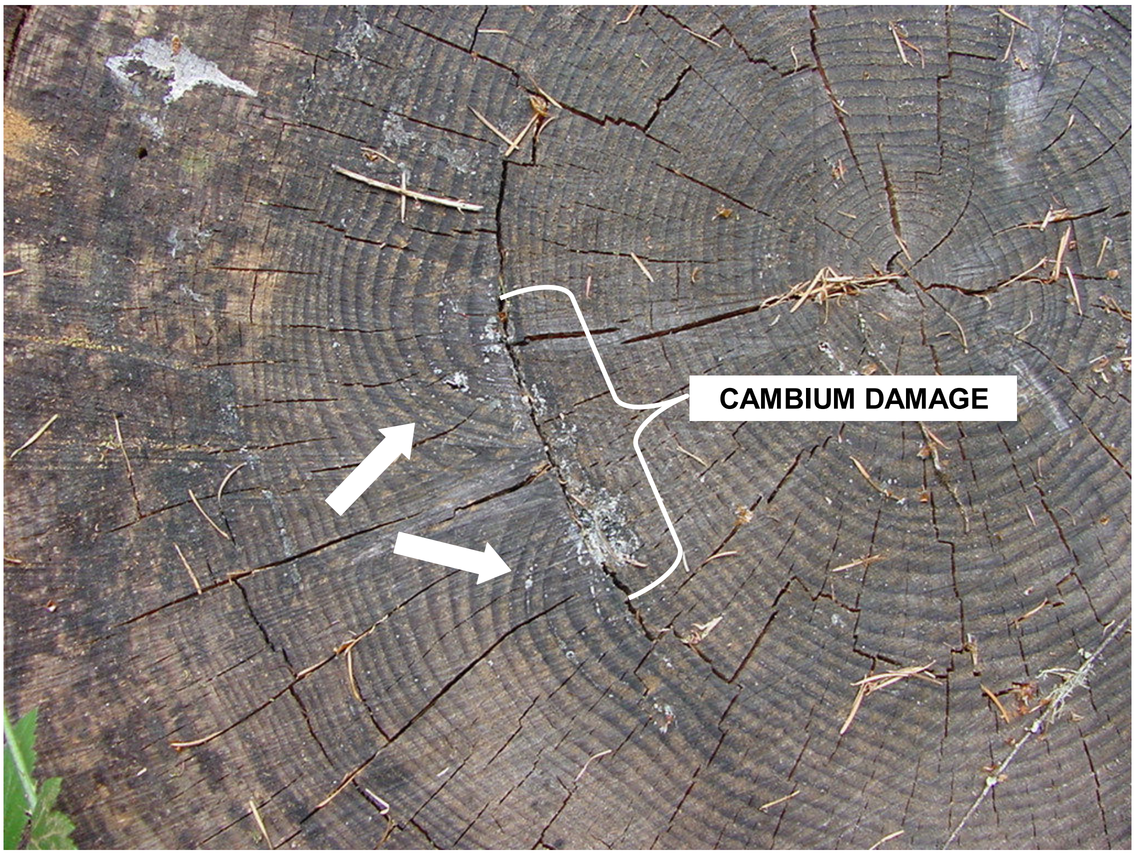


Figure 2.6: Typical Fire Scar Observed on a Douglas-fir Stump.
Note the incurved pattern of growth rings (arrows) as they successively heal over the wound. This injury occurred when the tree was approximately 34 years old. (Photo by the author)

Sources of ecological data used in this study also have their own strengths and weaknesses. For example, the mapping of historic habitats from historic air photos, while highly spatially explicit, can misinterpret or under-represent certain vegetation types (see Chapter 4).

Some types of ecological information used in this study are more difficult to quantify, and thus serve as corroborative rather than definitive data. For example, relic trees (Fig. 2.7) reflect change over time that is often evident in their architecture and in the age structures and species assemblages that they are associated with. For example, as its name suggests, Sugar Pine Flats in the Little River watershed contains a relic stand of *Pinus monticola.* Such stands are often associated with major Indian sites (Kimmerling and Lake, 2001). This stand, located close to a documented village site, is apparently no exception.

Figure 2.7: Relic Trees.
The highly branched architecture of the dead tree on the left indicates that it grew with little competition for light. It is now imbedded in a dense, young stand. The oak snag on the right signals a shift from open oak savanna to closed canopy conifer forest. (Photos by the author, 2002.)

2.4 THE CULTURAL HISTORY OF LITTLE RIVER

From the late 1500s to the present, the Little River watershed has been under the management of three distinct cultures. Although there is no general agreement on the cultural partitioning of that time span in the Umpqua Basin, I have differentiated three cultural phases -- the **Aboriginal Phase**, the **Euro-agrarian Phase**, and the **Industrial Phase --** based on the vast differences in local natural resource management technologies employed by each culture.

2.4.1 The Aboriginal Phase: before 1850.

During the Aboriginal Phase, indigenous peoples including the Kalapuya, Upper Umpqua, Cow Creek and Molalla tribes were the stewards of the upper Umpqua basin until a succession of epidemics and the relocation of survivors to distant reservations occurred in the early- to mid-1800s (Beckham and Minor, 1992). Native land managers had only broadcast burning as a tool for large scale management of resource patches (see Chapter 4), but had a depth of ecological knowledge built on thousands of years of experience (Johannessen, 1971; LaLande, 1980; Boyd, 1986; Beckham and Minor, 1992; Lewis, 1990).

The following description of the subsistence rounds and burning practices of the indigenous peoples that inhabited the upper Umpqua drainage is derived mainly from: (a) general reconstructions of the lifeways of the native peoples in other areas of the western Cascades similar to the Umpqua basin (Jonannessen et al., 1971; Beckham, 1977; LaLande, 1980; Boyd, 1986), (b) from direct accounts of aboriginal life in the Umpqua basin (Douglas, 1972; Riddle, 1953; and citations in Beckham, 1986; and Beckham and Minor, 1992), and (c) from archaeological research done in the Umpqua basin and compiled by Beckham and Minor (1992).

The upper Umpqua basin was home to four distinct groups of native people at the time of European contact (Beckham and Minor, 1992). From north to south, the Yoncalla, Upper Umpqua and Cow Creek Indians occupied the valley and foothills while the Southern Molalla occupied the highest elevation sites in the mountainous eastern portion of the Basin. It is most likely that the Little River drainage was occupied by the Upper Umpquas, with the possibility of some overlap with the Mollalas in the upper reaches to the east and with the Cow Creek Tribe to the south.

Although the Athabascan speaking Upper Umpqua Indians, the Kalapuyan speaking Yoncalla to the north, and the Tekelman Cow Creeks to the south may have been culturally distinct from one another, all three of these lowland peoples seem to have followed the same subsistence patterns of seasonal migration from the valley floor in the winter to the uplands in the summer (Beckham and Minor, 1992). The mountain dwelling Southern Molalla, however, may have wintered at intermediate elevations in the uplands and migrated to the alpine forests and meadows of the high Cascades in the summer.

The lowland Indians lived among relative abundance, subsisting on salmon and other anadromous fish runs, game animals and waterfowl, and such food plants as camas bulbs (*Camassia spp.*), biscuit root (*Lomatium spp.*), tar weed seed (*Madia spp.*), yampah (*Perideridia spp.*), acorns (*Quercus spp.*), and many other types of berries and seeds. Although the earliest inhabitants of the area were primarily dependent on meat from game, advancements in food processing artifacts through time suggest that plant foods become increasingly dominant in later periods (Beckham and Minor, 1992). Houses were built of split planks with floors set several feet below ground level.

The material technology of Umpqua Indians was based on fiber, bone and stone. Basketry had evolved to such high state of functionality that pottery was lost from the region (Beckham and Minor, 1992).

The societal structure of the local native peoples consisted of autonomous extended families that often coalesced into small villages. After root crops and fish were harvested and processed in the spring, these small groups left the valley and migrated east into the uplands, often gathering at favorite huckleberry (*Vaccinium spp.*) patches. It is here that various groups would meet, arrange marriages, trade, conduct business and cooperate in game drives. Although much less is known about the mountain dwelling Molallas, it is reasonable to assume that these people would not have missed the opportunity to at least trade with the lowlanders during these summer gatherings.

2.4.2 The Euro-agrarian Phase: 1850 to 1950.

The Euro-agrarian Period saw the influx of American settlers who used farming and ranching technology largely derived from their European heritage to reshape the land from the mid 1800s to World War II. Although the Umpqua Basin was resettled at different times in different places, I use 1850 to begin this period because that date begins the decade of the first land claims in the Little River watershed (Little River Watershed Analysis, 1995).

The early Euro-American resettlement culture introduced draft animal power, water power, and metal tools to the region (Fig. 2.8), and many early arrivals added broadcast burning to their management practices after observing its use by local Indians. These practices were later to be denigrated as “Paiute forestry” by early 20th century foresters (Pyne, 1983). A dramatic drop in fires beginning in the late 1930s (Fig. 3.10; Little river Watershed Analysis, 1995) suggests that fire suppression, although promoted by early 20th century land managers, was was becoming more effective toward the middle of the century: "Fire suppression was established with the Forest Reserves in 1906. Fighting fires became more effective with the advent of the Civilian Conservation Corps (1929), smoke jumpers (1940), lookouts (1930 - 1950), and improved communications." (Little River Watershed Analysis, 1995).

Figure 2.8: Early Logging Technology.
Water, animals and humans powered early logging technology, with yarding and transportation becoming increasingly driven by biomass fuels toward the end of the Euro-agrarian Phase. While this technology had a significant impact on lowland forests associated with rivers and streams large enough to transport logs, impacts to upland forests did not become significant until post WWII technology brought mechanized logging and trucking to the area. (Photos on file at the Douglas County Museum of History and Natural History.)

Because of the rugged terrain, and because higher grade timber was abundant elsewhere, logging in the upland forests of the Umpqua had minimal impacts on landscape patterns until the post-WWII era. In the Little River watershed, less than 2% of the drainage was impacted by roads and timber harvests before 1946 (Little River Watershed Analysis, 1995). Logging practices consisted of mostly single tree selection and high-grading of the most valuable trees.

2.4.3 The Industrial Phase: 1950 to 2000.

With the advent of chain saws, mechanized yarding and reliable trucking in the post-WWII years, selective cutting and high-grade logging gave way to clearcutting as the dominant timbering method. Clearcut logging, with a focus on extracting large, high-value trees, has been the predominant logging method used in the Little River watershed in the last half of the 20th century.

The earliest logging began at low elevations on the gentlest slopes and moved progressively to steeper upland slopes (Little River Watershed Analysis, 1995). Logging intensified in the closing decades of the 1900s and by the end of the century, nearly 60% of the land had experienced some form of timber harvest activity (Little River Adaptive Management Area Plan, 1997).

Land ownership is reflected in the timber harvest patterns visible in Fig. 2.9. One can clearly observe the near absence of native forests on private lands in the western portion of the watershed. The checkerboard pattern that characterizes much of former Oregon and California Railroad company lands now managed by the U.S. Bureau of Land Management is visible in the center, and the staggered setting logging pattern typical of the U.S. Forest Service Lands can be observed to the east.

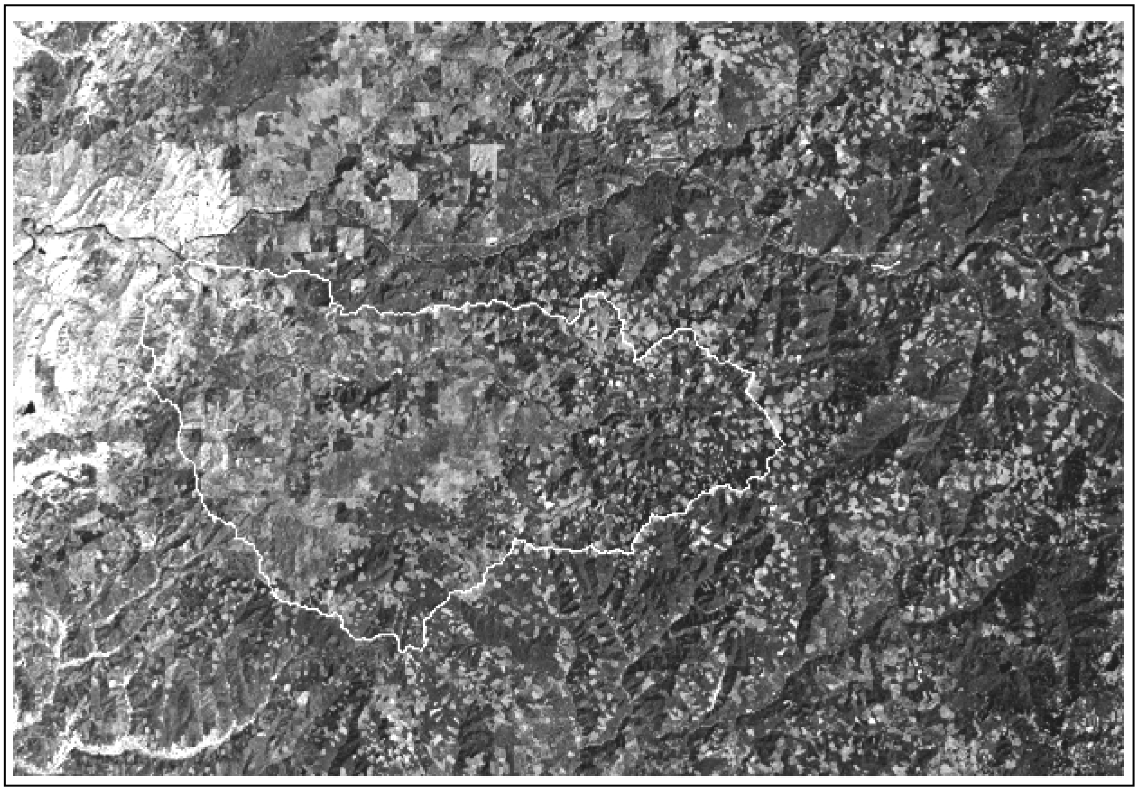


Figure 2.9: 1990 Landsat Image of the Little River Area.
Note the Bureau of Land Management "checkerboard" in the left-center of the image, and the "staggered clearcut" pattern on National Forest land on the right. The dark areas of largely undisturbed forests seen in the upper and lower right of this image are wilderness areas. The white line delimits the Little River watershed.

2.5 A HISTORY OF FORESTS AND FIRES IN THE UMPQUA BASIN

2.5.1 Umpqua Valley Grasslands

Historic evidence suggests that mid-nineteenth century Umpqua Valley landscapes were dominated by grasslands and oak savannas. For instance, an 1841 sketch of the southern valley near the South Umpqua River (Fig. 2.10) depicts an expanse of open country with scattered trees that appear to have wide spacing and open understories. The sketch clearly reveals (1) a pall of smoke in the background burning on Sept. 21st, 1841, (2) widely spaced savanna/woodlands in the middle

Figure 2.10: Umpqua Valley Landscape, Sept. 21, 1841.
In a journal entry dated Sept. 9, 1841, Henry Eld wrote “Our route has been through what might be called a hilly prairie country, the grass mostly burnt off by recent fires, and the whole country sprinkled with oaks so regularly dispersed as to have the appearance of a continued orchard of oak trees.” Note the pall of smoke from a broadcast fire rising in the distance. Sketch by Henry Eld of the Emmons Expedition.

distance, and (3) an Umpqua Indian observer in the foreground. This sketch will be further analyzed in Chapter 4.

The landscape structure depicted in Fig. 2.10 is reflected in the survey notes from U. S. Government Land Office records from 1853 (Fig. 2.11).

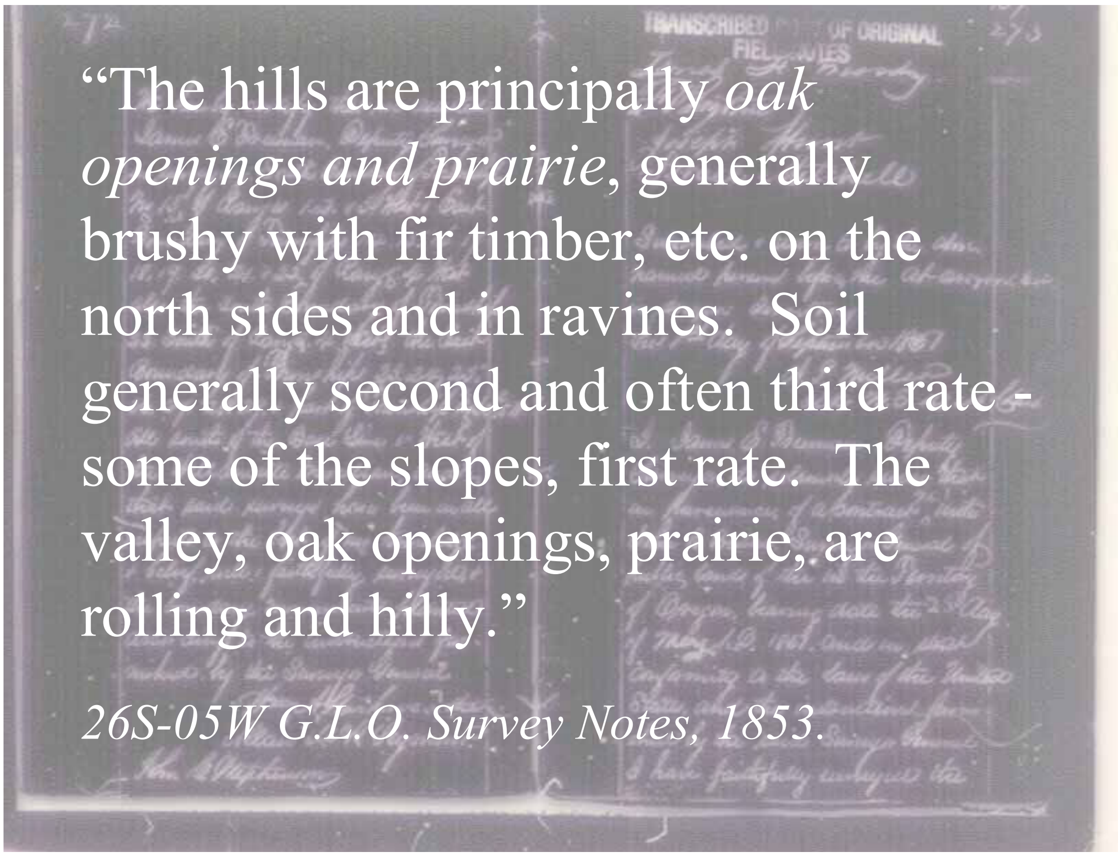


Figure 2.11: 1853 Gov't. Land Office Survey Notes for a Township in the Northern Umpqua Valley.
Surveyors who laid out the lines for the earliest cadastral surveys further documented the open landscapes of the Umpqua Valley. (my italics)

By 1895, an early USGS map (Fig. 2.12) documents the conversion of native prairie to "cultivated" land. Land development for farms, housing and industry has now claimed a large proportion of historic oak savanna in the Umpqua Valley, especially on the gentlest slopes.

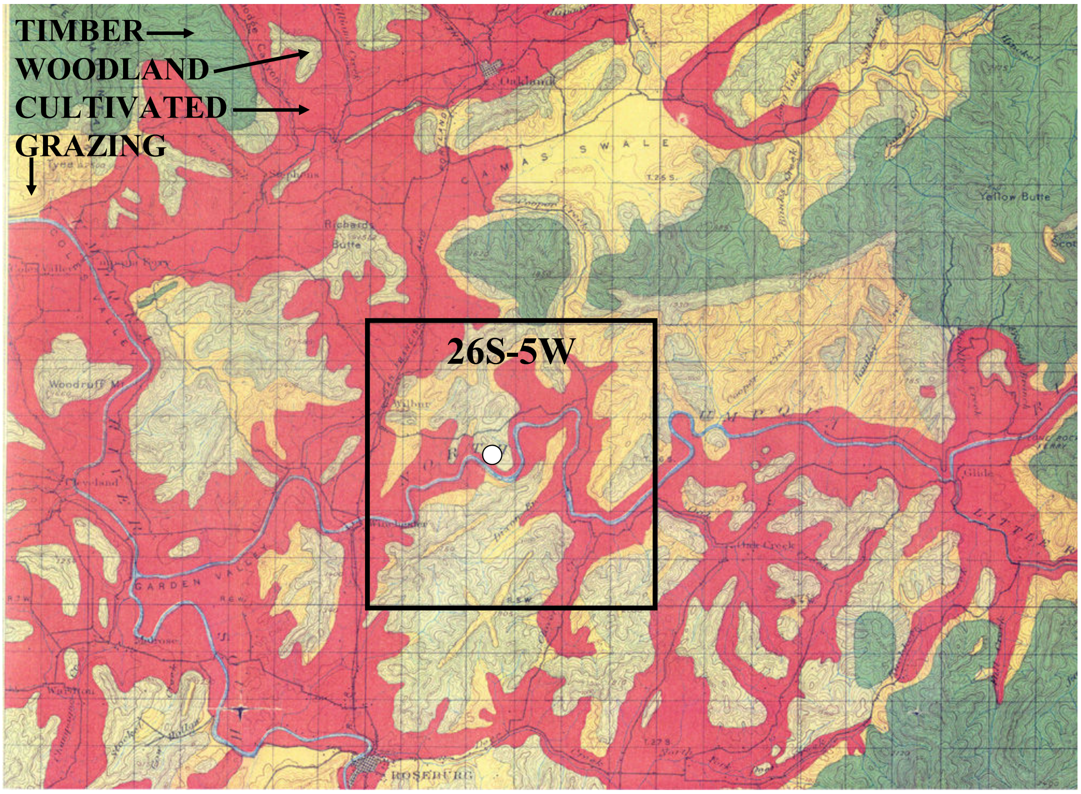


Figure 2.12: Umpqua Valley 1895 USGS Land Classification Map. Darker green areas are designated as "timber", lighter green as "woodland", yellow as "grazing" land, and red as "cultivated" land. The square delimits the township referred to in Fig. 2.11. The circle in the center locates the stump analyzed in Fig. 2.13. The westernmost portion of the Little River watershed can be seen toward the lower right of the map.

A number of lines of evidence suggest that in the grasslands and savannas of the Umpqua Valley, fires may have burned on 1 to 3 year cycles. Multiple fire scars observed in several pre-Euro-American oak stumps (Fig. 2.13) corroborate many historic accounts of settlers from the Willamette and Umpqua valleys describing the frequency of landscape fires set by Indians in lowland prairies and river bottoms (see Chapter 4). Fire scar records from a nearby dense oak stand that developed between 1880 and 1900 that was sampled at ground level in 1998 (Carloni, unpublished data) showed an average fire return interval of about 10 years. This suggests that more frequent fires may be necessary to maintain prairies and savannas.

Figure 2.13: Fire Scars in an Oak Stump Cut at Ground Level in the Umpqua Valley.
The fires recorded in the early life of this oak were not found on a nearby tree that was over 50 years old at the time they burned. It too had 5 scars within its first 16 years in the mid-1700s. This suggests that the scars resulted from short rotation fires that were only intense enough to injure young trees but not kill them. Most of these scars were not visible at the top of the first cordwood log (0.5m from ground level). (Photo by the author.)

On steeper slopes where ranching is more difficult, much of the open savannas have become in-grown with dense hardwood stands dominated by oak, madrone and Douglas-fir (Fig. 2.14). Much of this land was historically maintained by frequent burning, first by its Indian inhabitants, then by the Euro-American settlers who replaced them (Chapter 4).

Figure 2.14: Savanna In-filling, Umpqua Valley, 2003.
This recent photo was taken in the same township that was described as "oak openings and prairies" in the GLO notes in Fig. 2.11 above. The bald at the top of the slope is maintained by grazing. (Photo by the author.)

The historical and ecological evidence presented above is consistent with a trend from open prairies and savannas that were burned frequently during aboriginal times to crop and ranch land with steadily decreasing landscape fire during the Euro-agrarian resettlement period. During the industrial era, both rural populations and aforestation have expanded to create a wildland/urban interface (Fig. 2.14).

2.5.2 Upland Conifer Forests

A number of lines of evidence suggest that frequent, low-intensity fire was also a common driver of historic forest pattern in the Cascade forests of the Umpqua Basin.

Figure 2.15 was sketched by Henry Eld of the Emmons Expedition on Sept. 23, 1841. Clearly visible on the slope at the left of the sketch are small patches of openings embedded in what appears to be steep, dense forest matrix.

Fig. 2.15: Upland Landscape in the Umpqua Mts., Sept. 23, 1841.
Notice small patches of openings in dense forest on the left, possibly from small, patchy crown fires. Trees in the middle distance appear to be open forests at the fringe of a meadow. Note patchy meadows in the foreground close to where the party was camped. Note also the apparent steep slope bias in this sketch. Sketched by Henry Eld of the Emmons Expedition.

Assuming that Eld was sketching at the end of the day's march, shadows indicate that the view in Fig. 2.15 is to the north or northeast. This suggests that this slope has an easterly aspect that would be more likely to be heavily timbered than south or west slopes. These openings may simply be rock outcrops, or they may be the result of small crown fires spanning a few tree heights across. If they are fire marks, this would suggest that fires in dense timber may have burned with a fine-grained patch pattern (see Tiller Fire Intensity Map, Fig. 2.26). In the middle distance, however, the forest on the western flank of the slope in the background appears to be open understory parkland at the upper fringe of a meadow. This suggests that fires burned frequently enough to maintain bottomland meadows and the open spacing of the surrounding stands.

The patchy meadows in the foreground of Fig. 2.15 are most likely near a ridgeline trail the explorers were presumably following, and may reflect the use of fire to keep ridgeline trail systems open. This interpretation is reinforced by another Eld sketch from the previous day (Fig. 2.16) of an Umpqua Mountain trail depicting recently burned-off saplings on the ridge.

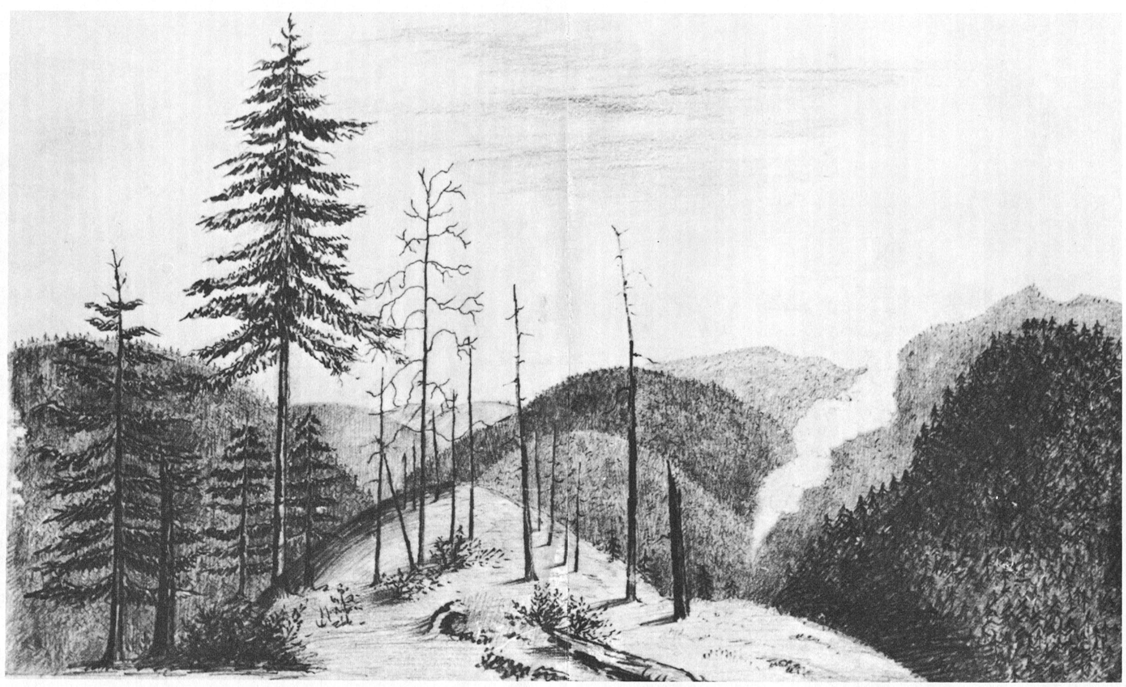


Fig. 2.16: Recently Burned Upland Ridgeline Trail, Sept. 22, 1841.
Another sketch from the Umpqua Mountains just south of the Little River watershed. Note again the smoke rising from the lower right part of the drawing and the recently burned-off ridge. Sketched by Henry Eld of the Emmons Expedition.

Since the onset of industrial forestry practices on US Forest Service land, a significant shift in landscape configuration from a matrix of structurally diverse forests embedded with patchy anthropogenic meadows and parklands (e.g. Fig. 2.19 left panel) to a matrix of plantations with islands of native forest and receding grasslands (e.g. 2.19 right panel). Landscape reconstructions carried out during the Little River watershed analysis process (Fig. 2.17) show the progression of landscape change during the last century. The Little River Watershed Analysis concludes:

> The watershed's current seral conditions are outside of the reference range conditions. The largest deviation is seen in the amount of late seral [forest] which has decreased by as much as 40 percent to 50 percent from recent historical pre-timber management levels. Mid-seral has increased by as much as 25 percent to 28 percent and early seral has increased by 9 percent to 25 percent.

Interestingly, the coverage of both interior habitat and late seral stands was greatest in the 1930s -- 80 years after the extirpation of the Upper Umpqua people, but before industrial forestry had begun. The relative amounts of early seral forests during each cultural phase suggest that while significant management may have taken place during aboriginal times relative to Euro-agrarian culture, Industrial Phase effects are significantly different from any past conditions in intensity, pattern or scale.

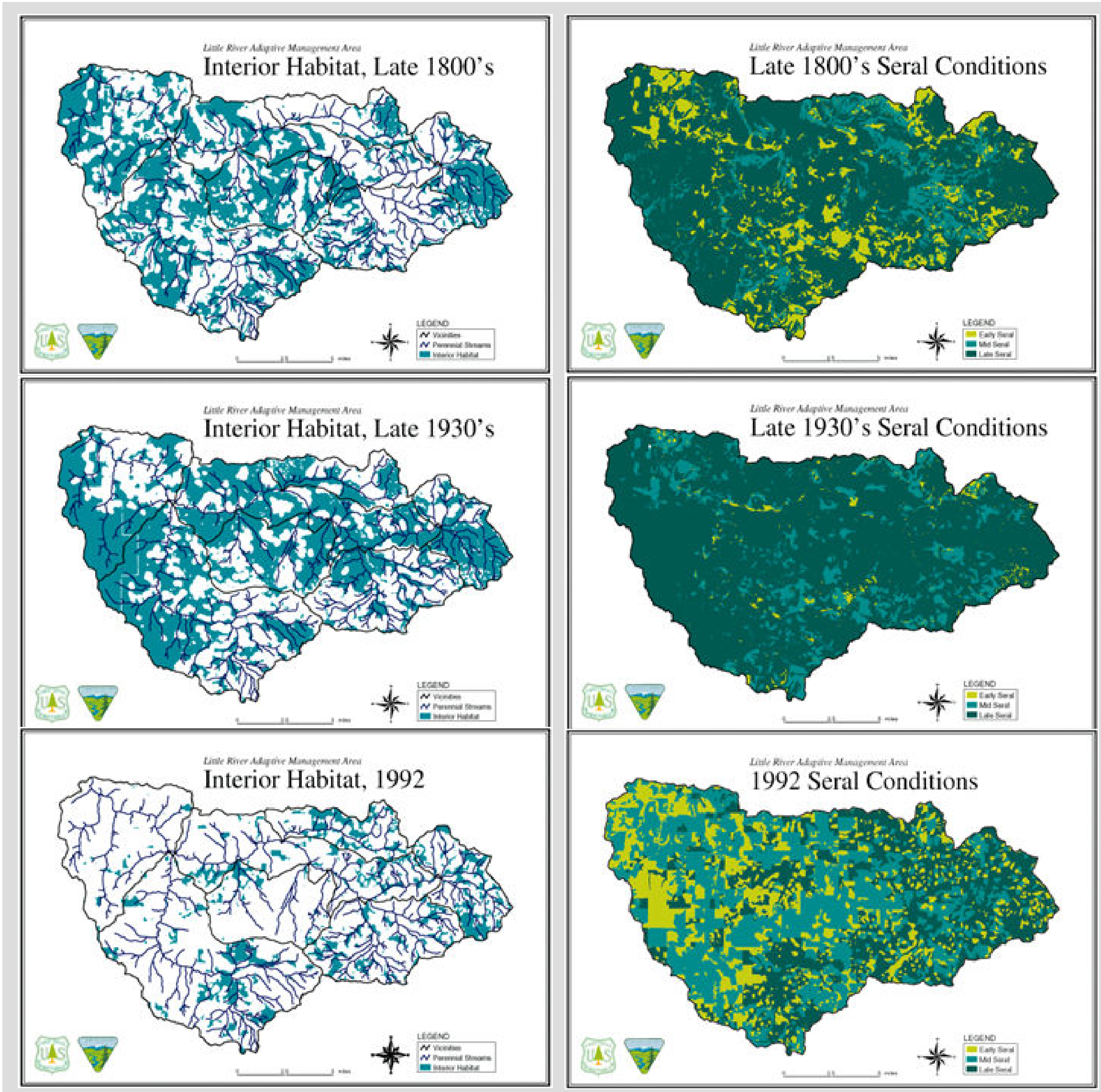
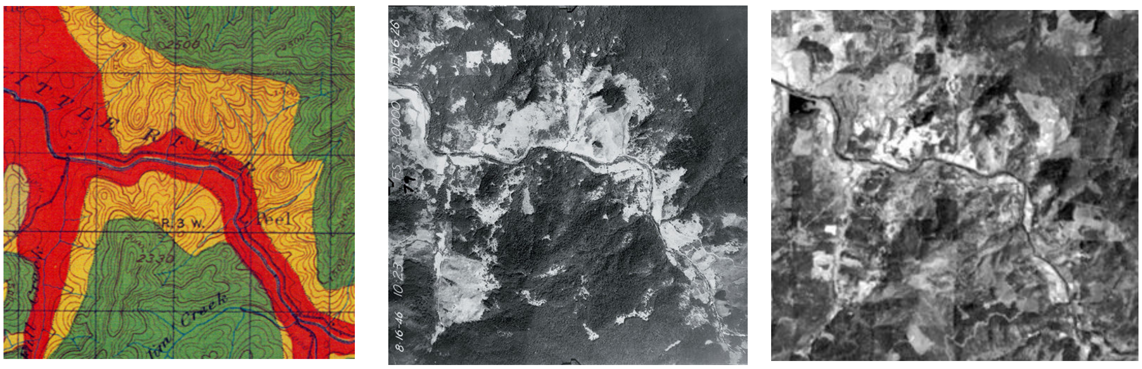


Figure 2.17: Interior Habitat and Seral Condition Changes in Little River. Reconstructions using 1946 aerial photos were carried out by Ray Davis and his crew at the UNF North Umpqua Ranger District. This series of maps on the left show interior habitat (blue areas), and the maps on the right show stand maturity: early seral=yellow, mid-seral=blue, and late-seral=green. Note the shift from relatively open habitat in the late 1800s to dense forest in the 1930s, and then the abrupt shift back to open habitats during recent decades. This progression appears to reflect the cultural changes in the area, and does not correspond to any known climate trends (see Chapter 3)

Figure 2.18 mirrors the pattern seen in Fig. 2.17, but at a finer scale. These government images form a chronosequence of 3 points in time at one location near the western edge of the Little River watershed.



1895 USGS MAP **1946 AERIAL PHOTO** **1990 LANDSAT**

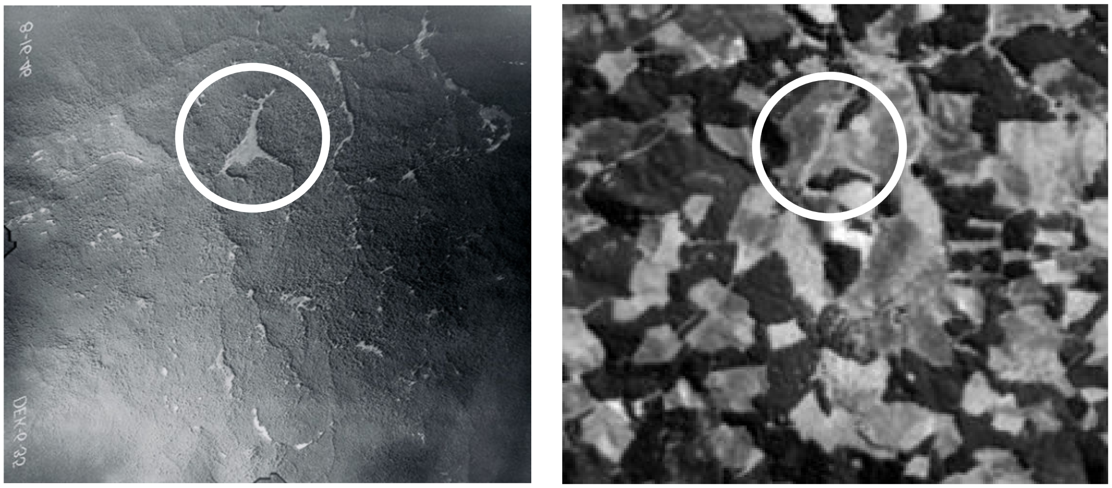
Figure 2.18: Shifting Forest Margins: 95 Years of Landscape Change in Western Little River.
In the leftmost map, red and yellow are open cultivated and grazing lands respectively. The center aerial photo documents encroachment of open lands by dense forests. By 1990, the "checkerboard" BLM land ownership pattern (see also Fig. 2.2) has become evident and clearcut logging is extensive. (Also note that the 1946 air photo shows a slight counter-clockwise rotation compared to the other images.)

The 1895 USGS map on the left of Fig. 2.18 documents land use during the middle of the Euro-agrarian Period. Cultivated lands (red) blanket the flood plains, and grazing lands (yellow) run up the valley slopes to the ridges. Green areas are forested. By 1946, agricultural activities had diminished, and forests had encroached on the open lands from the ridges downward (middle photo). This image also records the earliest traces of clearcut logging, seen as small squares in the upper left hand corner of the middle photo.

The 1990 Landsat image on the right in Fig. 2.18 reveals the impact of 40 years of industrial forestry on the land. Forested lands that had once formed the landscape matrix now are represented by patches in a matrix of clearcuts and even-aged plantations. The "checkerboard" ownership pattern across BLM managed O&C lands (Fig. 2.1) has become evident and clearcut logging is extensive.

Figure 2.19 documents the dramatic changes in the proportions and arrangements of landscape elements on Willow Flats at the northern edge of the Little River watershed. Although the 1946 photo shows the “corridor, yard and matrix” pattern common to aboriginal management patterns in many parts of the world (Lewis and Ferguson, 1999), by 1990 this configuration had been largely obscured.

Another shift in landscape structure is evident in the two photographs in Fig. 2.20, taken 63 years apart. The 1933 image is cropped from an Osborne panoramic photo looking east from the Red Butte Lookout in the Little River watershed. I shot the 1996 photo from the same structure (now badly deteriorated) with a 35mm camera. Again, note the shift from ridgeline meadow remnants to dispersed clearcuts.



1946 **1990**

Figure 2.19: Earliest Aerial Photo and Recent Landsat Image from Willow Flats: The Two Extremes?
Willow Flats straddles the Little River / North Umpqua Divide. Landscape configuration has changed from “corridors and yards” (Lewis and Ferguson, 1999) to the “fragmented forest” (Harris, 1983). Circles enclose the same wet meadow. The 1946 air photo was taken at the projected peak of forest cover (see Fig. 2.17), and the 1990 Landsat image may represent an historical low. Images are approximately 7.25 X 7.25 km.

Figure 2.20: Rephotography of the View East from the Historic Red Butte Lookout Into the Little River Drainage.
The 1933 image is cropped from an Osborne panoramic photo looking east from the Red Butte Lookout into the Little River watershed. The 1996 photo was shot from the same structure with a 35mm camera. Note the shift from ridgeline meadow remnants to dispersed downslope plantations. (1996 photo by the author.)

Tree ring counts from the stumps located in clearcut stands (Little River Watershed Analysis, 1995; Van Norman, 1998) or from increment borings of live trees (Current Vegetation Survey, 1995) record the age structures of stands sampled across the Little River watershed. These data reveal a number of trends at both the landscape level (Fig. 2.21) and the stand level (2.22).

The North Umpqua Ranger District and Van Norman datasets both show sharp increases in tree recruitment that peak in the mid- to late-1800s and fall off rapidly thereafter, while a much more gradual increase is observed in the Current Vegetation Survey (CVS) data. This discrepancy is undoubtedly due to the fact that because the top two datasets were collected from logging units, sampling is biased toward stands with mature saw timber, while young trees and old-growth with a lot of defect are underrepresented. The CVS data, on the other hand, were collected on a uniform grid, and sampled all age classes of trees down to 6 inches (15.25 cm) in diameter.

While the shape of their curves may differ, all three datasets in Fig. 2.21 do, however, show an increase in tree recruitment from the early 1800s through the mid to late century. In regions where large disparities exist in the natural life spans of their component tree species, short-lived species may skew the age structures toward younger trees (Perry, et al., 2004). For example, if some species lived only ~150-200 years, sampling in 1990s would appear to show increased recruitment beginning ~1800. Because all of the species in these databases have natural life spans well in excess of 500 years, this scenario is unlikely here. Rather, the surge of tree regeneration more likely reflects a change in ecological and/or cultural conditions.

Increased recruitment rates during the transition period from the Aboriginal to the Euro-agrarian Phase may be attributable to a number of causes: (1) the development of new, even-aged stands across the landscape following stand replacing fires, (2) the abrupt cessation of meadow management by native peoples and the conversion to even-aged forests, and/or (3) the in-filling of established stands with younger cohorts of trees (Fig. 2.22) in the absence of low intensity underburning. Although meadow infilling is well documented in the Little River watershed (Little River Watershed Analysis, 1995), the fact that the large majority of stands in the Little River and Van Norman datasets are *not* even-aged (see below) strongly supports the third alternative.

A fourth alternative – that climate change is responsible for the increase in tree recruitment – will be addressed in Chapter 3.

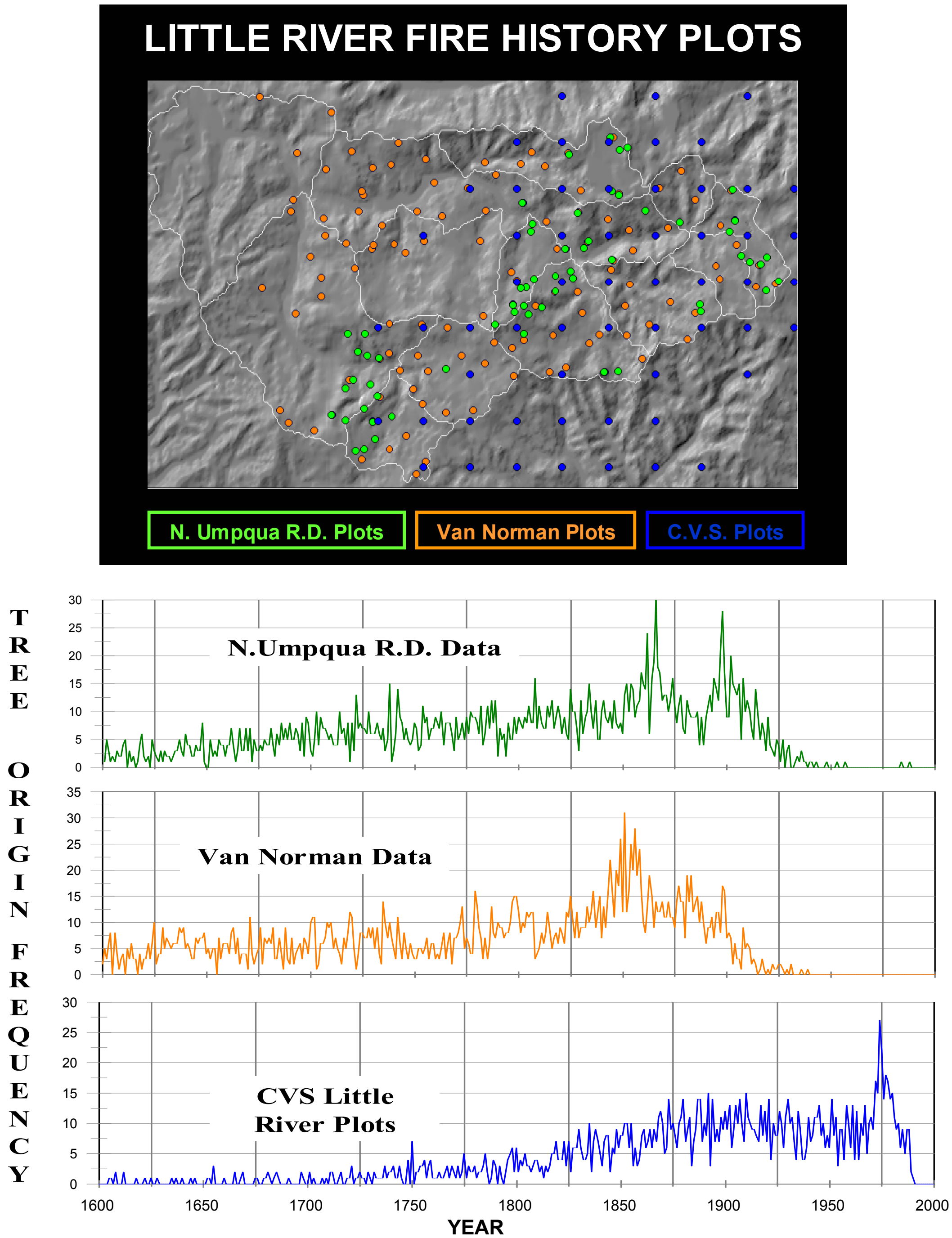


Fig. 2.21: Three Little River Tree Recruitment Datasets.
Three tree ring datasets were collected in and around the Little River watershed under different site sampling and data gathering protocols. They are displayed here as frequency of tree origins per year. The top two graphs display data from two fire history studies that sampled post-clearcut harvest units (Little River Watershed Analysis, 1995; Van Norman, 1998). The bottom set was collected during the Current Vegetation Survey (1995) using a uniform sampling grid, but lower precision increment bore-based age estimates. Plot colors on the map match data series line colors on the corresponding graphs.

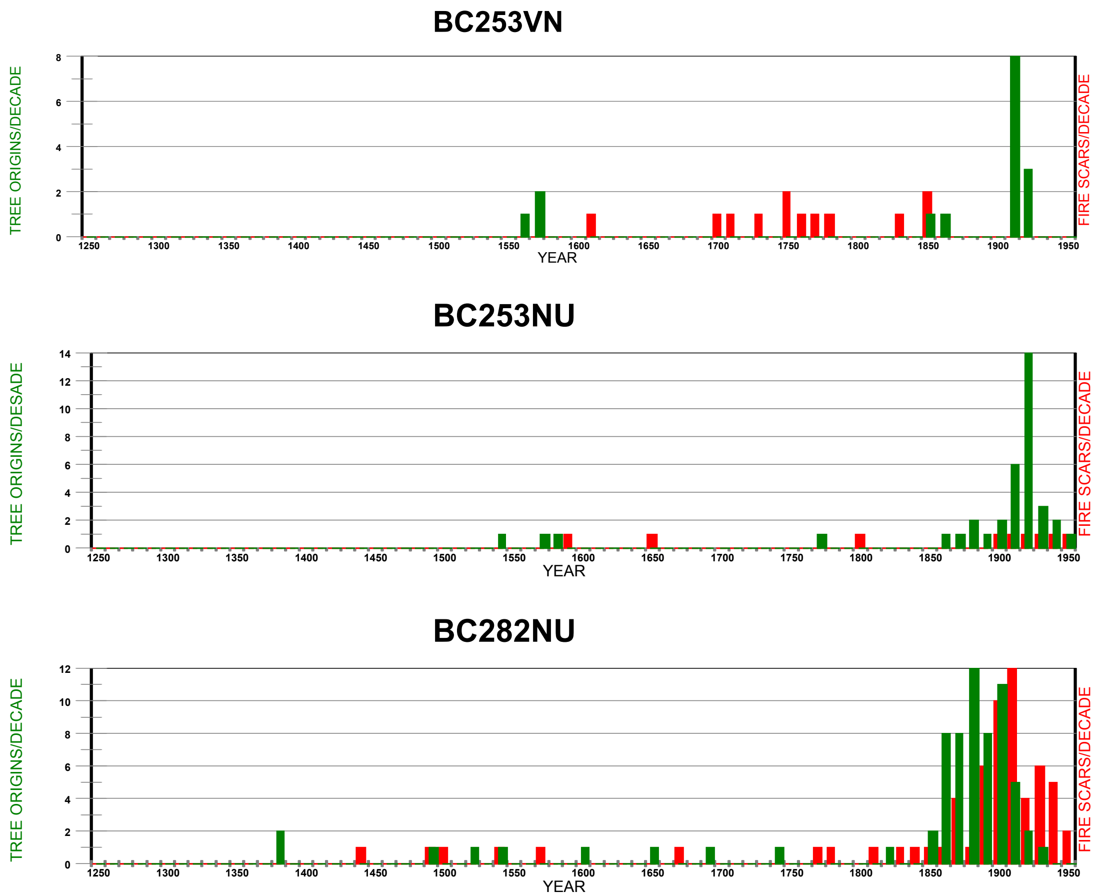


Figure 2.22: Stand Level Tree Recruitment and Fire Scar Frequency in Black Creek, Little River.
Green bars in these histograms represent the number of trees in each plot recruited within each decade. Note the dramatic increase in seedling recruitment after 1850. This pattern is typical of many stands in Little River. Red bars indicate the number fire scars recorded each decade. The top histogram is from the Van Norman (1998) dataset and the bottom two plots were from Little River Watershed Analysis data (1995). Note also the close agreement between the top two histograms produced from data that were collected by the two different teams from the same logging unit (BC253).

The two fire history datasets collected in the Little River watershed (Little River Watershed Analysis, 1995; Van Norman, 1998) both show an increase in the proportion of trees scarred per year from lows in the early 1800s to a peak in the 1850s and then a decrease into the early 1900s (Fig. 2.23). This pattern does not correspond with any local or regional climate trend, i.e., fire frequency reached its peak at the end of the Little Ice Age and *decreased* with the onset of a warming trend (see Chapter 3).

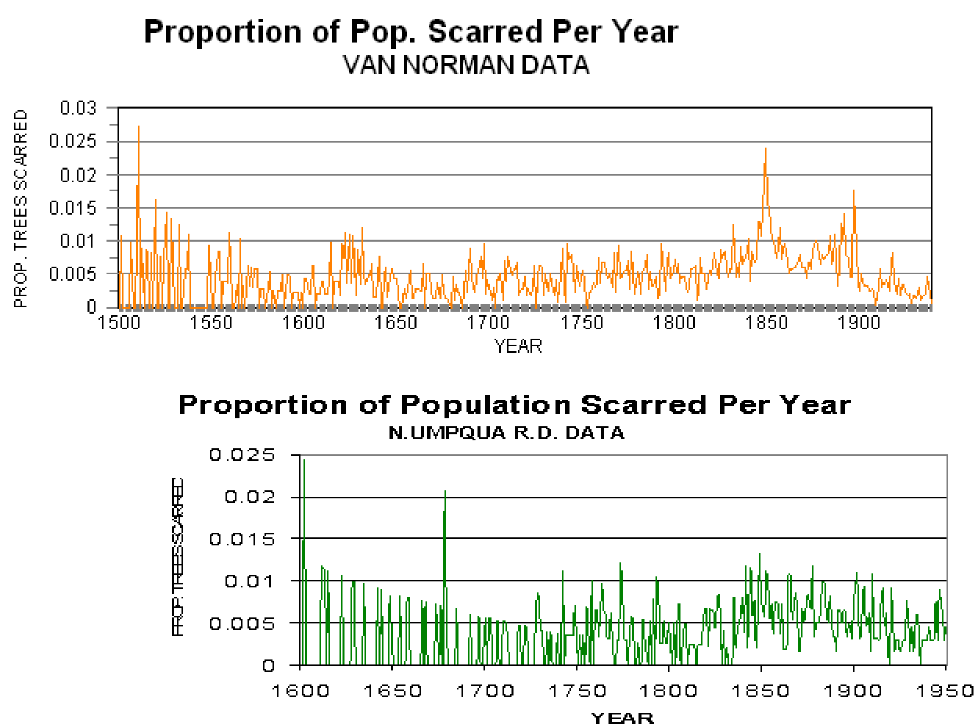


Figure 2.23: Landscape Level Fire Scar Data Little River.
These graphs of data from Van Norman (1998) and the Little River Watershed Analysis (1995) show the proportion of living trees that were scared each year. Note that a peak in the proportions of trees scarred in the mid-1800s is evident in both datasets.

A shift in the proportions of tree species across the landscape also suggests a change in fire intensity. Table 1 presents the results of an analysis of data from Current Vegetation Survey (1995) plots in and near the Little River watershed, and reveals a trend toward recruitment of more fire intolerant "avoider" species (Agee, 1993) (e.g. hemlock, true firs.) in the 1820-1990 time span compared to the 996-1820 period. This analysis suggests a change from a high frequency, low intensity fire regime that favored "resister" species (e.g. Douglas-fir, ponderosa pine) to one that now favors fire avoiders.

TIME SPAN	FIRE RESISTERS	FIRE AVOIDERS
996-1820	70.15%	29.85%
1820-1990	54.17%	45.83%

Table 2.1: Relative Shift in Percentage of Fire Resisters and Fire Avoiders
Tree species that are classified as "avoiders" are less able to survive fires than "resisters" (Agee, 1993). Note the increase in the proportion of fire-intolerant species in the more recent time span. (Data Source: Current Vegetation Survey, 1995)

Not only have the patterns of plant community types across the landscape undergone changes in the last 150 years, but the spatial and demographic structures of their component timber stands have undergone significant shifts as well. The practices of public and private timber interests from resettlement to the present have been coincident with the development of forest stands with historically high stocking densities (Tappeiner et al., 1997; Poage, 2000; Sensenig, 2002). Figure 2.24 references findings from their recent research projects in areas to the north, south and west of Little River. These studies found that stands growing during the Aboriginal Period developed over longer periods and at lower densities, and that post-Euro-American stands are developing at much higher stocking densities. Such dense, post-aboriginal forests (whether planted, naturally regenerated, or in-grown) have contiguous crowns, making them more susceptible to high mortality crown fires (Agee, 1993; WEEP Report, 2003; Perry, et al., 2004).

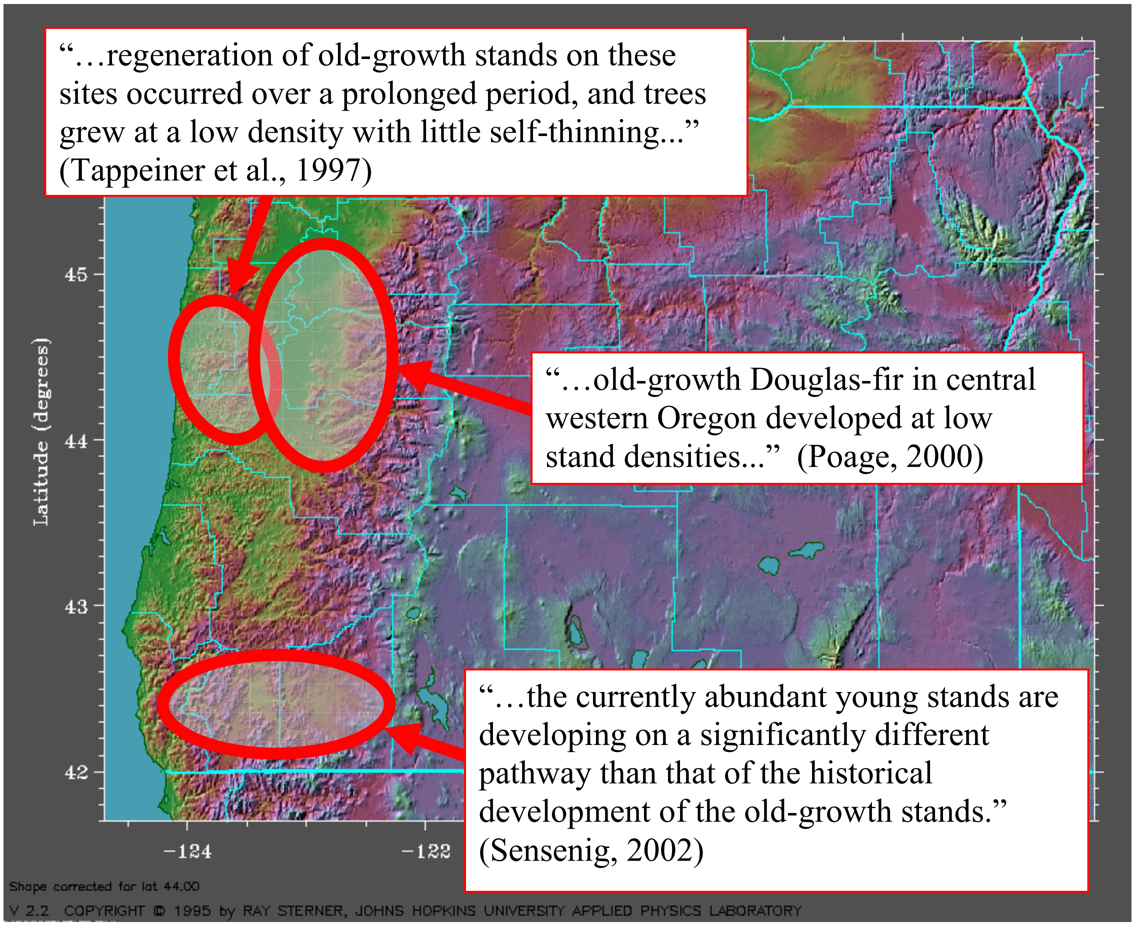


Figure 2.24: Studies of Old-growth vs. Young Stand Densities in SW OR. Locations of stand density studies along with quotes indicating a shift from widely spaced stands to high density, closed canopy stands.

While post-clearcut plantations are even-aged (and often single species), native stands in southwestern Oregon typically have a range of sizes and age distributions. This historic multi-cohort pattern is reflected in the Van Norman (1998) and Little River Watershed Analysis (1995) fire history datasets. When an even-aged stand is defined as one in which 80% of the trees germinate within 3 decades, only 11 of the 180 stands in these two datasets are even-aged (6.1%). Of all even-aged stands, 5 stands originated before the 1820s, while the other 6 formed from the 1830s to the early 1900s. Even when the even-aged criteria are relaxed to 70% recruitment in 5 decades, only 10% of the stands are even-aged -- 7 before 1820, and 11 after. This pattern suggests that even if stands start out as an even-aged cohort, intermediate disturbance from periodic, low intensity fires maintained them as multi-cohort stands.

Not all stands are equally susceptible to fire. Given that the ability of a tree to survive a fire increases with age (Agee, 1993), a shift toward younger stand ages also increases the odds of high intensity events (see Table 2.2 and Fig. 2.27) that may cause high severity crown fires to be propagated across a greater area.

While the age and spatial structure (and therefore fuel structure) of young stands in southwestern Oregon increases their risk of high severity fire, mature stands are also at increasing risk. Because of their open understories and lack of contiguous crowns, historic old-growth forests would have been highly resistant to high mortality crown fires. But during the last century and a half, many late seral stands have become thickly in-grown with a younger, shade tolerant conifer seedling cohort dating from the late 1800s through the present (Fig. 2.25).

Not only are these young, dense, even-aged stands highly susceptible to stand replacing wildfires, (especially plantations: WEEP Report, 2003), increased competition also makes them more prone to pest and disease attack (Goheen, 1995; Little River Watershed Analysis, 1995).

Figure 2.25: Crowded Understory Vegetation Creates Highly Flammable Stands
Dense understory vegetation forms contiguous fuels in the understory of mature timber stands, thereby increasing the risk of high mortality fires. (Photo by the author of a stand in the Little River watershed.)

The size of fires has also apparently increased since resettlement by Euro-Americans. According to an analysis of fire extent conducted in the Little River watershed (Van Norman, 1998), the largest historic fires were calculated to be no larger than about 7,000 acres (2830 ha). This is significantly smaller than recent fires on the Umpqua (see Section 2.6 below), and in southwestern Oregon (e.g. the half million acre (202,350 ha) 2002 Biscuit Fire). This shift toward larger fires is corroborated by the observations of 19th century forester John Leiberg recorded in his report to Congress on forest conditions in southwestern Oregon in 1900:

> The age of the burns chargeable to the era of Indian occupancy can not in most cases be traced back more than one hundred and fifty years. Between that time and the time of the white man's ascendancy, or, between the years 1750 and 1855, small and circumscribed fires were of frequent occurrence. There were some large ones… covering between 4,000 and 5,000 acres.

The fact that Leiberg categorizes four to five thousand acre fires as "large ones" suggests that aboriginal fires were typically much smaller than more recent fires.

2.6 THE 2002 UMPQUA FIRES

The conversion from native forests to even-aged plantations, and the increase in stand densities and fuel loads noted above would be expected to promote larger, more severe fires. That appears to have been the case during the Apple Fire and Tiller Complex (the largest fires ever recorded in the Umpqua River Basin) that burned up to the north and south boundaries of the Little River watershed in 2002.

Maps (Fig. 2.26) and statistics (Table 2.2) from the Umpqua National Forest's Wildfire Effects Evaluation Project (WEEP Report, 2003) tell the ecological story of the 2002 Umpqua fires. Several significant features of those fires emerge from these sources:

- Of the combined 88,686 acres (35,891 ha) within the official fire perimeters, only 35.6% actually burned, leaving a mosaic of burned patches surrounded by unburned forest.

- Of the acreage that did burn, over 50% experienced low intensity fire resulting in the removal of fine fuels and brush – an ecologically and economically beneficial outcome.

- Of the 18.1% of stands that did experience severe fire, 64% were tree plantations; 55% of all plantations burned as stand replacing fires, including 74% of those less than 20 years old.

- The Tiller Complex and the Apple Fire differed in both ignition pattern and spatial pattern. The Tiller Complex was sparked by a cluster of lightning strikes and burned in a patchy pattern, leaving over 70% of the area as unburned matrix. The Apple Fire is a suspected arson fire propagated from a single ignition point which burned over 57% of the forest in larger patches than the Tiller Complex.

Both Umpqua burns were really a cluster of smaller fires. Intensity maps of the 2002 fires (Fig. 2.26) reveal mostly isolated small fires rather than a monolithic blaze, especially in the Tiller Complex. From a landscape perspective, the fires created a cluster of small patches in a forested matrix, not large expanses of charred land with islands of survivors. Showing an even more benign pattern, a third fire, the N. Umpqua Complex (Limpy, Calf, and many more small fires) that burned north and east of the Apple Fire included just over 1000 acres of patchy burns with very little overstory mortality.

The Apple Fire was started from a single ignition at the head of a steep canyon with relatively even-aged native stands, mostly dating from the 1880s (Ray Davis, UNF Wildlife Biologist, pers. comm., 2002) and had larger contiguous patches of high mortality burns than the Tiller Complex, but it also experienced a much higher percentage of low intensity underburns that resulted in the removal of fine fuels and brush – an ecologically and economically beneficial outcome.

Of the acreage within the fire perimeters that actually burned, only 18.1% burned intensely enough to cause total stand mortality and of that, over 50% of the burned acreage experienced low intensity fire. However, post-logging plantations suffered a disproportionately high mortality compared to primary forests (Table 2.2). While only 10.5% of native stands that burned did so at high intensities, the results for plantations were quite different:

> Fifty-five percent of the plantation areas within the 2002 fire perimeter burned as stand-replacement fires… Plantation mortality is disproportionately high compared to the total area that plantations occupied within the fire perimeter. In fact, mortality in plantations accounted for 41 percent of all mortality on the fires, while the plantation area represented only 22 percent of the total area within the fire perimeter. Younger-age plantations were damaged more than the older plantations and the unmanaged forest… In fact, 74 percent of plantations 20 years old or less experienced stand replacement mortality. By comparison, mortality was only 40 to 50 percent in stands 21 to 50 years old. (WEEP Report, 2003)

While plantations make up 23.5% of the total acreage within the fire perimeters, they accounted for almost 55% of all high severity fires.

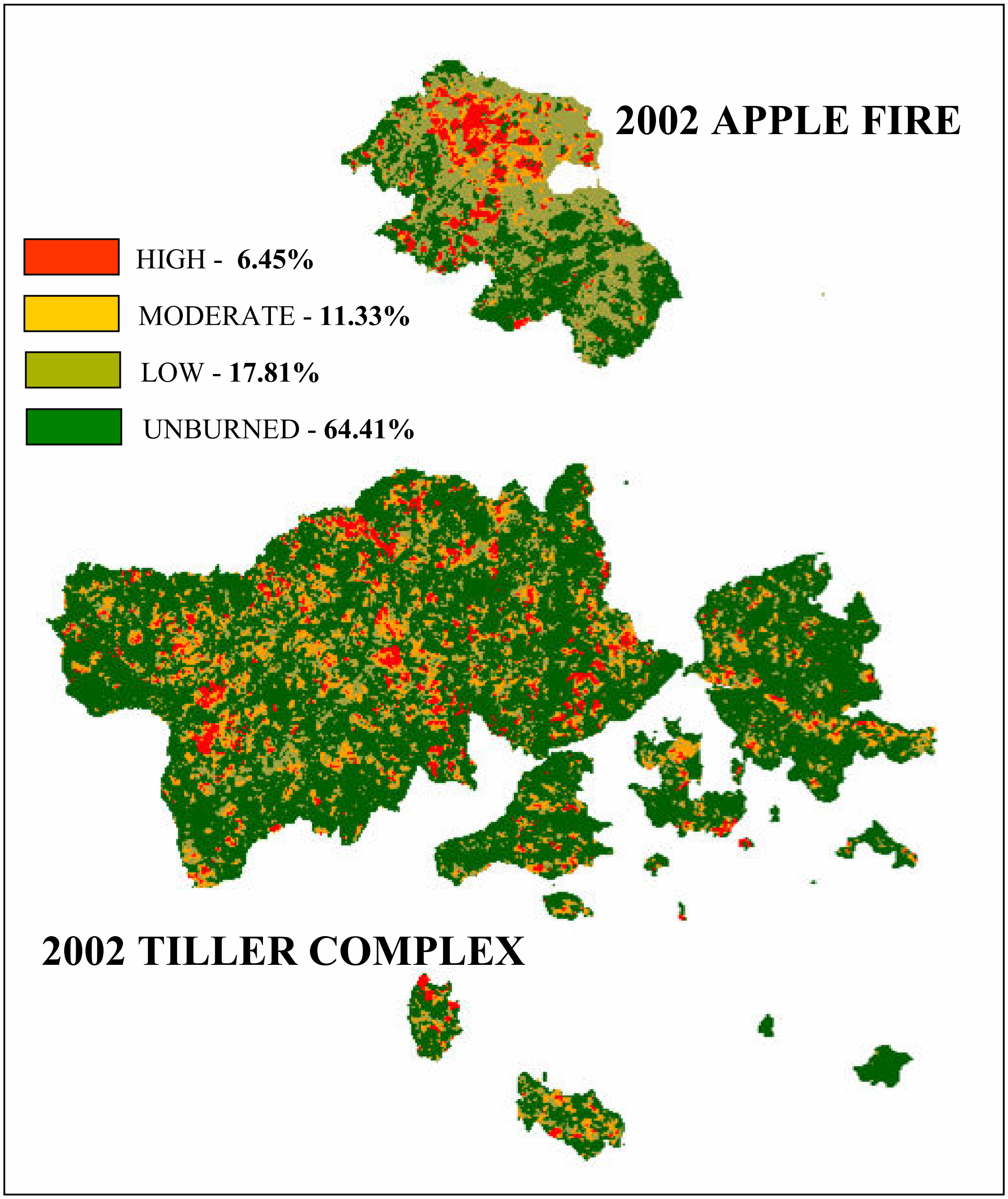


Figure 2.26: Fire Intensity in Apple and Tiller Fires.
Fire intensities were mapped from infrared images analyzed while the fires were burning. Note the proportion of unburned acres (dark green), vs. severely burned acres (red), and the patchiness of the fires. (Source: Wildfire Effects Evaluation Project, UNF. Apr. 2003)

BURN INTENSITY BY STAND TYPE

		Unburned	Low	Moderate	High	Totals	Percents
Apple Fire	**Old Growth**	3,803	3,980	567	375	8,725	46.24%
Umpqua NF	**Plantations**	1,887	1,806	714	1,120	5,527	29.29%
	Other veg	2,361	1,791	208	256	4,616	24.46%
	Totals	8,051	7,577	1,489	1,751	**18,868**	100%
	Percents	**42.67%**	**40.16%**	**7.89%**	**9.28%**	**100%**	
Tiller Complex	**Old Growth**	22,969	3,763	3,079	958	30,769	44.07%
Umpqua NF	**Plantations**	8,749	1,836	2,760	2,008	15,354	21.99%
	Other veg	17,357	2,615	2,719	1,005	23,696	33.94%
	Totals	49,075	8,214	8,558	3,971	**69,818**	100.00%
	Percents	**70.29%**	**11.77%**	**12.26%**	**5.69%**	**100%**	
Apple/Tiller	**Old Growth**	26,772	7,743	3,646	1,333	39,494	44.53%
Combined	**Plantations**	10,636	3,642	3,474	3,128	20,881	23.54%
	Other veg	19,718	4,406	2,927	1,261	28,312	31.92%
	Totals	57,126	15,791	10,047	5,722	**88,686**	100.00%
	Percents	**64.41%**	**17.81%**	**11.33%**	**6.45%**	**100%**	

APPLE/TILLER % HIGH INTENSITY BURN BY STAND TYPE

OLD-GROWTH = 3.38%

PLANTATIONS = 55%

PLANTATIONS < 20 YEARS OLD = 74% (Source: Wildfire Effects Evaluation Project, UNF Apr. 2003)

Table 2.2: Burn Intensities by Stand Types
Percentages of total acreage within the Umpqua fire perimeters in late 2002 based on satellite infrared imagery.

It is also interesting to note that differences in the sources of ignition for the two fires may have lead to different outcomes. As noted above, the Tiller Complex was ignited by a swarm of dry lightning from a storm that swept across a large area in the late summer, while the Apple Fire was human caused from a single point. Differences in ignition patterns may have lead to the differences in landscape pattern evident in Figure 2.26: the Tiller Complex exhibits smaller patch sizes within its perimeter and a smaller proportion of the landscape burned than the Apple Fire. These patterns may have resulted from many lightning strikes creating a series of small fires that acted as natural back-burns against each other (Tiller Complex), rather than one large fire front that can create large “fire weather” events (Apple Fire, Fig. 2.28).

Figure 2.27: Mortality and Management, 2002 Tiller Complex.
Photos of the Tiller Complex taken during the first winter after the 2002 fires. Severity was much greater in plantations (lower photo) than in unmanaged stands (upper photo) (WEEP Report, 2003). (Photos by the author.)

Figure 2.28: Fire Behavior, 2002 Apple Fire.
As noted in Table 2.2, mortality was higher in plantations (foreground) than in primary forest (background). Note the “stripe” of survivors running upslope through the middle of the plantation. This phenomenon is presumably due to mid-scale fire weather creating an insulating downdraft as the fire ran upslope on either side. (Photo by the author.)

Given the number of highly flammable plantations and the high density of fuels that have built up in native stands, the proportion of low to moderate intensity fires experienced by stands in the 2002 Umpqua fires is noteworthy. The relatively few stand replacing events occurring under fuel loads that are beyond historic extremes suggest that aboriginal burns must have been much more benign.

Clearly, the forests of the early 21st century have undergone significant changes since the early 1800s. But how much of this change can be attributed to Euro-

American management and how much to well-documented changes in climate over the same period? The following chapter explores the influence of one important climate variable – precipitation – on fire frequency and tree regeneration during the Aboriginal Phase as compared to the Euro-agrarian Phase.

CHAPTER 3: CHANGES IN THE HISTORIC RELATIONSHIPS BETWEEN PRECIPITATION, FIRE FREQUENCY AND TREE REGENERATION IN THE LITTLE RIVER WATERSHED.

3.1 INTRODUCTION

The pre-industrial landscapes of southwestern Oregon were home to peoples with two very different material cultures (see Chapter 2). Indigenous Americans occupied the land until their culture was destroyed by the diseases and depredations of the Euro-American culture that replaced them in the 19th century. Aboriginal Phase material cultures were heavily based on the mineral, plant and animal resources available to them in their local habitats, while Euro-Americans were able to tap into continental and global markets to convert increasing quantities of exported biomass to capital. Both cultures impacted the structure and function of the region's forests, but the patterns and extents of their influences are poorly documented and more poorly understood, especially during aboriginal times and during the first half of the Euro-agrarian Phase.

Although most fire ecologists agree that both climate and human activity affected pre-industrial fire dynamics in forested ecosystems, they differ in their beliefs about the *significance* of the impact of ancient humans on fire regimes relative to climate (Whitlock and Swetnam, 2002; LaLande, 2004). Were native-set fires restricted to small areas around villages and camps, and of little consequence to climate-driven landscape dynamics (Vale, 2002; Whitlock and Knox, 2002)? Or did they cover large expanses of the terrain, affecting species composition and distribution at both the stand and landscape levels (Lewis, 1993; Pyne, 1982; Boyd, 1986; Blackburn and Anderson, 1993; Robbins, 1997; LaLande and Pullen, 1999; Lewis and Ferguson, 1999; see also citations in Chapter 4)?

In this chapter, I attempt to provide insights into the relative roles of humans and climate on fire frequencies and tree regeneration patterns by first discussing the strengths and weaknesses of regional fire history data, and then by using two tree ring based datasets to examine the historic relationships between precipitation, fire frequency and tree regeneration in the Little River watershed. I compare relationships between pairs of these parameters during two of the three cultural phases described in Chapter 2: the Aboriginal Phase (before 1850), and the Euro-agrarian Phase (1850-1920). Results then are discussed in light of historic documents and current research in other parts of the western US.

3.2 REGIONAL FIRE HISTORY DATA AND THEIR INTERPRETATION

A number of recent studies in western Oregon have attempted to determine historic fire regimes using tree ring data, usually from stumps left in logging units (see below). Virtually all dendrochronological studies, however, are limited in their scope of inference by unavoidable deficiencies in one of more of the data standards discussed in Chapter 2 (precision, accuracy, representativeness, completeness and comparability).

If tree rings are cross-dated (Stokes and Smiley, 1968; Agee, 1993), precision may be quite high. However, owing to the time and expense associated with bringing cores or slabs of trees into the lab for sanding and microscopic analysis, most of the fire history studies from southwest Oregon are based on tree ring counts collected in the field. Thus, one must take the precision of such datasets into consideration when attempting to discriminate between discrete events.

The accuracy of tree ring data is highly dependent on the method used to gather samples. For example, Carl Skinner of the Pacific Southwest Research Station found that when stumps from typical logging units that had been tallied for fire scars were re-cut to near ground level, significantly more scars were recorded (pers. comm., 2004). I have also observed the same phenomenon in oak stands in the Umpqua Valley, noting more scars in the earliest rings of ground-level stumps when all but the lowest temperature fires would kill the young tree. Although Baker and Ehle (2001) recommend including the intervals between tree origin and first fire scar in mean fire interval calculations, data from stumps typically cut at a few feet above ground level would miss these early scars and bias mean fire interval estimates toward longer time spans (Dietrich and Swetnam, 1984).

Most plots for collecting fire history data in the Pacific Northwest are necessarily located in existing recent clearcuts, where tree ring records are most accessible. Therefore they reflect a number of sampling biases based on the economic viability of the timber sale. For example, Douglas-fir (a high market value species) constitutes 82.5% of the stumps sampled in the Van Norman dataset, but only 45.7% of the systematically sampled Current Vegetation Survey (1995) data.

The sample size of a fire history dataset gradually increases over the length of the record. Because the oldest trees on the landscape are usually the rarest, inferences drawn from the earliest years of the dataset are based on the smallest sample sizes. Data from a fire history study conducted in the Little River watershed (Van Norman, 1998) illustrates this issue. When these data are used to calculate the percentage of trees alive in a given year that were scarred that year (Fig. 3.1), it appears that fire was especially widespread through the mid-1500s. However, the sample sizes through those years are extremely small; the cumulative number of trees doesn’t exceed 100 until the year 1505. Thus, a small number of fire scars during the earliest years of a fire history dataset can create the appearance of a large jump in fire frequency, especially when old stumps are specifically chosen because of the presence of fire scars (see below).

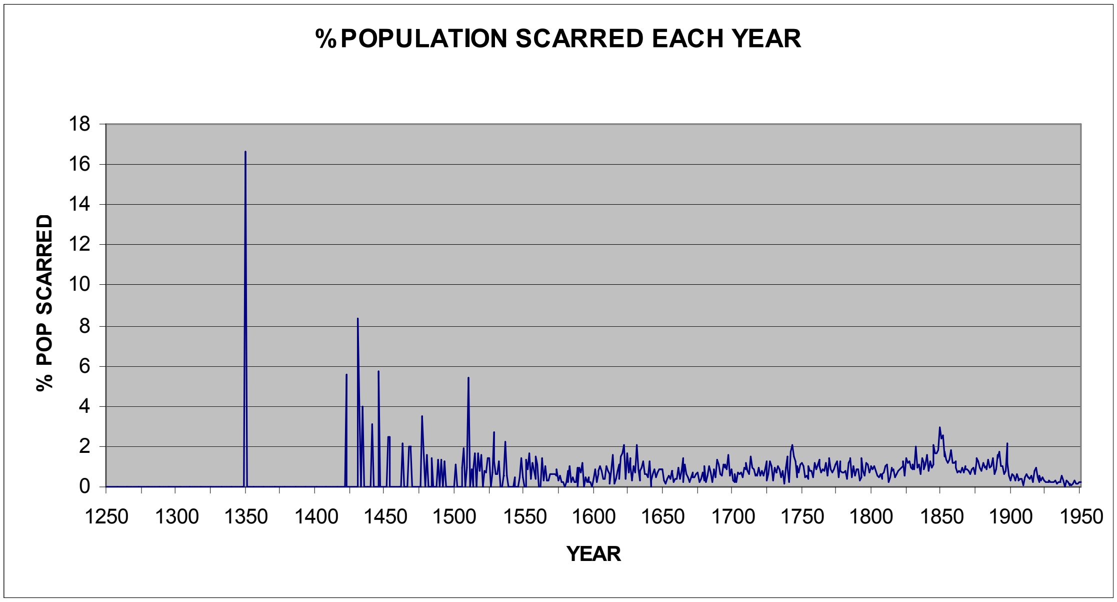


Figure 3.1: Change in Fire Pattern or Sampling Bias?
This graph shows the percentage of living trees that were scared each year. Note that what appears to be widespread fire from the beginning of the dataset into the early 1500s is based on fewer than 100 out of the nearly 3000 stumps in the total dataset. For example, the spike that appears in the mid 1300s is based on one scar in 6 trees, and the cumulative number of trees doesn't pass 100 until 1505. (Data Source: Van Norman, 1998.)

The completeness of the scar record also varies with the intensity of past fires and age structure. As trees mature, their bark thickens which makes them incrementally better able to survive fires of increasing intensity (see caption to Fig. 2.13). Because of this, low intensity fires do less damage to the cambium of more fire resistant older trees, which therefore tend to not record low intensity events. Typical fire injury data will therefore underestimate the occurrence of low intensity fires. High intensity fires, on the other hand, often kill the entire stand, erasing the fire record up to that point, making reconstructions of fire history in the distant past problematic (Weisberg, 1998).

In addition, the completeness of the Van Norman dataset is limited by the age of the youngest merchantable tree (1939), so analyses of Industrial Phase forest demographics are not possible. Moreover, because timber on the gentlest slopes was harvested earliest (and whose stumps are now too decayed for analysis), sampling is biased toward steeper, mid-slope stands which may not be representative of the entire landscape.

Protocols used for fire history data collection may affect the comparability of datasets. For example, the Current Vegetation Survey (1995) and the Little River Watershed Analysis (1995) procedures used uniform sampling radii around plot centers, while the areas sampled in the Van Norman transects varied greatly -- once evidence of a fire (three synchronous scars or 8 trees of the same age) was observed, the recording of data for the same fire was “de-emphasized” leading to plots that varied in size from 1370 m^2 to 6858 m^2 (Van Norman, 1998). Consequently, because the *area* sampled differed in each of the Van Norman plots, comparing these data to the uniformly sampled Current Vegetation Survey and Little River Watershed Analysis dataset must be done with caution.

The choice of plot locations within each clearcut may also skew the data. For example, in the protocol used by the North Umpqua Ranger District (1995), the oldest stumps bearing the most fire scars were chosen as plot centers, thus biasing the dataset toward older trees with proportionally more scars at the beginning of the chronosequence. This also occurs in the Van Norman dataset where stumps for sampling “were chosen based on size, species, and evidence of scars.” (Van Norman, 1998).

These reliability issues with tree ring data suggest that collection protocols must be thoroughly analyzed for bias, and that statistical inference beyond the plot itself must be applied cautiously.

After pointing out many of the same data reliability issues noted above, Weisberg (1998) reviewed a number of fire history studies conducted in the region, including one of the datasets used in this study (Van Norman, 1998). Figure 3.2 is redrawn from Weisberg (1998). Solid lines are periods interpreted by

Weisberg as being marked by “widespread or frequent fire”, while dotted lines are interpreted as periods of “more limited fire”. Brackets mark the beginning of “reliable” fire history records. The gray bar was added to indicate the beginning of Euro-American colonization of western Oregon, circa 1840-1870. Red identifies data from the Little River watershed.

Note the apparent agreement in the datasets that appears to show "widespread fire" occurring from the late 1400s until the late 1500s. As noted above, small sample sizes at the beginning of the chronosequence, and sampling biases toward multi-scarred, old trees call into question the validity of that interpretation, at least for the Van Norman data. However, because the cumulative sample sizes get larger in each successive year, the widespread fires recorded in most of the studies reviewed by Weisberg (1998) during the 1800s are more likely to be an accurate reflection of recent fire history.

The increase in fire frequency during the early 1800s peaking at mid to late century has been attributed to the onset of warmer, drier conditions at the close of the Little Ice Age (Van Norman, 1998; Weisberg, 1998). A number of problems exist with this interpretation.

First, there is little agreement on the precise beginning and end of the Little Ice Age. Pielou (1991) sets the boundaries of the Little Ice Age at 1350-1870, while Whitlock and Knox (2002) use 1650-1890 and Weisberg (1998) uses 1690-1840. Thus it is possible to choose dates that best fit the data.

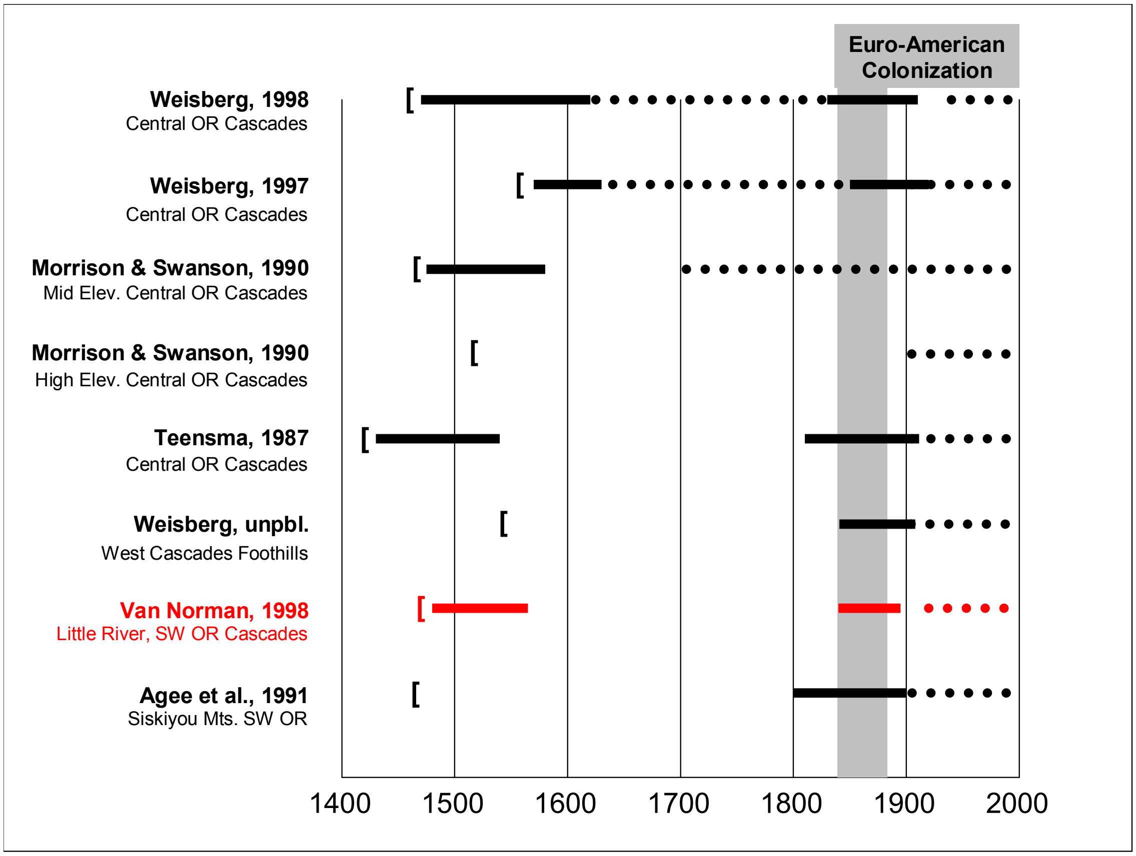


Figure 3.2: Regional Fire Histories as Interpreted By Weisberg (1998). Graphic representation of 8 fire history studies from the Cascades of western Oregon. The top six studies are from north of Little River and the bottom one is from south. Red identifies data from the Little River watershed. Solid lines are periods interpreted by Weisberg (1998) as being marked by "widespread or frequent fire" while dotted lines are interpreted as periods of "more limited fire"; brackets mark the beginning of "reliable" fire history records. The gray bar was added to indicate the beginning of Euro-American colonization circa 1840-1870. Redrawn from Weisberg (1998).

Second, although the cooler conditions of the Little Ice Age are well documented world-wide, the intensity of the cooling and its effect on precipitation may have varied from place to place. For instance, precipitation reconstructions based on tree ring analyses in Washington, Oregon and Northern California "…do not reveal long-term changes in mean conditions" from the mid 1600s to the present (Graumlich, 1985). It may be that the mitigating effects of the Pacific Ocean buffered the Pacific Northwest from more severe effects felt in interior and eastern regions of the continent.

Third, the Van Norman fire history dataset as well as the Little River Watershed Analysis (1995), and Current Vegetation Survey (1995) datasets (Fig. 2.21) indicate that rather then a decrease in tree recruitment that would be expected with the onset of warmer, drier conditions associated with the end of the Little Ice Age, tree recruitment *increased* significantly. Moreover, the Van Norman dataset records a *decrease* in fire frequency (Fig. 3.3) rather than the increase that would be predicted during the post-Little Ice Age warming trend.

Fourth, the end of the Little Ice Age in the mid to late 1800s coincides with the arrival of Euro-Americans to the Northwest, making it difficult to sort out climate responses from human impacts.

In attempts to gain insights into the relative impacts of humans and climate on forest demographics and fire dynamics in the Little River watershed, the remainder of this chapter compares precipitation, fire frequency, tree recruitment, and cultural histories during the Aboriginal versus the Euro-agrarian cultural phases.

3.3 GENERAL HYPOTHESES

Whitlock and Knox (2002) suggest that “Anomalous fire regimes, not predicted or explained as a result of prevailing climate or vegetation conditions, would point to human agencies.” Thus, if native-set fires were frequent, widespread, and systematic (Lewis and Ferguson, 1999), then the climate signal should be obscured, and fire, tree recruitment and precipitation should all be uncorrelated. If, on the other hand, climate was a major driver of fire patterns in the aboriginal forests of Little River, then one would expect to see three effects.

First, a greater number of fires should occur west of the Cascade Range during years of below average precipitation (a negative correlation) because of increased fuel desiccation (Whitlock and Knox, 2004). Since most non-human ignitions in the western US are caused by late summer storms that generate dry lightning accompanied by little precipitation (Rorig and Ferguson, 1999), drought years commonly experience lightning activity when fuels are driest. Indeed, preliminary data (Holmes and Krider, 2004) suggest that “The lower the rain volume per flash, the more efficient the lightning production by the storm.” Wetter conditions in the spring, and earlier autumn rains during high precipitation years should narrow the window during which fuels would be susceptible to ignition from dry lightning.

Second, precipitation fluctuations should be reflected in tree regeneration patterns. Whitlock and Knox (2002) suggest that in forests west of the Cascades, greater seedling establishment should occur during years of higher than average precipitation (a positive correlation) because of higher soil moisture levels prevailing during more of the growing season. Alternatively, in the arid forests east of the Cascades and in the southwest US, the growth of fine fuels during wet years would be expected to promote surface fires during the following dry season which would eliminate much of the new seedling cohort (Baisan and Swetnam, 1990; Swetnam and Betancourt, 1998; Whitlock and Knox, 2002; Norman and Taylor, 2003).

Third, in the absence of frequent ground fires that systematically remove regenerating seedlings, one would expect to see large cohorts of trees regenerated after years of frequent fires (a positive correlation). This is in line with the prevailing hypothesis among foresters in the Pacific Northwest that wildfires create a mosaic of stand-replacing events that become even-aged patches as a result or post-fire tree regeneration (Pickett and White, 1985; Oliver and Larson, 1990; Bonnicksen, 2000).

General hypotheses can be stated as follows:

H1: Fire occurrence is not correlated with climate from 1590 to 1820 but is correlated from 1850 to 1950.

H2: Tree regeneration is not correlated with climate from 1590 to 1820 but is correlated from 1850 to 1939.

H3: Tree regeneration is not correlated with fire occurrence from 1590 to 1820 but is correlated from 1850 to 1939.

3.4 DATA AND METHODS

3.4.1 The Graumlich and Van Norman Datasets

Two datasets derived from tree rings in the Little River watershed were used to test these hypotheses. As a climate indicator, I used historic precipitation records interpreted from tree rings by Graumlich (1985), and fire scar dates and tree age records from Van Norman's 1998 fire history study. Paired comparisons of these datasets are displayed in Fig. 3.3.

In her reconstruction of precipitation history, Graumlich (1985) compared tree ring widths from 41 sites in Washington, Oregon and northern California with recorded precipitation data starting in 1899 to develop a precipitation indexing algorithm. She then extrapolated precipitation history back through the prehistoric portion of the chronosequence. In the analyses below, I use her reconstruction of precipitation history for Red Butte near the geographic center of the Little River watershed (blue lines, Fig. 3.3a and b) based on 26 increment borings dating back to 1590 collected from Douglas-fir trees near timberline.

Fire scar and tree recruitment data were obtained from a dataset collected by Van Norman (1998) in the Little River watershed. Although tree ring records were not cross-dated, the counts were made in one season by two people, so the consistency of the data is deemed to be quite high (compared, for example, to the LRWA data that were collected by numerous Forest Service employees from the N. Umpqua Range District fire shop during their down time).

Recruitment frequencies were used with no data transformations, but fire scar data were converted from simple yearly frequencies to percentages of trees scarred per year (see Fig. 3.1 and 3.3a and c). Tree recruitment data were derived from ring counts of 3166 conifer stumps in clearcut logging units (Table 3.1). Species composition is as follows: 82.47% Douglas-fir, 6.25% western hemlock, 3.67% incense cedar, 3.25% western red cedar, 1.90% sugar pine, 1.26% grand fir, and less than 1% each of subalpine fir, noble fir, ponderosa pine and western white pine. All of these species have normal life spans that exceed the approximately 400 year length of my study, and therefore should not bias inferences drawn from these data.

Although Van Norman recorded pitch rings along with fire scars in her injury data, I use only fire scars in the following analyses because of the variety of other mechanisms besides fire that can cause pitch rings to form. The percentages of a total of 3276 fire scars found in each species are: 86.94% Douglas-fir, 5.49% incense cedar, 2.59% western hemlock, 2.23% western red cedar, 1.16% grand fir, and less than 1% each of sugar pine, ponderosa pine subalpine fir and noble fir. Again, the great majority of scars were recorded in Douglas-fir stumps, so differences in species scarring potential probably add little bias to the dataset.

SPECIES	% TREE AGE DATA	% FIRE SCAR DATA
Douglas-fir	82.47	86.94
Western Hemlock	6.25	2.59
Incense Cedar	3.67	5.49
Western Red Cedar	3.25	2.23
Sugar Pine	1.90	0.73
Grand Fir	1.26	1.16
Subalpine Fir	0.63	0.36
Ponderosa Pine	0.25	0.46
Noble Fir	0.19	0.06
Western White Pine	0.03	0

Table 3.1: Species Composition and Fire Scar Percentages from Van Norman (1998) Data.
The Van Norman tree age dataset is derived from ring counts of 3166 conifers from clearcut logging units, the great majority of which were Douglas-fir. A total of 3276 fire scars were recorded from these stumps, again largely from Douglas-firs.

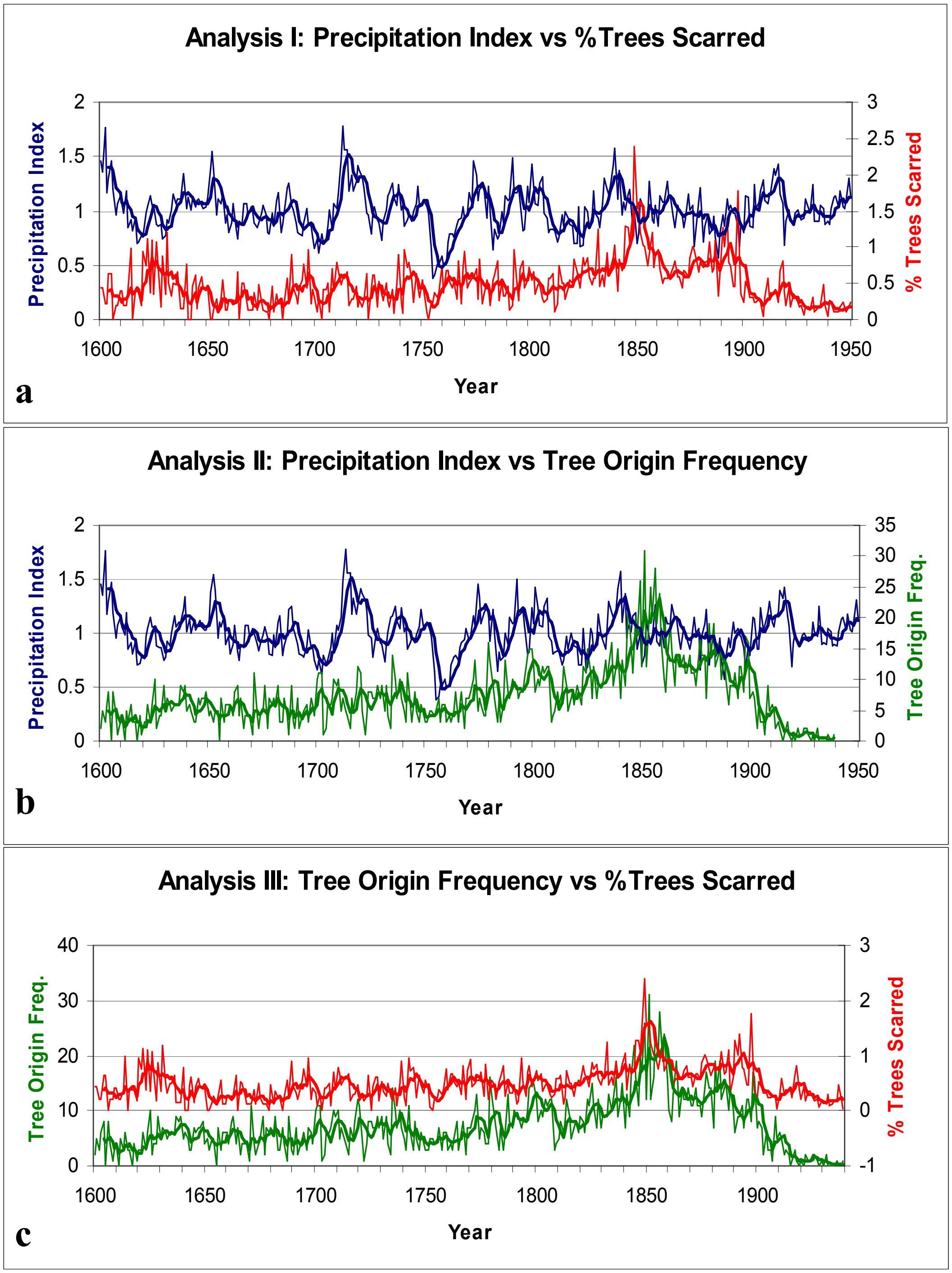


Fig. 3.3: Comparisons of Precipitation Index, Tree Recruitment and Fire Scar Data.

Paired comparisons of precipitation and percent fire scars (Fig. 3.3a, Analysis I), precipitation and tree recruitment (Fig. 3.3b, Analysis II), and tree origin frequencies and percent fire scars (Fig. 3 c, Analysis III), all with 5 year moving average trend lines.

The bias toward Douglas-fir in data collected from commercial logging units as compared to the systematically sampled Current Vegetation Survey data (1995) (see Table 2.1) actually serves to improve data accuracy by minimizing the contribution of records from other tree species with potentially different scarring tendencies.

3.4.2 Statistics

Raw data obtained from the public domain were organized into spreadsheets, and divided into time series spanning the aboriginal Phase (1590 to 1820) and the Euro-agrarian Phase (1850-1950). Simple linear regression analyses were then used to look for trends in precipitation vs. tree regeneration, precipitation vs. the percentage of trees scarred by fire, and the percentage of trees scarred vs. tree regeneration. Scatter plots are displayed below along with their correlation coefficients (r) and the probabilities that their best fit slopes are not zero (p).

In addition, Systat analytical software (Systat Software Inc., 2004) was used to test regression models using both precipitation and fire as explanatory variables to look for interactions between these two variables and tree regeneration response. Systat was also used to evaluate the degree of autocorrelation of the time series in each cultural phase, and to assess the cross correlation between percentage of trees scarred and tree regeneration.

3.5 ANALYSIS I: THE RELATIONSHIP BETWEEN PRECIPITATION AND FIRE BEFORE AND AFTER EURO-AMERICAN RESETTLEMENT

The beginning date for this analysis (1590) is determined by the earliest record in the Graumlich (1985) precipitation dataset. I chose 1820 to end the Aboriginal Phase (see Chapter 2) because (with the exception of epidemic disease) there is little evidence of direct European influence before that time. I chose 1850 to begin the Euro-agrarian Phase because the first homestead in the Little River watershed was established in 1851, and 1950 to end this phase because of the widespread institution of mechanized logging and coordinated fire suppression programs at about that time (Little River Watershed Analysis, 1995).

3.5.1 Hypotheses and Tests: Precipitation vs. Fire Frequency

In terms of the available datasets, a testable hypothesis can be stated as follows:

> *H1a: Van Norman fire scar frequencies are temporally correlated with Graumlich's Precipitation Index values after 1850, but not before.*

Because the number of scars recorded in a given year is partly a function of the number of trees in the dataset that were alive that year and partly a function of fire frequency, I calculated the *percentage of living trees scarred each year* ($S_{\%}$), by dividing the number of trees scarred in a given year (S) by the cumulative number of sampled trees (T) that were alive and potentially exposed to fire during that year ($S_p = S/T*100$). This percentage was then used as a response (dependent) variable, with Graumlich's Red Butte Precipitation Index (PI) as the explanatory (independent) variable in a simple linear regression analysis.

> *H1b: Van Norman fire scar frequencies are temporally correlated with Graumlich's Precipitation Index values for the following year after 1850, but not before.*

Because fires can occur in the spring and early summer during the growing season, or in the late summer and early fall before winter rains set in, their frequency may be affected by the precipitation index of the following year as well as that of the current year. Therefore, in order to assess the effect of precipitation on fire scar frequency after tree growth had ceased, I again used the percentage of trees scarred as the response, but used the following year's precipitation index as the explanatory variable.

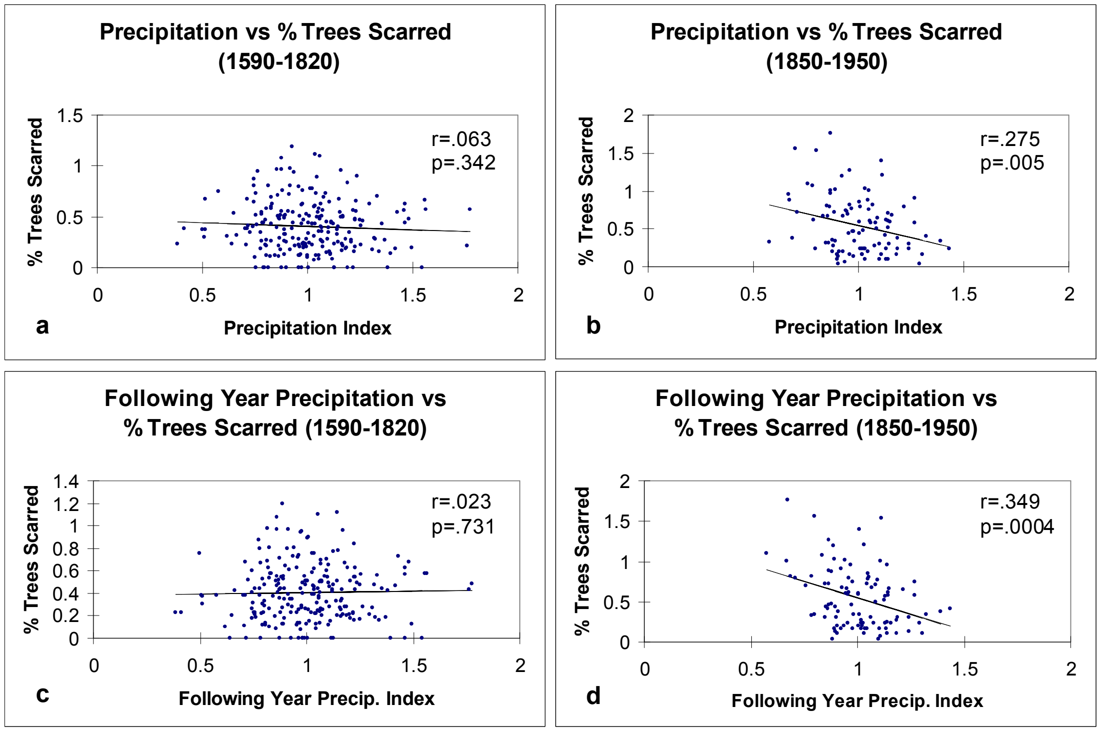


Figure 3.4: Precipitation vs. Percentage of Trees Scarred per Year. Scatters on the left (a and c) are Aboriginal Phase, those on the right (b and d) are Euro-agrarian Phase. As hypothesized, no correlations are observed from 1590 to 1820. However, note that the significant negative correlation (p=.005) observed in post aboriginal times becomes stronger (p=.0004) in the following year. This suggests that precipitation may influence fire frequency both during the growing season and after growth has stopped if early rains shorten the fire season.

3.5.2 Results of Analysis I: Precipitation and Fire Frequency are Not Correlated Before Euro-American Resettlement

Results of this analysis support *H1*. Fire scar frequencies from 1590 to 1820 show no relationship to precipitation (Fig. 3.4a and c) during the Aboriginal Phase. However, from 1850 to 1950 a significant negative correlation ($p = 0.005$) exists between climate and scar frequency during the current year (Fig. 3.4b), and the relationship between fire and the following year's precipitation is considerably stronger ($p = 0.0004$). These results suggest that in post-aboriginal times, high rainfall years are associated with fewer fires than low rainfall years, and vice versa.

3.6 ANALYSIS II: THE RELATIONSHIP BETWEEN PRECIPITATION AND TREE RECRUITMENT BEFORE AND AFTER EURO-AMERICAN RESETTLEMENT

The span of this analysis (1590 to 1939) is determined by the earliest record in the Graumlich precipitation dataset, and by the most recent record in the Van Norman fire history dataset. For the same reasons noted above, I again chose 1820 to end the aboriginal period, and the 1850 to 1939 time span to look at the relationship between fire and tree recruitment during the Euro-agrarian Phase.

3.6.1 Hypotheses and Tests: Precipitation vs. Tree Recruitment

For this analysis, hypotheses can be stated as follows:

> *H2a: Van Norman tree origin frequencies are temporally correlated with Graumlich's Precipitation Index values after 1850, but not before.*

In this regression, the response variable is Van Norman's Origin Frequency (O_f). Again, Graumlich's Red Butte Precipitation Index (PI) functions as the explanatory variable in a simple linear regression.

> *H2b: Van Norman tree origin frequencies are temporally correlated with Graumlich's Precipitation Index values for the previous year after 1850, but not before.*

To assess the possible effects of the previous year's precipitation on tree origin frequencies of the following year, I used the PI from the prior year as the explanatory variable.

H2c: *Van Norman tree origin frequencies are temporally correlated with Graumlich's Precipitation Index values for the following year after 1850, but not before.*

To assess the possibility that the following year's precipitation had an effect on the survival of trees that germinated during the previous year, I used the next year's PI as the explanatory variable.

3.6.2 Results of Analysis II: Precipitation and Tree Recruitment are Not Correlated Before Euro-American Resettlement

H2 is supported by the data from the Aboriginal Phase: tree recruitment from 1590 to 1820 is again uncorrelated with yearly precipitation (Fig. 3.5a, c and e). The results from the Euro-agrarian Phase, however, were only marginally significant from 1850 to 1939, revealing a *negative* correlation between precipitation and recruitment, i.e., higher precipitation years are associated with *fewer* tree origins (Fig. 3.5b and d). Regeneration cohort sizes are weakly correlated with precipitation during their origin year ($p = .030$), and in the previous year ($p = .029$). The effects of the following year's precipitation on regeneration success, however, was not significant ($p = .280$).

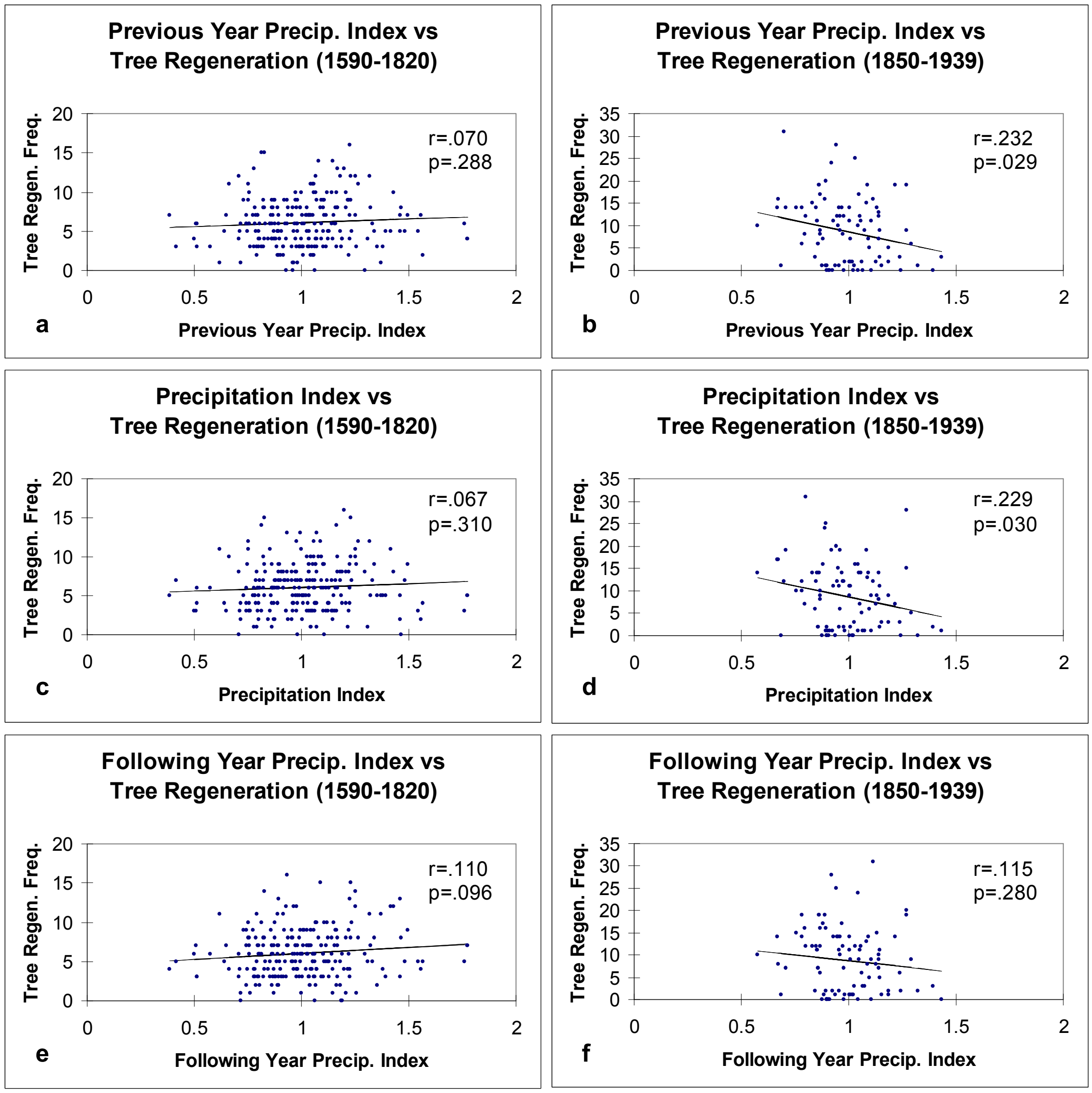


Figure 3.5: Precipitation vs. Tree Origin Frequencies per Year.
Scatters on the left (a, c and e) are Aboriginal Phase, those on the right (b, d and f) are Euro-agrarian Phase. The lack of correlations between precipitation and tree regeneration from 1590 to 1820 support Hypothesis 2. After 1850, note the weak negative correlations between tree regeneration and precipitation during the current year ($p = .030$) and precipitation during the previous year ($p = .029$). Precipitation during the following year, however, is *not* significantly correlated with seedling survival frequency ($p = .280$).

3.7 ANALYSIS III: THE RELATIONSHIP BETWEEN FIRE AND TREE RECRUITMENT BEFORE AND AFTER EURO-AMERICAN RESETTLEMENT

The following analysis examines tree regeneration following fires during the Aboriginal Phase compared to the Euro-agrarian Phase. The span of this investigation is the same as that used in Analysis I, and was delineated for the same reasons.

3.7.1 Hypotheses and Tests: Fire Frequency vs. Tree Recruitment

Hypotheses:

> *H3a: Van Norman tree origin frequencies are temporally correlated with Van Norman fire frequencies after 1850, but not before.*

The explanatory variable in this regression is the percentage of trees scarred per year ($S_{\%}$) and the response variable is origin frequency (O_f).

> *H3b: Van Norman tree origin frequencies are temporally correlated with Van Norman fire frequencies from the previous year after 1850, but not before.*

Again, the explanatory variable is $S_{\%}$, but the response is the O_f of the following year.

3.7.2 Results of Analysis III: Fire and Tree Recruitment are Not Correlated Before Euro-American Resettlement

As in Analyses I and II, no correlation is evident between fire scar frequency and tree recruitment in the years from 1590 to 1820 (Figs. 3.6a and c). From 1850 to 1939, however, dramatic positive correlations exist between fire scar frequencies and tree origins during the same year ($p = 5.72 \times 10^{-11}$; Fig. 3.6b), and during the following year ($p = 2.96 \times 10^{-15}$; Fig. 3.6d).

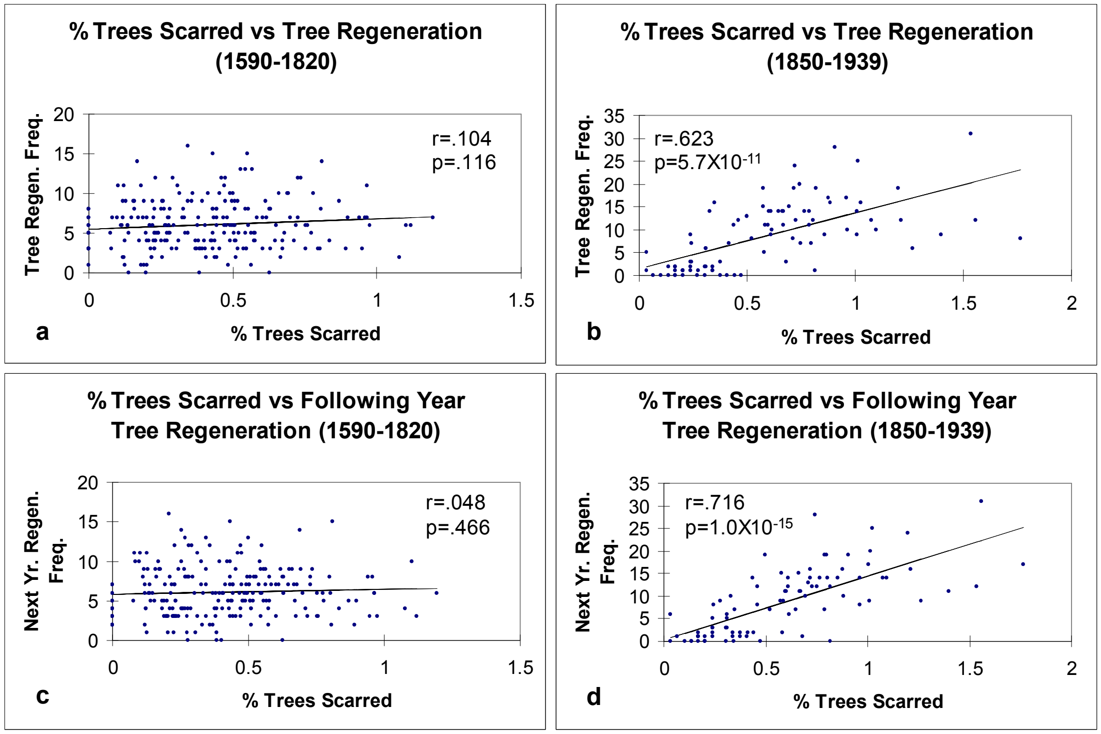


Figure 3.6: Origins per Year vs. Percentage of Trees Scarred per Year. Scatters on the left are Aboriginal Phase, those on the right are Euro-agrarian Phase. During aboriginal times (3.6a and 3.6c), fire frequency does not appear to be linked to tree recruitment during the same or following year (p=.116 and .466 respectively). However, recruitment is strongly associated with high-frequency fire years after Euro-American resettlement during the current year ($p=3.1X10^{-11}$, Fig. 3.6b) and during the following year ($p=1.0X10^{-15}$; Fig. 3.6d).

3.8 AUTOCORRELATION PATTERNS

The degree of serial correlation in the three time series used in the above analyses (Fig. 3.7, 3.8, 3.9) was also assessed using autocorrelation plots. Assessing the degree of autocorrelation is an important consideration when evaluating the validity of regression analyses such as those presented above (Ramsey and Schafer, 1997). Autocorrelation plots graph the likelihood that any measurement will be similar to the one before it, and therefore not an independent sample. If response (dependent) variables lack independence, a basic assumption underlying regression analysis is violated.

Autocorrelation plots can also point the way toward further time series analyses. Since the bar at each lag (year) estimates the likelihood that a measurement taken at any time will be similar to the measurement that many years ago, periodicities in the series can reveal themselves and suggest further analysis.

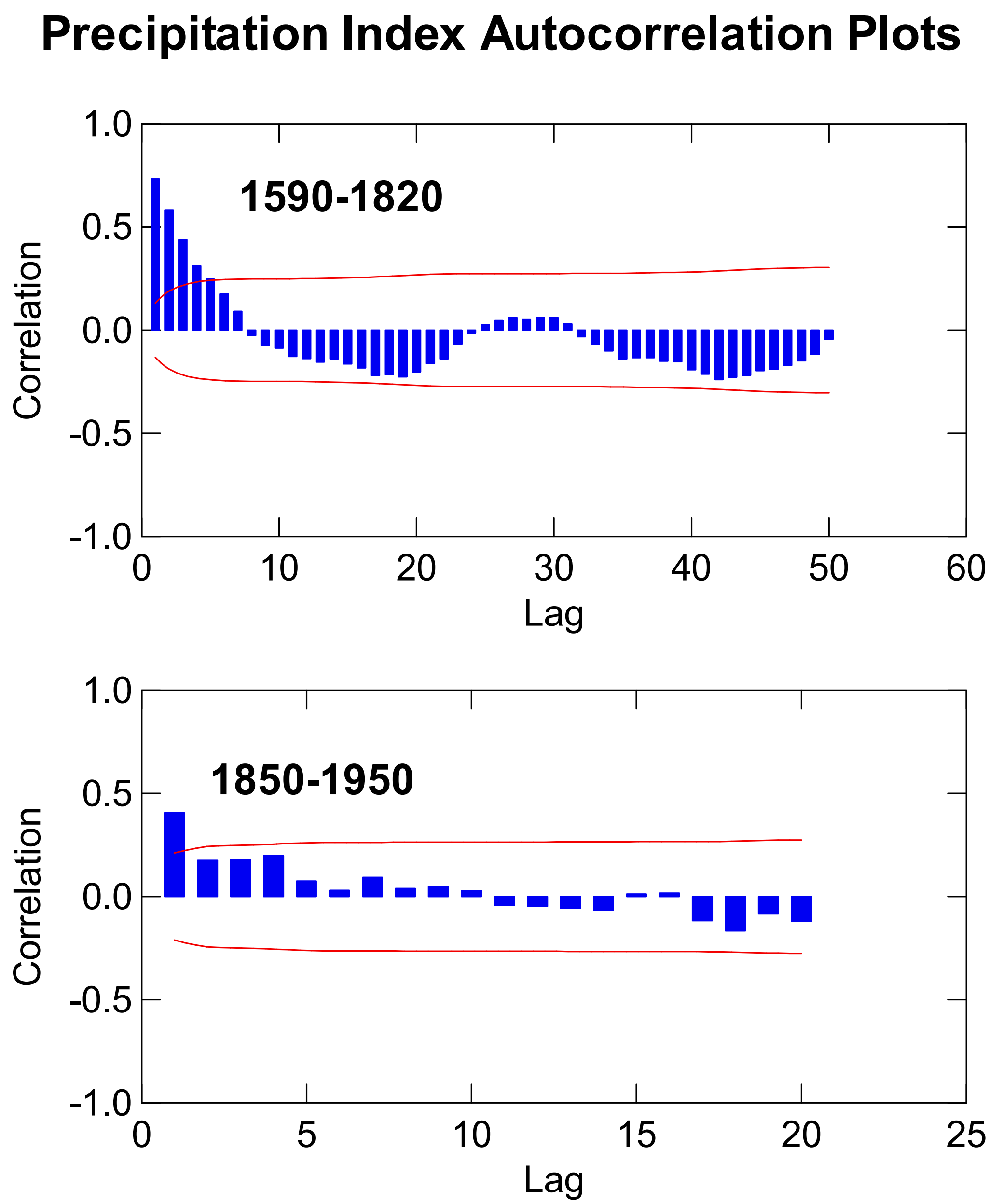


Figure 3.7: Autocorrelation Plots For Precipitation Index During the Aboriginal Phase vs the Euro-agrarian Phase
These plots graph the likelihood that any precipitation measurement will be similar to those at a given number of years (lags) previous. Red lines indicate 95% confidence intervals. Note the strong autocorrelation with measurements from the previous four to five years during the Aboriginal Phase (top panel), compared to the Euro-agrarian Phase (bottom panel). Since these precipitation series are always used as the explanatory variables, the significant serial correlation should not affect the strength of the regression inferences. Note also the approx. 25-28 year periodicity in the 1590-1950 series that appears to shorten by a decade or so in the 1850-1950 series.

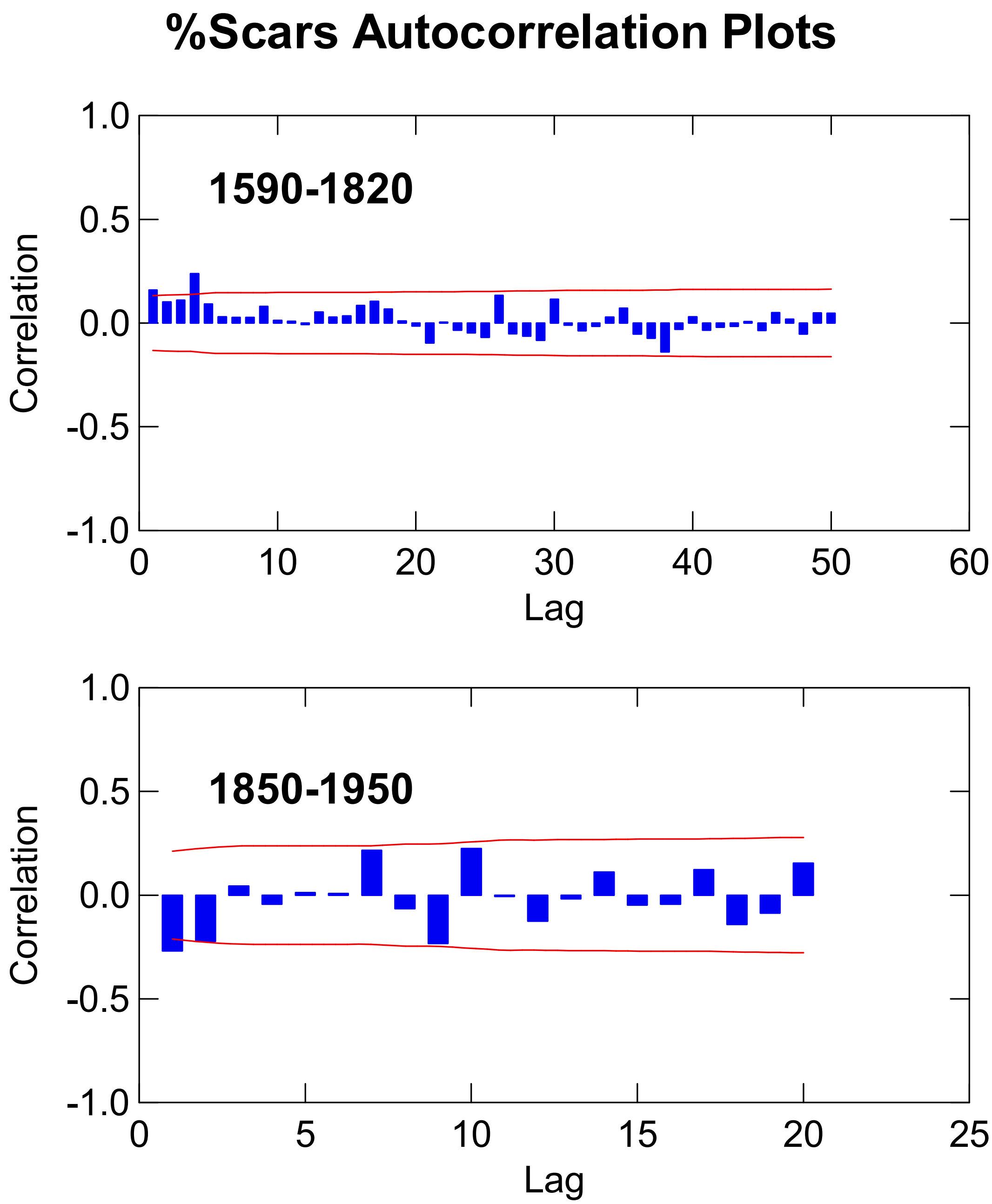


Figure 3.8: Autocorrelation Plots For %Trees Scarred Each Year During the Aboriginal Phase vs the Euro-agrarian Phase
These plots graph the likelihood that any fire scar percentage will be similar to those at a given number of years (lags) previous. Red lines indicate 95% confidence intervals. Data from 1850-1950 have been differenced to remove bias due to the strong downward trend in the series (Fig. 3.3). Note that the amount of autocorrelation in both series is minimal.

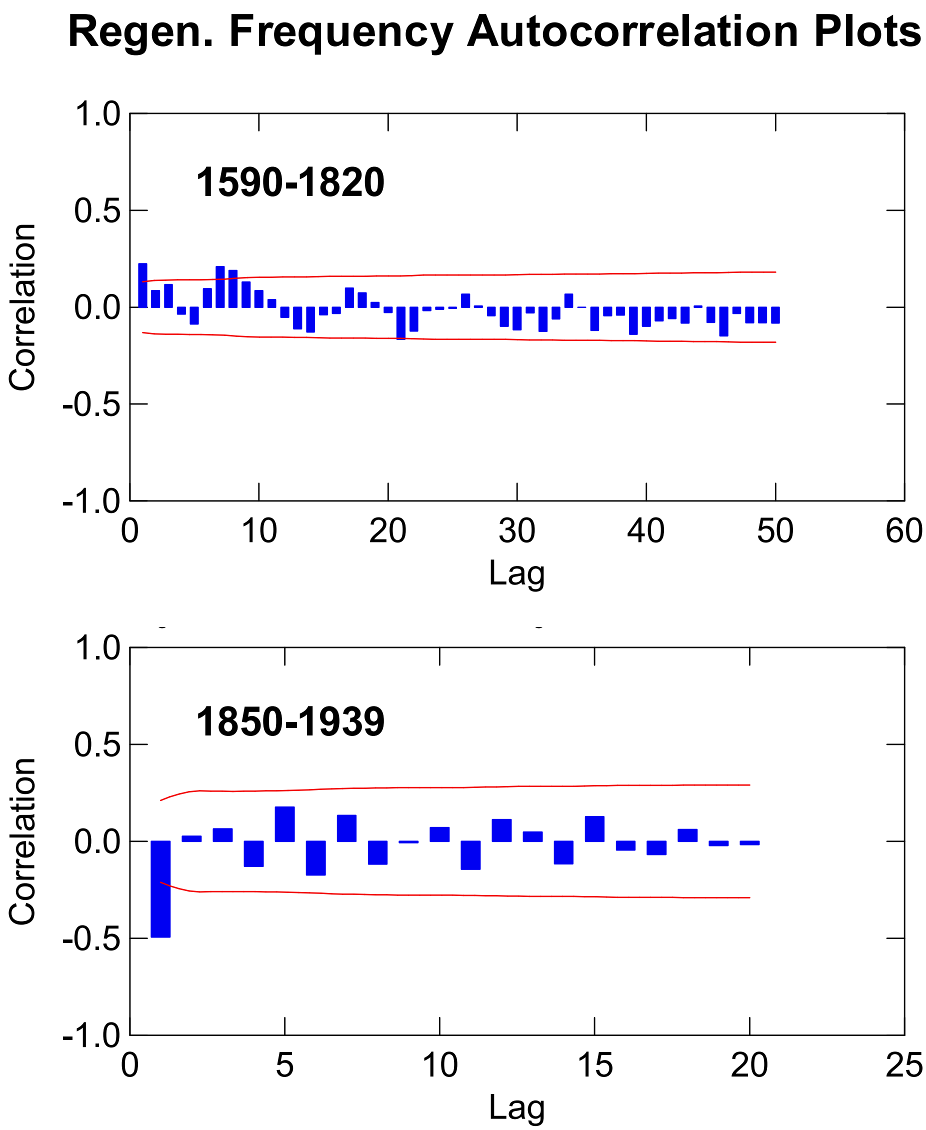


Figure 3.9: Autocorrelation Plots For Tree Regeneration Frequency During the Aboriginal Phase vs. the Euro-agrarian Phase
These plots graph the likelihood that any regeneration frequency will be similar to those at a given number of years (lags) previous. Red lines indicate 95% confidence intervals. Data from 1850-1939 have been differenced to remove bias due to the strong downward trend in the series (Fig. 3.3). Note the significant positive correlation with the previous year's regeneration during the Aboriginal Phase (top panel) reverses to a negative correlation during the Euro-agrarian Phase (bottom panel). Note also that the apparent 7-8 year periodicity in the 1590-1820 series is absent in the 1850-1939 series.

3.9 DISCUSSION

3.9.1 Effects of Precipitation on Landscape Dynamics

Results of all three of the analyses presented above are in broad agreement: no statistically significant correlations between any of the parameters are evident during the Aboriginal Phase, while all of the trends that emerge after Euro-American resettlement are moderately to highly significant. However, it is important to bear in mind the limitations of the datasets noted earlier in this chapter. The Van Norman data were *not* cross-dated and therefore are likely to have some degree of imprecision, especially in the earliest centuries of the record. This may contribute to the wide scatter around some of the regression lines, especially Fig. 3.5. Although the Graumlich data *are* cross-dated, variability in patterns of wet and dry years, especially extremes, is greater during the Aboriginal Phase compared to the Euro-agrarian Phase, and thus may have obscured underlying trends in the regressions from the earlier phase.

Table 3.2 lists the differences in the variances of the datasets in each of the two cultural phases. Note that while the variance in precipitation index data is highest during aboriginal times, this may be somewhat mitigated by the sample variances for fire scar and tree regeneration data that are *lowest* during that period. Moreover, when the precipitation index values in the 1590-1820 series that are outside the range of the 1850-1950 data are removed, Aboriginal Phase scarring and regeneration still show no significant response to precipitation. Thus the lack of correlations between parameters from the Aboriginal Phase, and their presence during the Euro-agrarian Phase, are more likely to reflect causal relationships rather than statistical error.

MEANS / VARIANCES	**1590 to 1820**	**1850 to 1950**
Precipitation Index	1.003 / 0.050	1.002 / 0.026
% Trees Scarred	0.782 / 0.149	0.743 / 0.275
Tree Regeneration	6.061 / 9.675	8.722 / 51.798

Table 3.2: Sample Means and Variances During the Aboriginal Phase (1590-1820) vs. the Euro-agrarian Phase (1850-1950)
Note that sample variance for precipitation is higher during aboriginal times, but that variances for fire scar and tree regeneration data that are higher after Euro-American resettlement.

The results of comparisons between historic precipitation and fire frequencies reported in Analysis I (Fig. 3.4) support the hypothesis that fire was not correlated with precipitation before 1820. During the Euro-agrarian Phase, on the other hand, these variables are significantly negatively correlated ($p = .005$ for current year and $p = .0004$ for following year).

The scatter around the regression lines (Fig. 3.4b and d) suggests that (1) the lack of cross-dating of the Van Norman dataset noted above has added extra noise to the system, and/or (2) other variables (such as temperature) may be interacting with precipitation to partly obscure the simple fire response. The latter seems likely, as recent work on climate change in the Pacific Northwest (McKenzie et al., 2004) found a strong effect of yearly temperature and precipitation on area burned in Oregon from 1916 to 2002. The weak autocorrelation in the scar data series (Fig. 3.8) is unlikely to have significantly affected the results.

It is interesting to note that, although the pre-1820 data (Figs. 3.4a and c) show no *linear* correlation between precipitation and fire during aboriginal times, the most frequent fire years appear to occur during years of average rainfall. This pattern may indicate that although plenty of fuel may be produced during years with above average precipitation, conditions remain too moist to carry many management fires. Drought years would be expected to produce less fuel, and conditions may have made setting landscape fires too dangerous, as reported by Indian informants in northern Alberta (Lewis, 1977; Lewis and Ferguson, 1999). During average years, however, fuel and moisture levels would have been ideal for controlling low intensity management fires.

Figure 3.3 also shows a striking drop in fire frequency to below historic levels during the early 1900s. Figure 3.10 displays archival data from the Umpqua National Forest from 1910 to 1990 showing the annual number of fires recorded, the total annual acres burned, and the average acreage of the fires. The dramatic drop in the amount of acres burned per fire in the 1920s undoubtedly reflects the introduction of effective fire suppression technology during that time.

Interestingly, a regression of percent trees scarred on precipitation index during the period from 1920-1981 again revealed no correlation ($p = .395$), suggesting that human activity has obscured the climate signal in two different periods: first during aboriginal times through systematic ignition, and again during the Industrial Phase through systematic suppression.

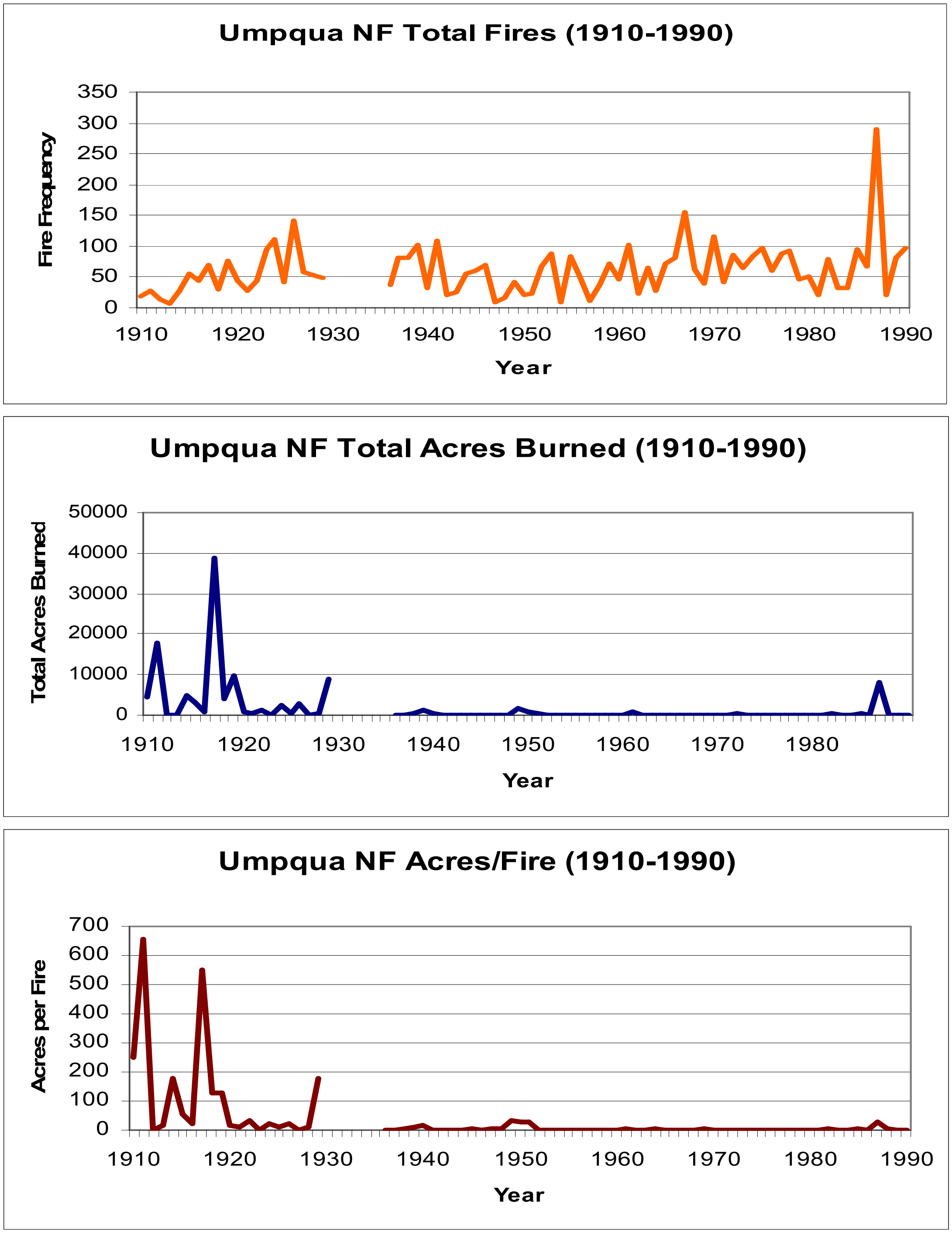


Figure 3.10: Historical Forest Fire Data for the Umpqua NF, 1910 to 1990. The top graph displays the number of fires recorded per year. The middle panel shows the number of acres burned per year, while the bottom graph presents the average number of acres per fire. The dramatic drop in the amount of acres burned per fire in the 1920s may mirror the onset of effective fire suppression technology. (Data missing from 1932 to 1936.)

Analysis II indicates that tree recruitment is also not correlated with precipitation during aboriginal times (Fig. 3.5a, c and e), while the trend after 1850 (Fig. 3.5b and d) is negative and weakly statistically significant ($p = 0.030$ for current year, and $p = 0.029$ for previous year's precipitation). As in analysis I, the wide scatter around the linear trendlines in the post-aboriginal plots may again be due to data imprecision and/or the influence of other unmeasured variables. In addition, the strong negative first-lag autocorrelation in the 1850-1939 time series (Fig. 3.9) undoubtedly contributes to this variability.

Because I assumed Little River forests to be typical of western Cascade forests where regeneration should be highest during wet years (Whitlock and Knox, 2002), I expected to see the predicted positive correlation between precipitation and tree regeneration after Euro-American resettlement. Therefore, the *negative* correlation after 1850 was a bit of a surprise. Rather than the increase in recruitment that I expected to see during and after wet years, tree recruitment *decreased*. It is also surprising that precipitation in the year following germination is not correlated with increased seedling survival (Fig. 3.5f).

Given that the Little River watershed tends to be somewhat drier than the Coast Range and the western slopes of the central and northern Cascades, it is possible that tree recruitment followed a pattern more typical of the arid forests to the south and east. In the ponderosa pine forests of the southwestern US and northeastern California, wet years are thought to increase the growth of fine fuels that are subsequently more likely to carry low intensity ground fires that would kill many newly established young trees but would leave few scars on mature trees (Baisan and Swetnam, 1990; Swetnam and Betancourt, 1998; Norman and Taylor, 2003). This trend is also predicted for the arid Pacific Northwest forests east of the Cascades (Whitlock and Knox, 2002).

In the Little River watershed, however, the concomitant *decrease* in fire scars recorded during and after wet years (Fig. 3.4b and d), suggests that this relationship may not be operating in the more mesic forests of southwestern Oregon, at least within a one year lag period. Moreover, multiple regression models designed to test for interactions between fire and precipitation on tree regeneration indicate that virtually all of the explaining power in the 1850-1939 period is from percent scarring (Dave Perry, pers. comm., 2005). Interestingly, precipitation *does* contribute weakly during the 1590-1820 period, but it's still the percentage of fire-scarred trees that explains more of the variation, albeit much more weakly than in the 1850-1939 period. Further research is planned to refine these models.

It is possible that a one year lag is not enough to reveal trends between wet periods and subsequent fires. Figure 3.3a compares precipitation with fire frequency in the Little River watershed, and indicates that during the Aboriginal Phase, wet periods with potentially higher fuel production did not necessarily lead to widespread fires in subsequent dry periods. For example, while there was an increase in scarring during a dry period following a very wet period in the early 1600's, the largest excursion into wet conditions occurring in the early 1700s was *not* followed by an increase in fire frequency during the extremely dry 1750s and 60s – in fact, fire frequency in the 1750s was well below average. Fire in the aboriginal forests of Little River sometimes tracked with precipitation and sometimes against, but became more closely entrained after Euro-American resettlement in the mid 1800s.

Rather than being an effect of soil moisture or surface fire behavior, the association between lower recruitment numbers and wet years after 1850 could instead be due to greater seedling mortality caused by increased competition from grasses and other pioneer species promoted by wet conditions. This conclusion is reinforced by the fact that higher precipitation in the following year is also not correlated with larger recruitment cohorts (Fig. 3.5f).

Analysis III reveals the relationship between yearly fire frequency and subsequent tree recruitment during the Aboriginal and Euro-agrarian Phases.

While again no correlation is observed during the Aboriginal Phase, the temporal association becomes dramatically significant from 1850 to 1950 (Fig. 3.6b and d). However, in order to assess the validity of this statistical inference, three issues need to be taken into consideration.

First, the variances of both variables differ between the time spans. However, for both percent scarring and tree recruitment frequency data, variances are greater in the 1850-1950 time span. While this would be expected to add more error to the regressions from the Euro-agrarian Phase, correlation coefficients and probabilities are still highly significant.

Second, there is significant first-lag autocorrelation in the tree regeneration frequency time series for both the 1590-1820 series and the 1850-1939 series (Fig. 3.9), which violates the assumption of response variable sample independence. While this warrants caution in drawing conclusions from probabilities generated from these regressions, the fact that the autocorrelation is positive during aboriginal times but *negative* after 1850 suggests that the ecosystem may have functioned significantly differently during the two phases.

Third, both 1850-1939 time series trend strongly downward (Fig. 3.3). This could produce a strong statistical correlation where no causal relationship exists. For example, while a decline in recruitment *is* recorded in the systematically sampled Current Vegetation Survey data (Fig. 2.21) from the early 1900s through the middle of the century, the sharp decline in recruitment frequencies recorded in the Van Norman dataset is undoubtedly also due to sampling bias -- younger trees are less merchantable and therefore less likely to be available to sample as stumps in logging units.

However, the significant cross correlation of the previous year's scarring percentage with regeneration frequency (Fig. 3.11) suggests that the two parameters *are* ecologically related during post-aboriginal times: before 1820 there are no significant ($p < .05$) correlations between scarring and tree recruitment at any lag (Fig. 3.11 a). After 1850, however, there are several significant lags, including one between the percentage of scarring in one year and regeneration in the following year (Fig. 3.11 b). Because these are cross correlations on year-to-year differences rather than absolute values, the likelihood of spurious correlation due to unrelated but jointly downward trends is small (Systat, 2005).

If the statistical inferences from Analysis III are valid, this suggests that the recently observed short pulses of even-aged recruitment following wild fires (Pickett and White, 1985; Oliver and Larson, 1990; Bonnicksen, 2000) may be more of a post-aboriginal phenomenon.

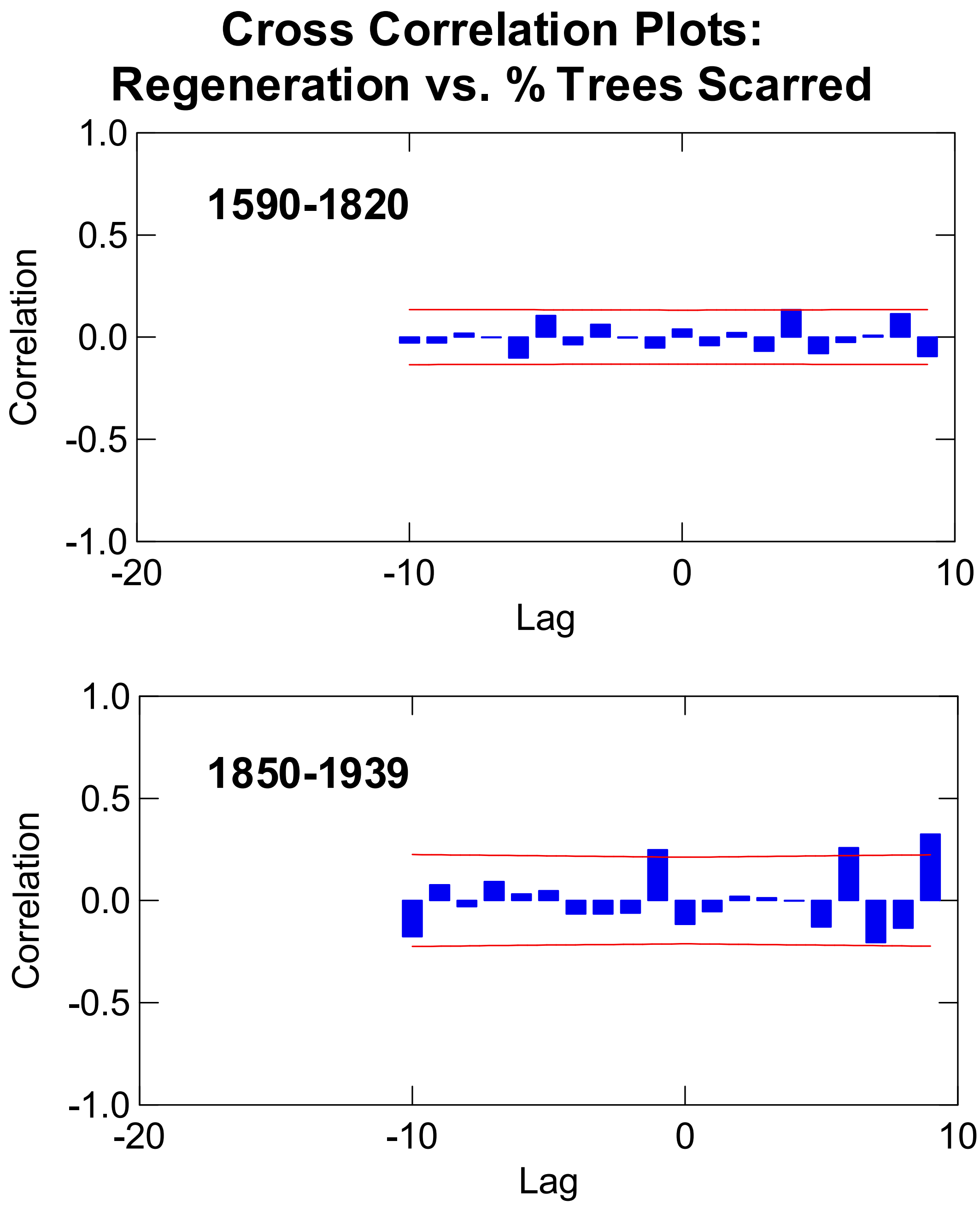


Figure 3.11: Cross Correlation Plots for %Scarring vs Tree Regeneration Frequency During the Aboriginal Phase vs the Euro-agrarian Phase
These plots graph the likelihood that regeneration frequency is correlated with fire scarring at a given number of years (lags) previous. Red lines indicate 95% confidence intervals. Data from 1850-1939 have been differenced to remove bias due to the strong downward trends in these series (Fig. 3.3). Note that no statistically significant correlation exists between percent scarring and recruitment before 1820, but that a moderately significant correlation between scarring and recruitment emerges from the 1850-1939 data.

Other interesting relationships emerge from the autocorrelation plots discussed above. For example, note that the periodicity evident in the 1590-1820 series (Fig. 3.7, top panel) is *not* reflected in a similar periodicity in the percent scar and/or tree regeneration series (Figs. 3.8 or 3.9) during that time span as would be expected If precipitation was an important driver of forest dynamics.

Another intriguing pattern is seen in the top panel of Fig. 3.9. The autocorrelation plot for tree recruitment during 1590-1820 reveals a 7-10 year periodicity in tree recruitment frequency, which is also reflected in preliminary Fourier analysis (Dave Perry, pers. comm., 2005). Because it is so frequent, this cycle is unlikely to be climate related, but instead may be a consequence of the fluctuating production of seed by Douglas-firs, which commonly produce heavy seed sets across the landscape during periodic “mast years”. This frequency is within the range of the 2-11 year cycles reported for the variety of Douglas-fir (*Pseudotsuga menziesii var. menziesii*) found in southwestern Oregon (Stein and Owston, in press).

While the above analyses were able to show weak to moderate correlations between precipitation and forest dynamics during the Euro-agrarian Phase, no linear correlations are evident in any of the comparisons during the Aboriginal Phase. However, climate must certainly have played *some* role in shaping the ancient landscapes of southwestern Oregon. For example, interactions between El Niño Southern Oscillations (ENSOs) and Pacific Decadal Oscillations (PDOs) are reported to form teleconnections with historic (1700 to 1905) climate that are reflected in tree ring fire scar records in ponderosa pine forests in the American Southwest (Westerling and Swetnam, 2003) and on the eastern slope of the Cascades in northern California (Norman and Taylor, 2003).

Finding an ecological signal from these oscillations in southwestern Oregon, however, is problematic for a couple of reasons.

First, the effects of Pacific Ocean temperatures on western climates have varied substantially from north to south and from century to century (Dettinger et al., 1998; Westerling and Swetnam, 2003). During the late 20th century, El Niño events typically exhibited a "dipole" spatial pattern between the Pacific Northwest and the American Southwest: dry conditions prevail in the north while wetter than average conditions are experienced in the south. The opposite is true for La Niñas. The phase of the Pacific Decadal Oscillation may interact with ENSOs to strengthen or weaken the effects of El Niño/La Niña events. However, Westerling and Swetnam (2003) note that the "pivot point of the wet/dry dipole tends to shift south or north on decadal time scales" from northern California through northern Oregon. Thus, the weather of southwestern Oregon may be entrained with that of the southwest US when the pivot point is located to the north, or with the weather of the Pacific Northwest when the pivot point is shifted to the south.

In a northeastern California study of fire/climate dynamics from 1700 to 1849, Norman and Taylor (2003) suggest that in ponderosa pine forests where lightning is seldom the limiting factor for fire occurrence (Swetnam and Baisan, 1996; Allen, 2002), Indian-set fires were merely supplemental to climate-driven wildfire. During the same historic time span, however, Keeley (2002) and Zybach (2002) document frequent fire in the lightning limited but heavily populated California and Oregon Coast Ranges, respectively. Thus it may be that in areas where lightning is common and vegetation is fire tolerant, humans need only enhance natural fire in preferred habitats. On the other hand, if lightning is uncommon but pyrogenic vegetation is preferred, then anthropogenic fire becomes a much more important factor in maintaining desired landscape structure and function (Keeley, 2002).

Although pollen and charcoal analyses appear to link fire to climate in other parts of the Pacific Northwest at the regional/millennial scale (Whitlock, 1992; Worona and Whitlock, 1995; Sea and Whitlock, 1995; Grigg and Whitlock, 1998; Long, et al. 1998; Pearl, 1999), the above results suggest that the historic relationship is obscure or non-existent at the landscape to stand spatial scales, and at the decadal to annual temporal scales in southwestern Oregon.

3.9.2 Human Influences on Landscape Dynamics

If precipitation, fire frequency and tree recruitment are not correlated until *after* Euro-American settlement in the Little River watershed, what then *were* the forces driving historic forest patterns, and what caused them to change?

Several lines of evidence presented below suggest that burning by the indigenous people of Little River had a significant impact on their landscape, and that the decrease in management fires and an increase in fire suppression during the Euro-agrarian phase has lead to the observed increases in stand densities, and to the decreases in the number and size of meadow patches and corridors in the forest matrix. However, a number of recent studies from the southwestern US and the Pacific Northwest intermountain region suggest that heavy grazing by cattle and sheep may also have contributed to increases in stand densities (Savage and Swetnam, 1990; Bahre, 1991; Belsky and Blumenthal, 1997). Most of these studies were conducted in ponderosa pine forests, and conclude that intensive grazing, especially by sheep, remove grasses that 1) compete with tree seedlings for moisture and nutrients, and 2) carry low intensity ground fires that kill young tree seedlings but leave mature overstory trees unharmed.

In the Little River watershed, however, sheep grazing is unlikely to have contributed to the increases in tree recruitment recorded in the Van Norman, Little River Watershed Analysis, and Current Vegetation Survey datasets (see Fig. 2.21), for a number of reasons.

First, in all three datasets displayed in Fig, 2.21, recruitment begins to increase early in the 1800s, and peaks in the mid 1800s before any significant amount of sheep grazing had taken place in the area, although recruitment frequencies fall off more slowly in the CVS dataset. In an 1898 report to the US Dept. of Agriculture on sheep grazing in the Cascade Range Forest Reserve (of which The Umpqua National Forest was then a part), Frederick Coville made the following observations concerning the timing of the introduction of sheep into the area:

> The first domesticated sheep brought into Oregon came from California in 1843, but from that year until 1860 sheep grazing was only a small industry.

Coville goes on to observe that:

> In general, over grazing in the Cascades has only been begun, or perhaps the facts are better expressed by the statement that up to the present time [1897] overgrazing is limited to a few areas in a part of the Mount Hood District and a part of the Three Sisters District [well north of the Little River watershed].

The Little River Watershed Analysis (1995) also notes that “sheep and timber were added to economy with the arrival of the railroad in 1872”, after spikes in tree regeneration had already occurred in many stands.

Additional evidence that sheep grazing probably did not contribute to increased stand densities in the Little River area comes from other historic reports indicating that sheep grazing not only removed competing grasses from the site, but young tree seedlings as well. Coville noted that:

> Overgrazing on a very small scale can be seen almost anywhere in a sheep country, on bedding grounds and along well-worn routes of travel by sheep. In such situations are commonly seen the primary effects of overgrazing; namely, the weakening or *killing not only of the herbaceous vegetation, but of shrubs, seedling trees, and the smaller saplings*. (my italics)

In an 1897 report to the US Geological Survey, Arthur Dodwell and Theodore Rixon make the following observation while assessing the timber resources present in what was then the Cascade Forest Reserve:

> Large numbers of sheep, amounting to several thousand, are annually driven from Prineville and neighborhood up into the eastern portion of the [Cascade] reserve, some bands crossing the divide and grazing down the North Fork of the Umpqua and along the different divides west of the Cascade Range, leaving the reserve about the end of September… These sheep ate up everything in sight, *destroy[ing] all the young growth*… (my italics)

Not only do these reports suggest that sheep had little to do with the increase in timber density observed in the Little River watershed in the late 1800s, but Coville makes the following observation concerning the influence of Indians on landscape structure:

> Historically considered, we must look to the Indians as the first manipulators of forest fires in this region. It is a clearly established fact, based on observation, that the Indians of the Willamette Valley in western Oregon were accustomed before the advent of white men in that region, to as late a period as the early forties, to set fire to the grass for the purpose of burning off. Their object in doing this is supposed to have been chiefly (1) to cause a fresh growth of grass in the autumn common upon which enormous quantities wild fowl descended to feed, particularly geese, and (2) for the purpose of killing and roasting for food the great quantities of grasshoppers that in certain years feed upon the grass. Similar uses of fire by the aborigines and other parts of the western United States have been recorded by which they were enabled to keep certain large areas denuded of timber. Upon the cessation of these fires, by reason of the intervention of white settlers, the timber has begun again to encroach upon such areas, and in the Willamette Valley, for example, we now see frequent groves of Douglas spruce *(Pseudotsuga mucronata)* and white fir *(Abies grandis)* about 50 years of age, of remarkably uniform and symmetrical growth, which have developed through their natural seeding without human assistance… The Indians probably cannot be accused of starting fires to a large extent accidentally, or setting fires indiscriminately, but it is undoubtedly true that in certain seasons it was their custom to *set fires in the mountains intentionally and systematically,* in

> connection with fall hunting excursions, when deer were driven together in killed and large numbers. (my italics)

Coville's observations from the Willamette Valley are reflected in current conditions in the Little River watershed. Many meadows that appear in historic photos are now significantly encroached by young timber, and many have disappeared altogether (see Fig. 2.20 and 4.14). Lack of frequent ground fires that killed seedlings but spared older trees would account for this. This is especially true for areas known to shelter Indians during historic times. Illahee Flats and Thorn Prairie, well known Indian camps just north and east of Little River whose meadow areas have shrunken dramatically after the extirpation of its original inhabitants, are good examples.

Changes in stand structure would also be expected to reflect changes in fire dynamics. Because even low intensity ground fires kill seedlings and many saplings, intentional short rotation fires set during the Aboriginal Phase would have left a series of small survivor cohorts after each event. On the other hand, meadow abandonment and longer rotation lightning fires would have promoted the development of more even-aged stands under Euro-American management. Therefore, stands that developed under Indian management would be expected to be more uneven-aged, while Euro-agrarian Phase stands would more likely be even-aged.

This is indeed the case in the Little River watershed where over half of the even-aged stands in the two Little River fire history databases cited above originated during the transition to the Euro-agrarian Period (1820-1850). Moreover, many stands in the Little River watershed have relatively even-aged cohorts of trees in their understories that date from the time of Euro-American settlement (Little River Watershed Analysis, 1995; Van Norman, 1998). If ground fires were frequent and systematic, recruitment would be very spotty and would lead to the development of such uneven-aged stands. This is evident only in the pre-1850 age distributions in the histograms. The post-aboriginal periods show the pulses of recruitment one might expect in the absence of frequent, low intensity fires.

The Van Norman (1998) data and the Little River Watershed Analysis (1995) data both show a gradual increase in fire scars starting in the early 1800s and peaking in the 1850s (Fig. 2.23). This trend begins well before the earliest reported end of the Little Ice Age, and begins to fall off toward the late 1800s when a warming trend would be expected to increase fire occurrence and intensity. Graumlich's reconstructions of precipitation in both the regional Southern Valleys and at Red Butte in Little River show no obvious correlation with fire frequency (Fig. 3.3a).

This pattern may better reflect the movement of Indian refugees into the uplands to escape settlers and diseases (Dave Brauner, OSU Archaeologist, pers. com., 1998). Since the available fire data are derived from logging units on steeper, more inaccessible sites (both to settlers and later to loggers), an increase in fire scars during the late Aboriginal Phase is consistent with this hypothesis.

This interpretation is corroborated by historic accounts of Indian movements in the decades leading up to their genocide. In 1855, headman Nez-zac and the surviving members of the Upper Umpqua Athabascans were camped in the lowlands (probably at the confluence of Little River and the North Umpqua River). According to local historian Lavola Bakken (1973), when war broke out in southern Oregon, Nez-zac became alarmed.

> … he knew the soldiers who came to protect the white men could not distinguish between a peaceful Umpqua and a warring Rogue. The chief lead his braves upriver to the Illahee [a 2200 ft. (670 m) elevation meadow just north of Little River], *a place remote from the settlements.* (my italics)

The late 1700s to mid 1800s is also the period when horses were being introduced to indigenous peoples across the west. Although anecdotal evidence suggests that horses came late and in small numbers to the Umpqua, I know of no historical documentation corroborating that. Even in small numbers, horse travelers would still need periodic yards along ridgeline corridors for pasture and camping (see Chapter 4). Therefore, increasing horse travel may have progressively lead to more aggressive meadow burning in the uplands, first by native riders, then by settlers and sheep herders until the government fire suppression programs began in the early 1900s (Fig. 3.7). The same Illahee mentioned in the quote above was also used for tribal gatherings with horse racing into historic times (Bakken, 1973).

The quantitative analyses presented in this chapter, along with corroborating historical data, indicate a strong landscape management role for indigenous peoples, and suggest that historic climate drivers may have been overridden by aboriginal management activities. The following chapter will explore the connection between people and place by investigating the spatial relationships between archaeological features and fire history in the Little River watershed.

CHAPTER 4: HUMANS, FIRE AND FORESTS: MODELING ABORIGINAL LAND MANAGEMENT IN THE LITTLE RIVER WATERSHED

4.1 NTRODUCTION

Although biological communities have been coevolving with lightning-sparked landscape fire since the dawn of woody plants, anthropological research suggests that indigenous peoples have had a strong hand in shaping the recent fire patterns of the world (Pyne, 1993). Across North America, numerous sources, both historical and ecological, support this view (Fig. 4.1). But the evidence is often anecdotal, and often without metadata linking it to a specific time and/or location. Although it's clear that indigenous peoples the world over burned systematically for agro-ecological purposes, few spatially explicit studies have been done to link historic human activities to ecological effects at landscape or regional scales.

I attempt here to sharpen our picture of historic landscapes and the fires that shaped them by analyzing archaeological, ecological, and historical records at the region, landscape and stand level in order to reconstruct the interactions among forests, fires, and cultures in the Little River watershed.

4.2 INDIANS AND FIRE IN SOUTHWESTERN OREGON AND NORTHERN CALIFORNIA

Pacific Northwest native societies were deeply integrated into their landscapes, and used a wide variety of materials collected over extensive areas (Lewis, 1993; Boyd, 1986; Beckham and Minor, 1992; Blackburn and Anderson, 1993; LaLande, 1995; Williams, 2001). But local material cultures persist only to the extent that key species and habitats on which they depend remain abundant, productive and resilient (Perlin, 1989; Diamond, 2005). Archaeological evidence from the Umpqua indicates that material cultures remained relatively unchanged for approximately 2000 years before contact (Isaac Barner, pers. comm., 2000) suggesting that the stewardship practices of recent peoples were sustainable.

The picture of ancient southwestern Oregon landscapes emerging from decades of anthropological and historical studies is one of a land systematically burned to create what the Indians referred to as “a fine and beautiful open country" (LaLande and Pullen, 1995) (Fig. 4.2). Reports from early explorers and settlers note that the Indians set extensive, annual fall fires, burning off most of the grasslands of the low elevation western interior valleys (Douglas, 1972; Riddle, 1953; Boyd, 1986) (see Figs. 4.2 and 4.3).

Many historical reports of burning by Indians also provide insights into *why* they burned. Many of the food plants traditionally used by Northwestern Indians are stimulated by fire (Lewis, 1993; Boyd, 1986; Anderson, 1993). Grassland burning stimulates the lush growth of meadow vegetation, producing both food for indigenous peoples and forage for the animals they depended on. With the coming of autumn rains, prairies that had been burned in the fall became flush with germinating seeds and a bloom of invertebrates -- food for huge flocks of game birds migrating south along the Pacific Flyway (Riddle, 1953). Many of these avian species are now rare or altogether lost from the region.

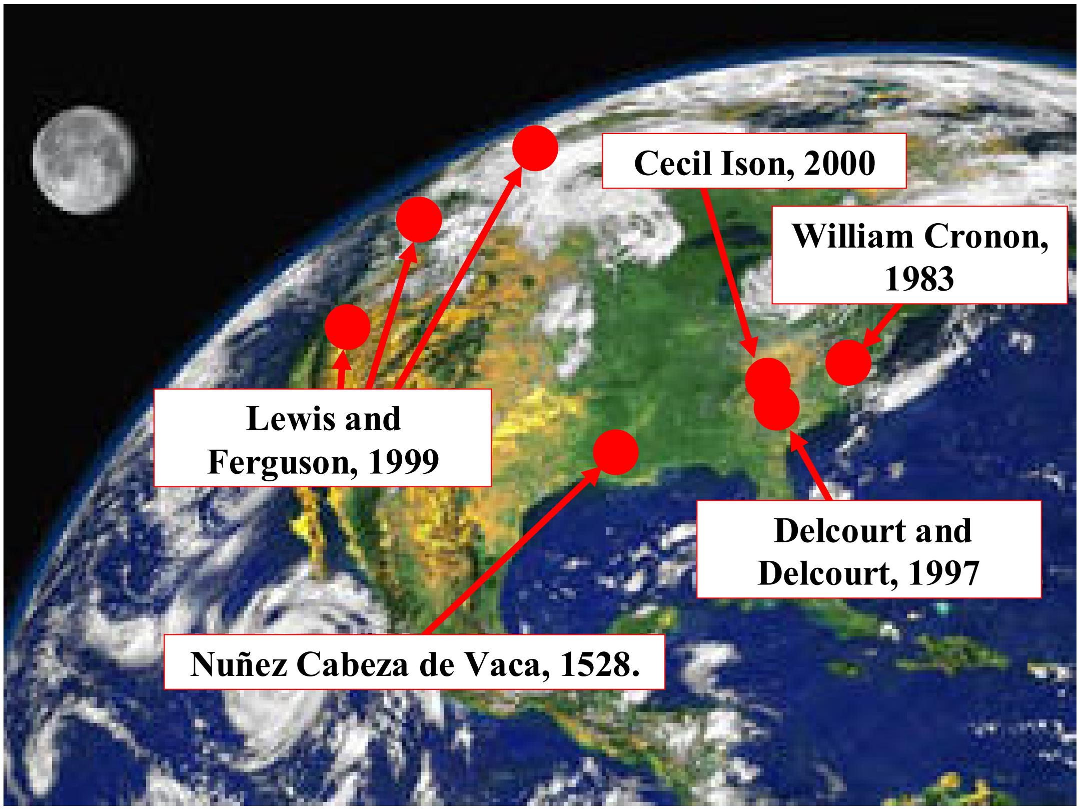


Figure 4.1: North American References to Native Burning.
Possibly the first European to have witnessed broadcast burning by Native Americans was the shipwrecked Spaniard, Nuñez Cabeza de Vaca, who documented indigenous peoples of the Gulf Coast burning to control mosquitoes in 1528. William Cronon (1983) cites numerous accounts of landscape burning by Indians for ecological purposes in colonial New England. Sediment cores provide ecological evidence of pre-Columbian landscape fires in Southern Appalachia that were associated with Indian occupancy (Delcourt and Delcourt, 1997). Lewis and Ferguson (1999) compared the burning practices of indigenous peoples from Northern California, Western Washington, and Northwest Alberta (they also added corroborating evidence from Australia). They describe a network of human generated "corridors and yards" for travel and hunting superimposed on a mosaic of "natural burns".

David Douglas and other early explorers to the area observed the use of landscape fire by Indians (Fig. 4.2), and oral histories of native people corroborate those accounts. Henry Lewis (1990), an anthropologist whose original work documented landscape burning by Northern California Indians, suggests that "…habitat fires were no less important for the Shastas, Umpqua, and other tribes of the south and southwestern part of [Oregon].” Fires were set to encourage food plants, to create forage for game, to drive game, to stimulate suckering of shrubs for arrow shafts and basket woods, and to clear trails and campsites, among many other reasons (Lewis, 1993; Blackburn and Anderson, 1993; Anderson, 1993; Lewis, 1999; Boyd, 1999). In an extensive bibliography of references on Indian burning practices, Williams (2001) lists these among the 13 reasons cited for the setting of landscape fires by indigenous people of the region.

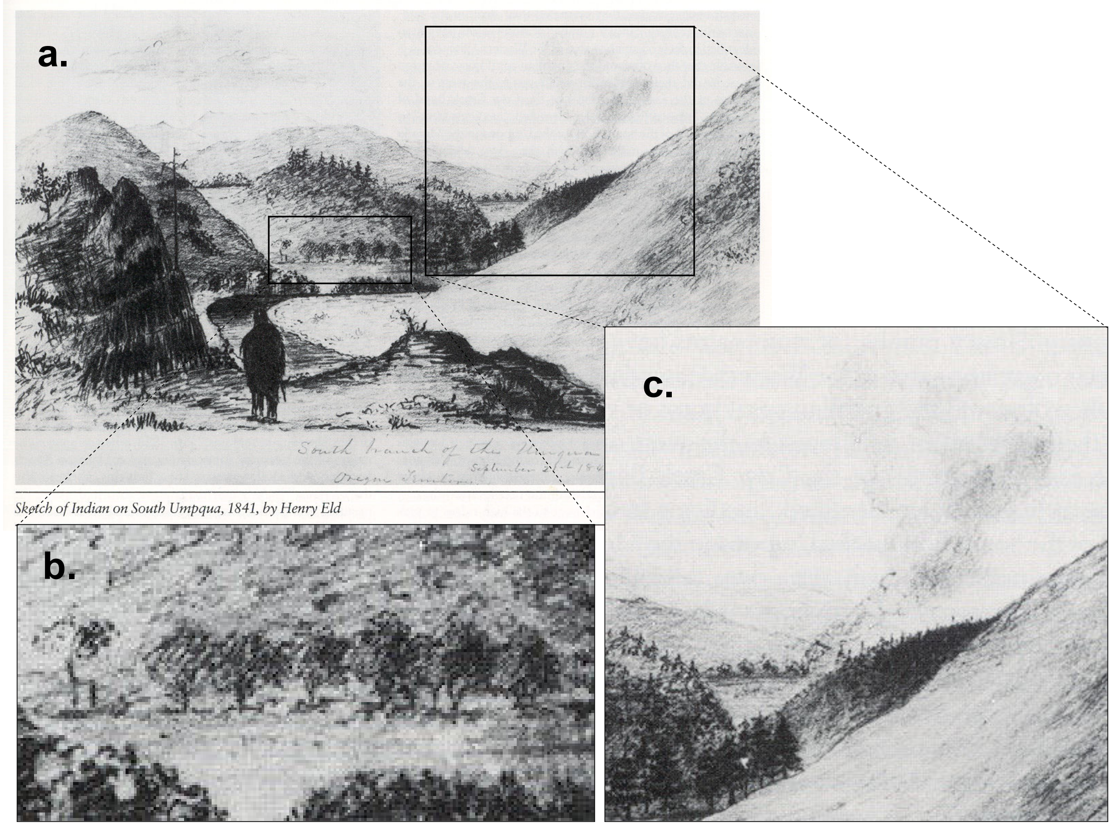


Figure 4.2: Pattern and Timing of Savanna Fires in the Umpqua Valley. Analysis of a landscape sketch by Henry Eld. Note open prairie and savanna in panel **a**. Panel **b** is an enlargement of the middle distance showing an “orchard of oak trees". Panel **c** enlarges the background showing smoke from a landscape fire burning on September 21st, 1841.

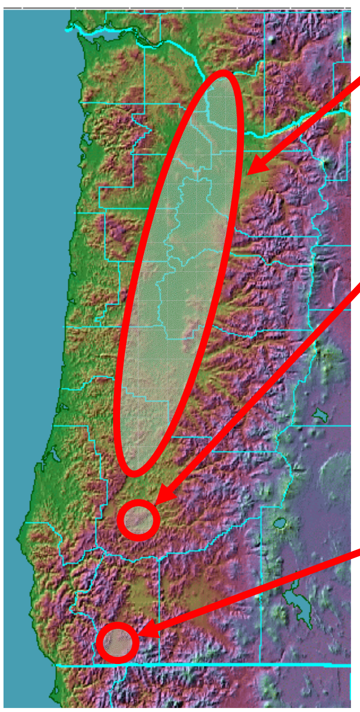
In the Umpqua Valley, tarweed fields were routinely burned so that the seed was more easily harvested, and lowland berry patches were also maintained by fire (Riddle, 1953). Grasshoppers and yellow jacket larvae were also collected just behind the flame fronts, and small islands of unburned vegetation served as "yarding" areas where congregating deer could be more conveniently taken (Douglas, 1972).

Among accounts of the use of fire in the uplands of southwestern Oregon and northern California are reports of fire circles used to drive game to a central location (Clark, 1905; Lewis, 1993; Boyd, 1986). During such drives, participating bands of Indians cooperatively organized fire drives during which the services of all able-bodied males were required. After the election of a hunt chief, a perimeter would be set up and at an agreed upon signal, fires would be set to burn toward the center. A high degree of cooperation and communication would have been necessary to maintain a closed circle so as not to let game escape from the center. The best hunters would then kill the trapped and confused game, sometimes using only clubs. The meat was then divided among the families by the hunt chief according to need. Although no eyewitness accounts exist for this practice in the Umpqua basin, fire drives were conducted by the Kalapuya tribe which includes the Yoncalla band in the northern Umpqua basin (Boyd, 1986).

The grasslands of the interior valleys of western Oregon apparently burned frequently (see Fig. 2.13). Among the many accounts of Indian burning in the Willamette Valley cited in Boyd (1986) is from an observation made by pioneer Lewis Judson in the late 1800s that states:

> …fir groves had been found necessary by the Indians to induce deer and other wild game to stay in the valley. The groves were undisturbed by fire…The Indians burned right up to imaginary lines, but never was the fire allowed to go past or get out of hand. So some authority must have existed among them because *biennially* the prairies were burned. (my italics)

Burning also killed the seedlings of tree species that would quickly have formed closed-canopy woodlands that support far less human food than meadows and savannas. Pioneer George Riddle, whose family homesteaded in SW Oregon in the 1850s noted that "…the *annual* fires set by the Indians prevent young growth of timber…". (Riddle,1953, my italics)



"Some of the natives tell me it [burning] is done for the purpose of urging the deer to frequent certain parts to feed, which they leave unburned and of course are easily killed."
David Douglas, 30 Sept. 1825

"…the annual fires set by the Indians preventing young growth of timber…"
George Riddle, Umpqua settler, 1850s

"In passing through the woods we suddenly came on to an Indian woman who was blowing on a brand to set fire to the woods probably, we stoped to speak to her, but she was sullen, & dogged, & made no reply, & we passed…We found the woods in fire in several places & at times had some difficulty in passing some of the gullies where it was burning".
Henry Eld, Emmons Expedition,1841

Figure 4.3: Locations of Historic Documentation of Indian Burning Practices.
Quotes from early explorers and settlers. Outlined areas indicate the location of the reports.

The burning practices of local Indians were readily adopted by the Euro-Americans who followed. In a 1939 oral history taken as part of a depression-era Work Projects Administration effort entitled "Reminiscences of Southern Oregon

Pioneers", Charles Oliver Criteser, speaking about Umpqua Valley grasslands in the late 1800s, is quoted as saying: "It is now all grown up to undergrowth, which at places is thirty feet high and can't even be walked through". The interviewer goes on to note that:

> In the old days he kept his grazing land in good shape by burning it off every year. Now, there are laws that do not allow this to be done except where it has been slashed off and a crew of men are on hand to watch and controlled fire, which expense is not warranted in the returns to be derived. The result is the thick brush and the passing of the grazing lands. The Indians, he said, followed this plan of *annual burning* in order to get grazing lands for their ponies. (my italics)

Although these reports point to a strong role by Indians in grassland management, evidence for the use of broadcast burning in forested landscapes in southwestern Oregon is less abundant. However, the historic records that exist still strongly support the use of systematic fire by indigenous peoples for agro-forestry purposes.

Brush was often burned to increase the productivity of fruit and nut bearing shrubs and to promote suckering for arrow shafts and basket materials ([Lewis, 1993; Anderson, 1996). Indian informants noted that upland huckleberry fields were periodically burned to maintain their vigor (Beckham and Minor, 1992). Henry Eld and the 1841 Emmons Expedition undoubtedly were witnessing an example of this type of burning when he wrote about coming upon an Indian woman blowing often a brand she was using to “…set fire to the woods probably” (Fig. 4.3).

This same journal entry from Eld also sheds light on the intensity of these historic upland fires. He notes that “We found the woods in fire in several places & at times had *some difficulty* in passing some of the gullies where it was burning.” (my italics). The use of the phrase “some difficulty” suggests that the fires were not dangerous conflagrations, but rather small, patchy surface fires that were little more than nuisances to avoid.

Indians who escaped interment in distant reservations in the 1850s continued to burn the forest into the 1900s. An 1869 diary entry from an upland settler with an Indian wife in the South Umpqua drainage noted that they had "Set the mountain fire." (Thomason, 1869, cited in Beckham and Minor, 1992). Two early rangers on the Umpqua National Forest note forest fires set by the Indians. Charles Collins (1982, cited in Beckham and Minor, 1992) recalled the persistence of Indian families setting fires into the early 1900s. John C. Kuhns, a ranger with the newly established Forest Service, photographed Thorn Mountain in 1911 with the caption "...showing country burned over by Indians years ago." (John C. Kuhns photo collection, Umpqua National Forest archives).

The Kuhn photos and other archival photo collections at the UNF headquarters also document a patchwork of burned areas in the uplands, although their origins are not noted. Beckham and Minor (1992) also note that in upland sites "Annual burning controlled the forest understory and contributed to the abundance of game and berries...".

In a 1938 interview, Charles Franklin Watson, who was born in 1857 in the village of Peel in the Little River watershed, recalled witnessing Indians burning both grassland and upland forests:

> Mr. Watson remembers very clearly the time when these hills were barren and covered with grass. There were few trees, only a scattering tree here and there. Bald Mountain which is now covered with dense forest growth, in his early days was good grass land, hence its name… Mr. Watson is of the opinion that this was due to the *Indians burning off the land each year*. They would fish and hunt in the hills and then as the winter season approached, they would come out of the hills burning the grass and small growth behind them. Doing this every year made the fires so light that there was *no damage to the big timber*. (my italics)

Periodic light fires of this nature would be expected to leave behind forests of widely spaced, large trees of various ages with diverse understories of the grasses, forbs and shrubs that provided much of the food and fiber to native peoples. Indeed, stand demographic data from two recent studies in the Little River watershed (Little River Watershed Analysis, 1995; Van Norman, 1998) show the vast majority of stands to be uneven-aged.

Many place names in the upper Umpqua drainage alluding to fire-adapted grassland and savanna vegetation are commonly associated with areas where closed canopy forests now exist (e.g. Fish Creek Desert, Big and Little Oak Flats, Peter Paul Prairie, Burnt Mt., etc.). Historic panoramic and aerial photographs from Little River (see Chapter 2) still reveal patchy openings, often along ridge tops and near known habitation sites. Again, this evidence suggests that the historic forested landscapes of the Umpqua contained significant areas of park-like forests with widely spaced large trees and probably little understory vegetation, along with corridors and patches of prairie and open savanna.

The patterns created by Indian fires in the forests of the Pacific Northwest (as well as in the boreal forests of Canada and in Australia) tended toward what Lewis and Ferguson (1999) refer to as “yards, corridors, and mosaics.” Meadow areas in the forests were fired along with ridges that connected them (Fig. 4.16).

Chuck Jackson, an elder of the Cow Creek Tribe, recalls fires being started in the upper South Umpqua drainage in the 1930s, and that the forest understory was open enough to ride a horse through at a gallop (pers. comm., 1994). Moreover, given the strong dependence of humans on the sense of sight in locating and utilizing resources in their environment, it is reasonable to postulate the use of fire to maintain lines of sight, especially from high vantage points, in order to find landmarks and monitor game movements.

Early descriptions of much of the forest as being in an open, park-like state (LaLande and Pullen, 1999) are consistent with the recent findings for stands in the Oregon Cascades and Coast Range (Tappeiner et al. 1997; Paoge, 2000; Sensenig, 2002). Tappeiner et al. (1997) found early growth rates of old-growth trees to be more typical of trees grown at low stocking densities (100-120 trees/ha) than of trees currently growing in young, un-thinned stands (often >500 trees/ha). They suggest that periodic, low intensity fire was likely responsible for reducing stocking levels rather than self-thinning.

Vestiges of these open stands and their connections to native management are often found near sites with documented aboriginal activity and are evidenced by (a) very large, old "relic" trees with highly branched "open grown" architecture imbedded in a matrix of substantially younger, even-aged cohorts (Fig 2.12), (b) annual rings from relic trees showing suppressed growth only as far back as the origin of the young even-aged cohort in which they are imbedded (pers. obs.), and (c) origin dates of the even-aged in-growth cohort that commonly post-date the period of Indian occupancy (see below).

4.3 OBJECTIVES

Given the numerous historical reports of aboriginal burning in and near the Umpqua Basin, it is highly likely that the Indians of Little River were using landscape fire systematically for agro-ecological purposes as well. But if Indians were systematically burning forested landscapes, what ecological signals might we expect to observe?

At the landscape level, we should find historic meadows, savannas and parklands located near archaeological sites and near the historic trails connecting them. It is reasonable to surmise that Indians would burn more extensively and more often around the areas where they spent the most time.

In order to generate a spatially explicit model of indigenous fire use in the Little River watershed, I set the following objectives:

- To gather and organize spatial data on the historic vegetation patterns of the Little River watershed.
- To gather and organize spatial data on the settlement patterns of the Indians of Little River.
- To model the travel networks used by the Indians of Little River.
- To compare Indian land use patterns with vegetation patterns in order to test hypotheses concerning their spatial correlation.

4.4 MODELING HISTORIC TRAVEL NETWORKS

For the following analyses, I used the Idrisi GIS from Clark Labs (2002). I first mapped the 80 known archaeological sites in the Umpqua study tract. I then modeled the most ergonomic travel routes among these sites by developing four friction surfaces and generating least cost pathways among 10 well dispersed and well documented "target" sites. The resulting travel networks were then compared, and the networks that came closest to the most independent archaeological sites (i.e., those not used as modeling targets) were selected for use in subsequent analyses.

4.4.1 Archaeological Site Mapping

In order to put the Little River landscape into the context of the surrounding region, I chose a mapping rectangle that extends from 43^{o}, 00' to 43^{o}, 30' north latitude and 123^{o}, 30' to 122, 00' east longitude (Fig. 2.1).

The locations of 80 archaeological sites were obtained from BLM and Forest Service archaeologists. Sites were then digitized using Idrisi software (Clark

Labs, 1999), and identified as either river associated sites, upland sites or toolstone quarries (Fig. 4.4). Because so many of the sites are poorly studied, no attempt was made to classify them as to their specific uses (e.g. “village”, “hunting camp”, etc.) Ten well documented and well dispersed sites were then chosen as target nodes from which to generate least-cost pathways.

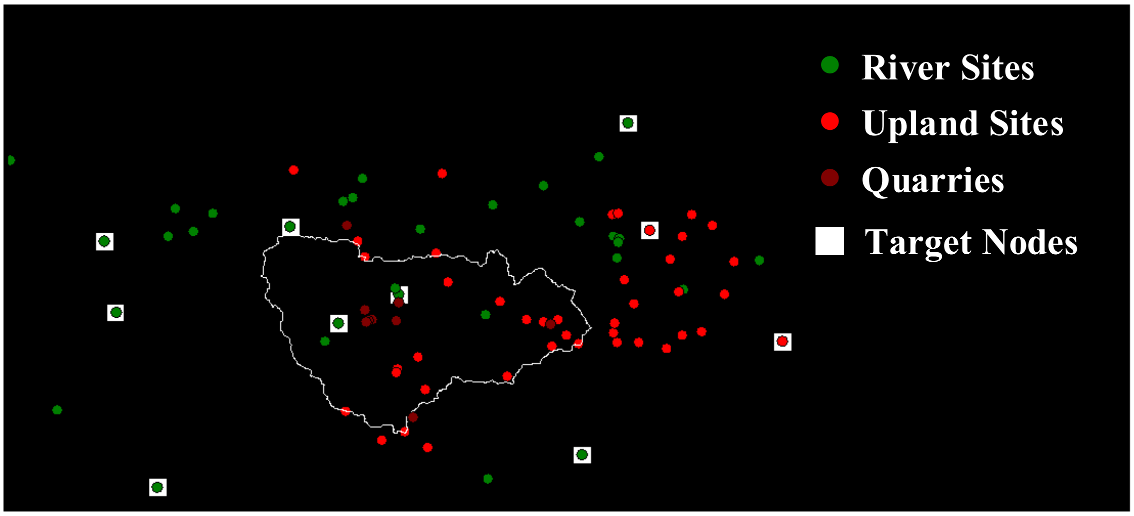


Figure 4.4: Archaeological Sites in the Little River Vicinity. Locations for 80 archeological sites were obtained from Forest Service and BLM records. Sites were then digitized using Idrisi software (Clark Labs, 1999), and identified as either river-associated sites, upland sites or toolstone quarries. Ten well-documented sites were then chosen as target nodes from which to generate least-cost pathways. River and upland sites were classified according to their position on the landscape. Quarries are areas where toolstone was acquired. Because of the sensitive nature of archaeological sites, no landscape features are displayed.

4.4.2 Modeling Friction Surfaces.

Friction surfaces are generated by assigning resistance values to each cell on the map. Various resistance factors can be added layer by layer to create a map of friction across the terrain. For this study, travel friction surfaces were modeled using digital elevation models (DEMs) of the study area, and digital line graphs (DLGs) of rivers and streams for the study area. These layers were obtained from government sources and converted to Idrisi file formats (Idrisi GIS, Clark Labs, 2002) and imported into the GIS.

Friction Model 1 was created by using elevation as the major resistance factor to travel; ergonomic costs increase when climbing hills, and decrease when descending. In order to discourage Idrisi from using river beds as least-cost paths, a friction of 50 units (equivalent to climbing 50 meters in elevation) was applied to a 180m (3 cell) buffer around rivers with hazardous currents (Fig. 4.5). These rivers can therefore be *crossed* with little effort, but the cost for walking up the middle of the river would make that path prohibitive.

Friction Model 2 was constructed by converting elevation to percent slope and using that as the major resistance to travel. This makes downhill travel just as expensive as uphill travel for any given slope. Percent slope was chosen as the friction factor over slope in degrees because resistance values increase exponentially rather than linearly. This more closely approximates the actual effort involved in walking mountainous terrain. As in Model 1, a hazardous river friction factor was applied to this model as well, but in this and subsequent models represents negotiating a 50% slope (Fig. 4.6).

Friction Model 3 used Model 2 as its base, but adds an additional 20 friction units to 120m (2 cell) buffers around perennial streams (Fig. 4.6).

Friction Model 4 also used Model 2 as its base, but increases the friction associated with perennial streams from 20 units up to 50 (Fig. 4.6).

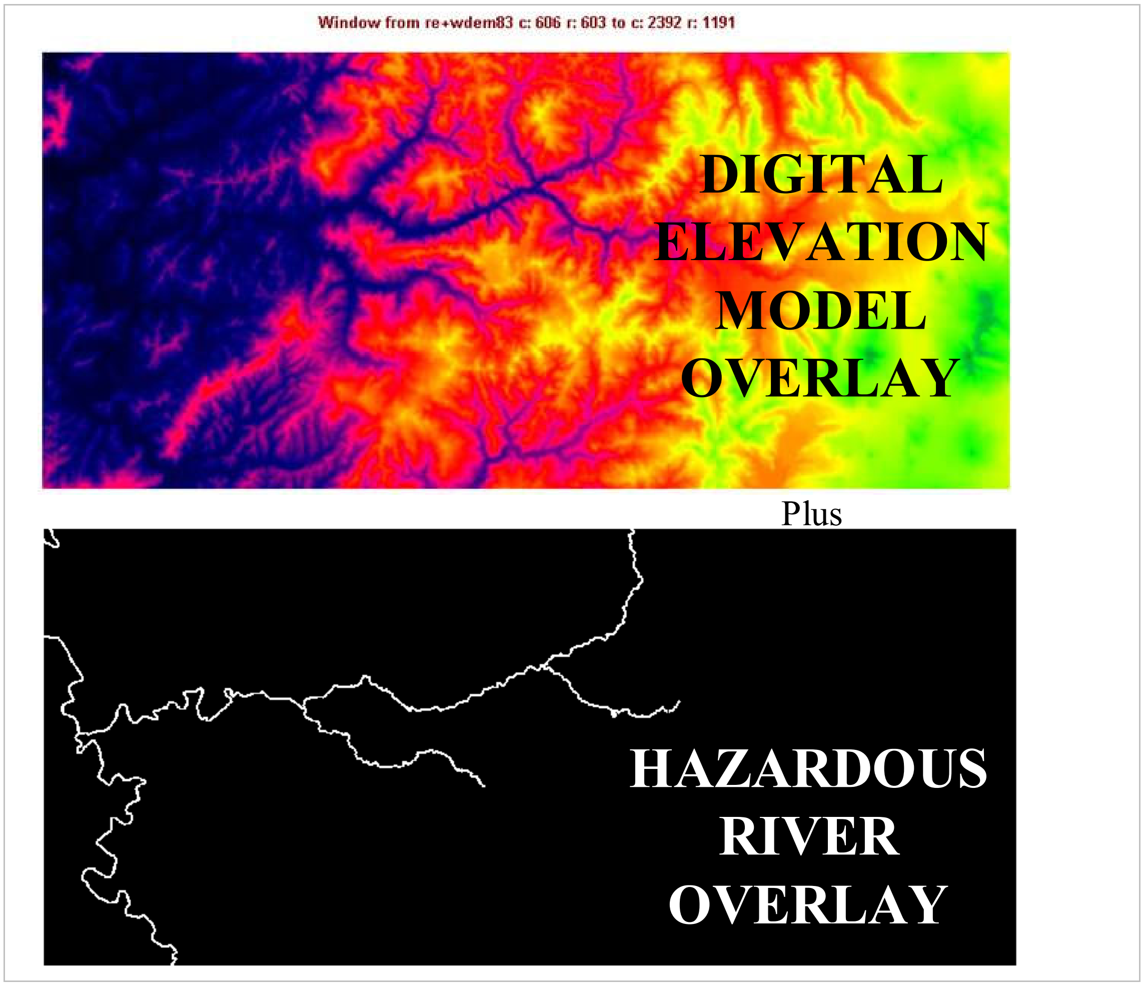


Figure 4.5: Model 1 Travel Friction Layers.
Model 1 was created by overlaying a map of hazardous rivers (bottom panel) on a map of elevations (black represents lowest elevations, green represents highest). Thus, walking is difficult uphill, and easy downhill. A small amount of friction is encountered crossing rivers, but a prohibitively high resistance discourages river beds as pathways.

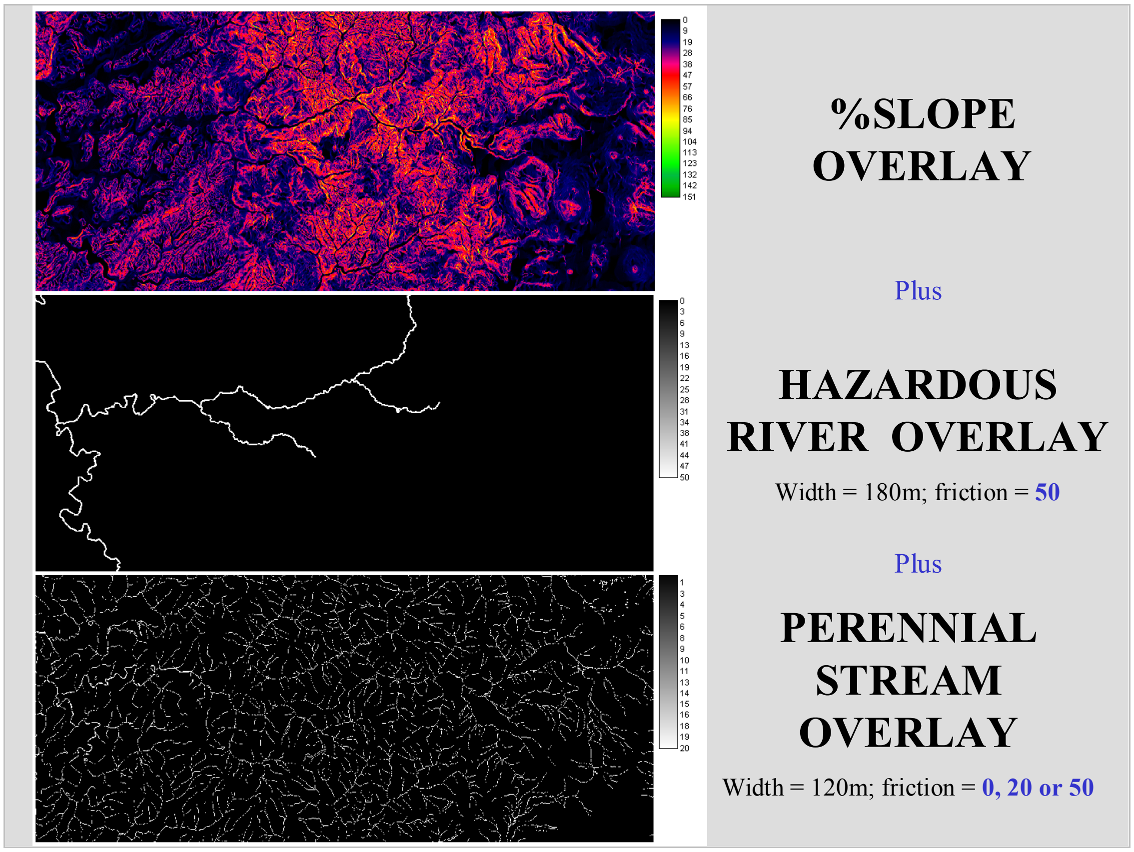


Figure 4.6: Model 2, 3 & 4 Travel Friction Layers.
These friction models all use slope rather than elevation (black is flat, green is steepest), and again overlay the hazardous river layer, but they add resistance for perennial streams from 0 units in Model 2, to 20 in Model 3, and 50 in Model 4. These models all generate paths that tend to follow upland ridges and flats, but models that assess high resistance values for streams tend to nudge the paths to higher, drier ground.

4.4.3 Generating Least-Cost Pathways

A set of cost surfaces for each friction model was created for the 10 selected archeological target nodes using Idrisi's COSTGROW algorithm (Clark Labs, 2002). This module starts at a chosen origin point and moves outward in every direction, adding friction units cell by cell until it reaches the map boundary. Idrisi's PATHWAY algorithm was then used to calculate the least-cost pathway across each cost surface from the 10 target nodes to the origins of each cost surface. In several cases, I ran pathways between two nodes from opposite directions to test the accuracy of the algorithms. In all cases, Idrisi calculated exactly matching pathways. All of the individual node to node pathways from each of the 4 friction models were then combined to form 4 travel networks among the 10 selected archaeological sites.

An example of this process using friction Model 1 and a cost surface propagated from the Colliding Rivers site (a village site near the confluence of Little River with the North Umpqua) is shown in Figs. 4.7a-c.

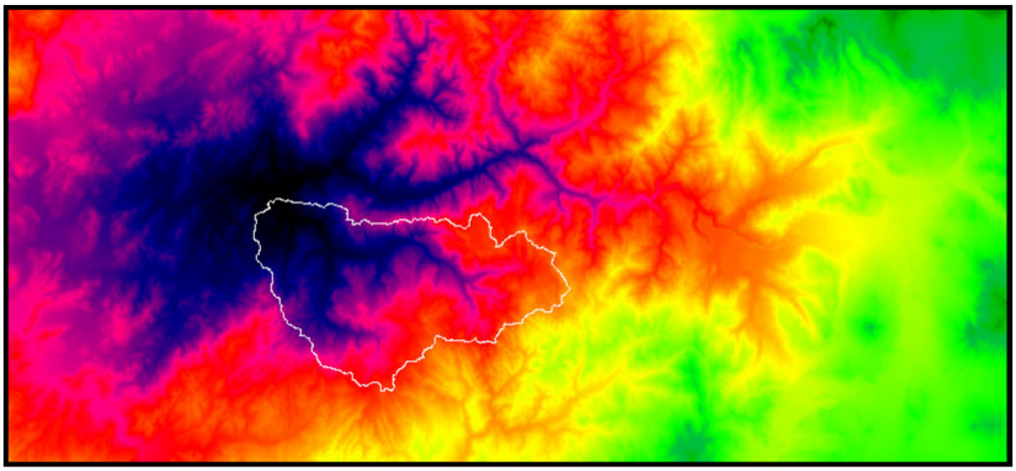


Figure 4.7a: Model 1 Cost Surface Propagated From Colliding Rivers.

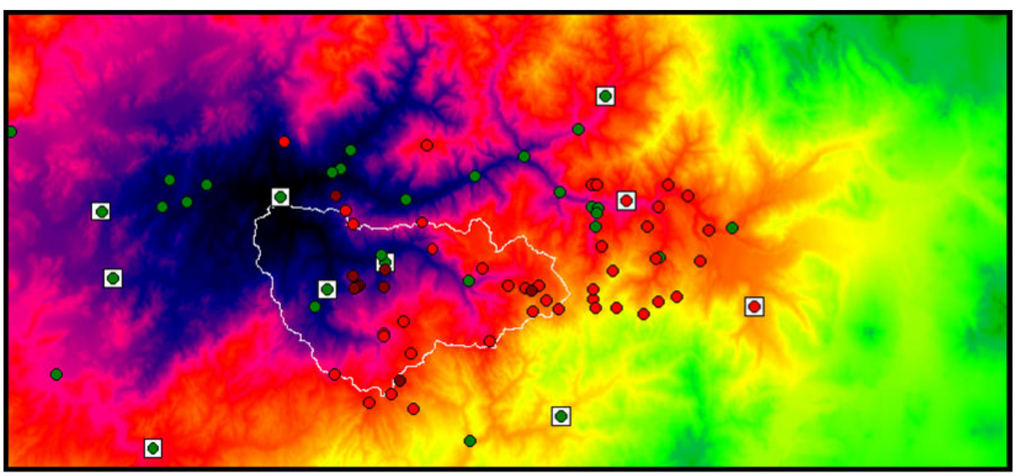


Figure 4.7b: Archaeological Sites and Target Nodes.

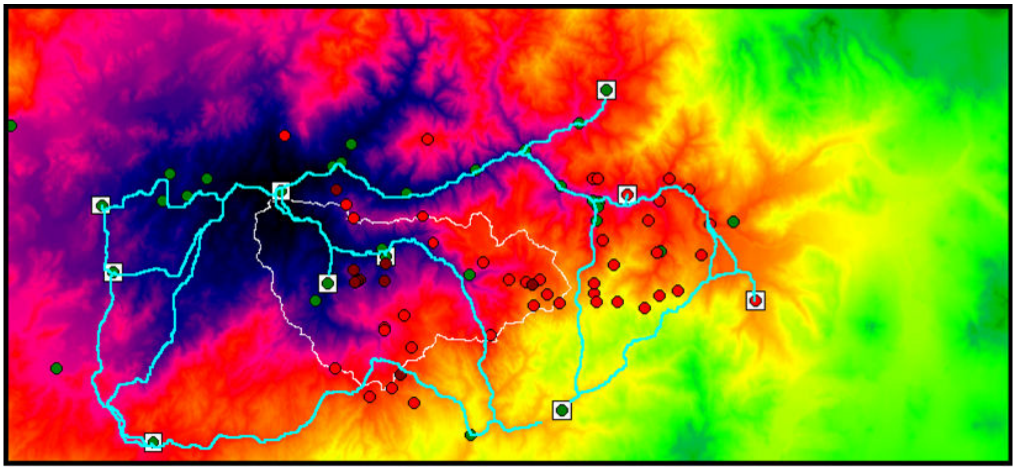


Figure 4.7c: Least-Cost Pathways Among All Target Nodes.
Model 1 is used as an example to illustrate the steps in generating least-cost pathways among archaeological sites. Map 4.7a shows a cost surface generated from the Colliding Rivers site. Idrisi's COSTGROW algorithm moves out in every direction from that site to the map edges, adding the friction values from each cell as it goes (lowest cost destination cells are black, highest cost destinations are green). Map 4.7b shows the locations of archaeological sites used as target nodes (white squares) for running least-cost pathways. Note in Map 4.7c that pathways generated by Model 1 tend to pass near or through archaeological sites associated with rivers (green dots).

4.4.4 Model Validations

The following analyses assess how close the pathways modeled among the 10 target sites come to the set of non-target sites as compared to a set of random points. To avoid edge anomalies, a map window closely bordering the Little River watershed was extracted from the larger study area map (Fig 4.8). Figure 4.9 shows the path networks generated from each of the four friction surfaces described above.

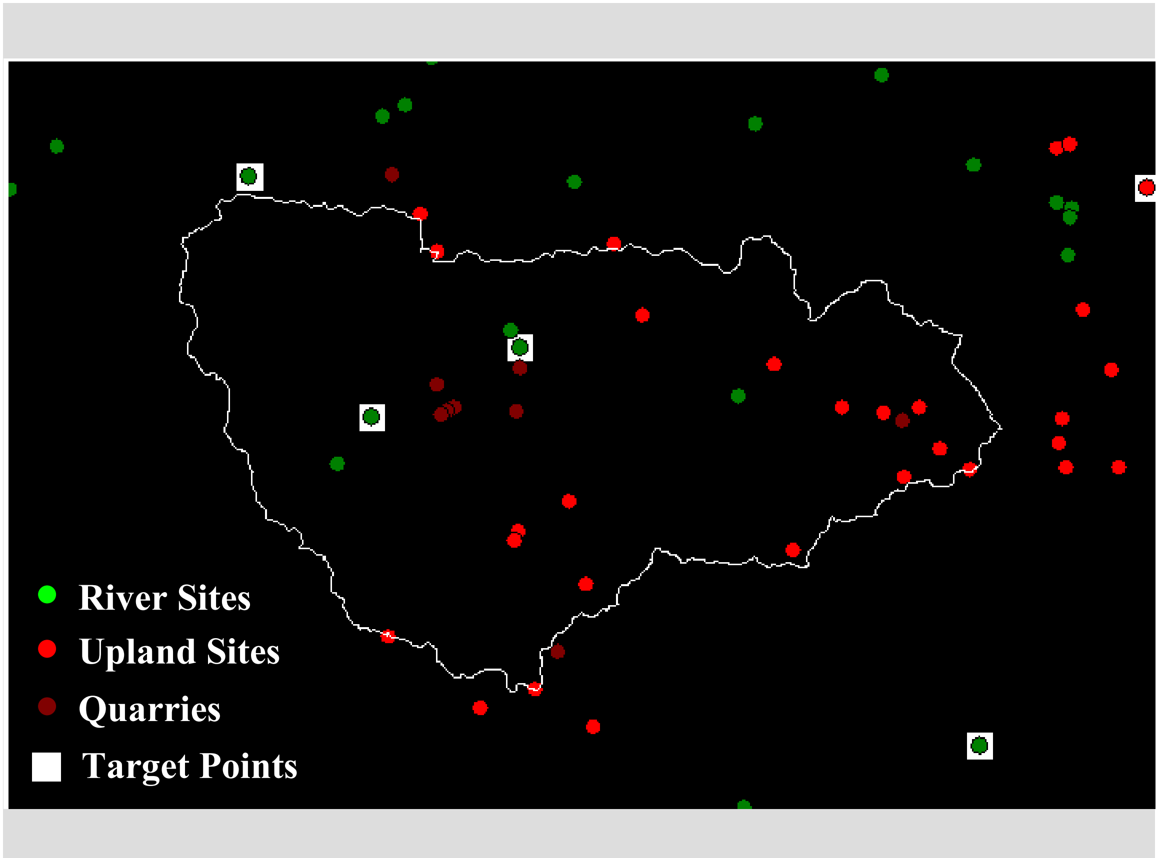


Figure 4.8: Little River Map Window with Archaeological Sites Plotted. Archaeological sites in the Little River vicinity used in the modeling of least cost pathways.

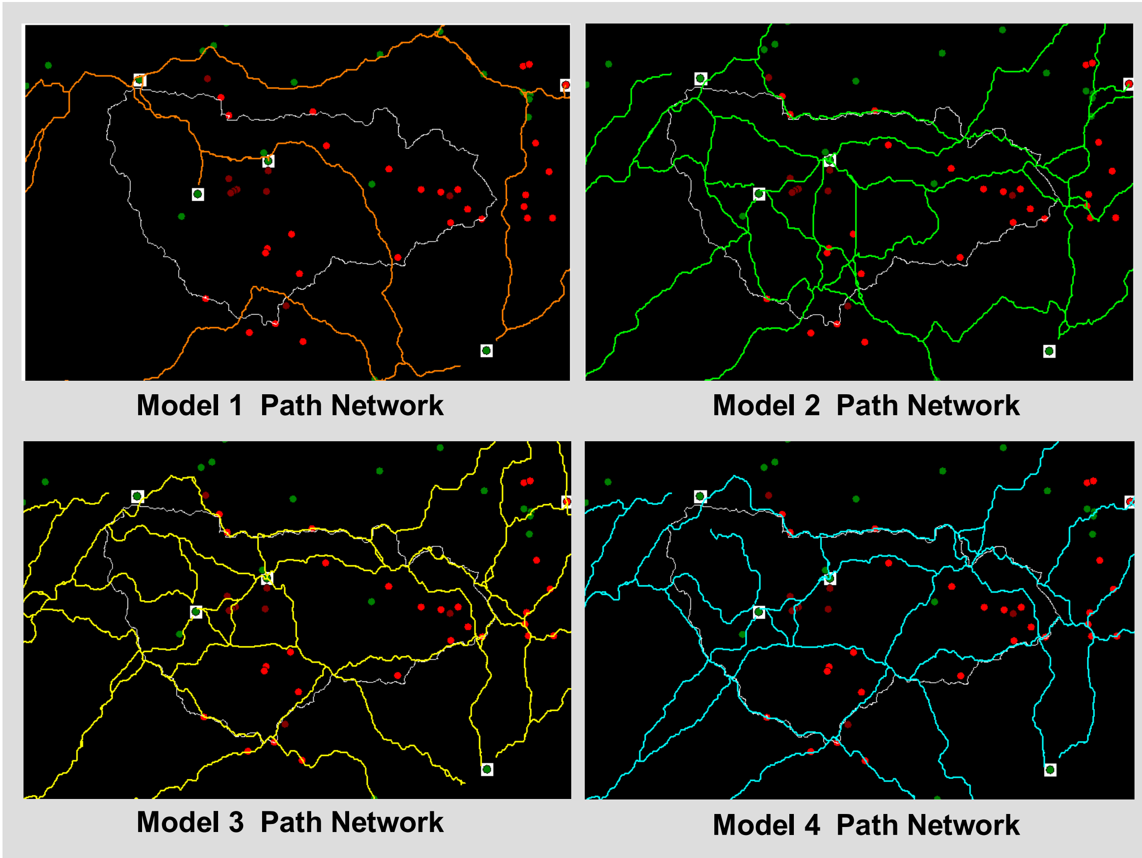


Figure 4.9: Least-Cost Pathway Networks.
All models had a fixed cost for crossing hazardous rivers. Pathway 1 is generated across a cost surface largely based on elevation. Because least-cost paths from this model have a tendency to follow gravity, it does a good job of intersecting river sites (green dots). Pathways 2, 3, and 4 were all based on slope rather than elevation. Because stream friction increases from Model 2-4, the paths are forced to drier ground.

Using Idrisi's DISTANCE module, I produced a distance surface for each travel network. This algorithm moves away from any specified map object (in this case, the travel network pathways) in all directions, and assigns a distance value to each cell as it passes. Figure 4.10 is an example of the distance surface propagated from the Model 1 Path Network.

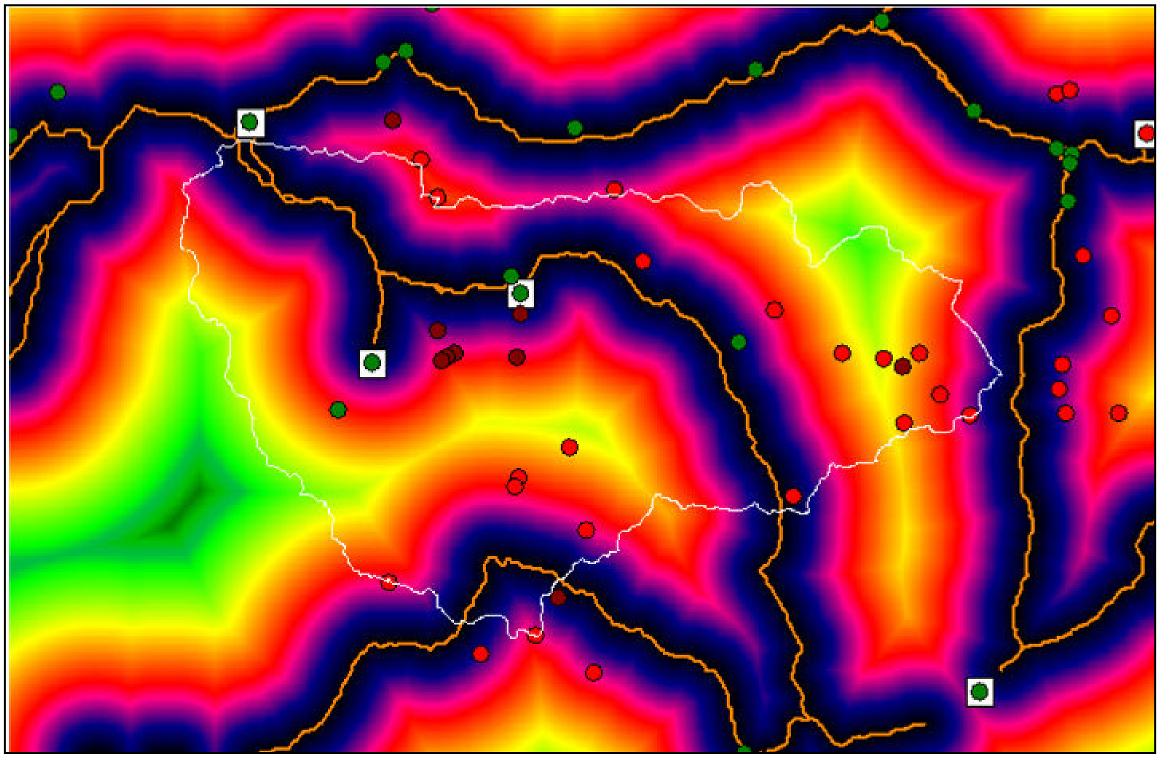


Figure 4.10: Distance Surface from Model 1 Path Network.
Idrisi's DISTANCE module moves away in every direction from the path network feature (orange lines) and adds the distance as it goes. Blacks and blues are close to the pathways, while yellows and greens are farthest away. Archaeological sites are displayed on this surface. Note the close correspondence between this path network and river sites (green) but NOT upland sites (red). Upland sites are strongly correlated to the combination of path networks generated by friction Models 2 and 4.

The match between archaeological sites and each travel network model was then assessed by comparing the proximity of the 52 archeological sites within the map window that were *not* used as target nodes in each model to that network. Because these sites were not used for generating pathways, they represent independent samples.

Once the distance surfaces were completed, I used Idrisi's EXTRACT module to record the distance values from three archaeological site categories to each network. I extracted values for the 15 sites associated with rivers, the 37 upland sites, and the 52 sites of all kinds including toolstone quarries. Then using

Idrisi's SAMPLE module, I generated 15, 37 and 52 stratified random sub-samples from the same map. I then used a standard one-sided t-test to compare the differences in the mean distances of each site category vs. mean distances of the randomly generated samples of the same size.

Although these samples are not normally distributed and have unequal standard deviations, I chose to use a simple t-test for comparing these means because t-tools are robust against departures from normality if the skewness of the samples are similar, and robust against differing standard deviations if the sample sizes are similar (Ramsey and Schafer, 1997). These samples meet both of those criteria.

As a test of the robustness of t-testing using the samples describe above, I ran a comparison using the Wilcoxon Rank Sum test (a non-parametric statistical tool) in the S-Plus statistical software package (Mathsoft, 1997). Results were similar to a t-test on the same data. However, the large number of identical values ("ties") in most comparisons makes ranking problematic. Therefore, t-tools were judged to be more useful than the Wilcoxon Rank Sum test.

An example of this analysis performed for all sites on all four path networks combined is presented in Figs. 4.12 and 4.13. The p-values derived from these tests are quite conservative because (a) the sub-sampling used to meet the t-tools criterion of similar sample sizes greatly decreased the degrees of freedom available for each test, and (b) in many cases paths generated from one node to another pass near or through other target nodes that were not used in generating that particular pathway but were nonetheless removed from the sample.

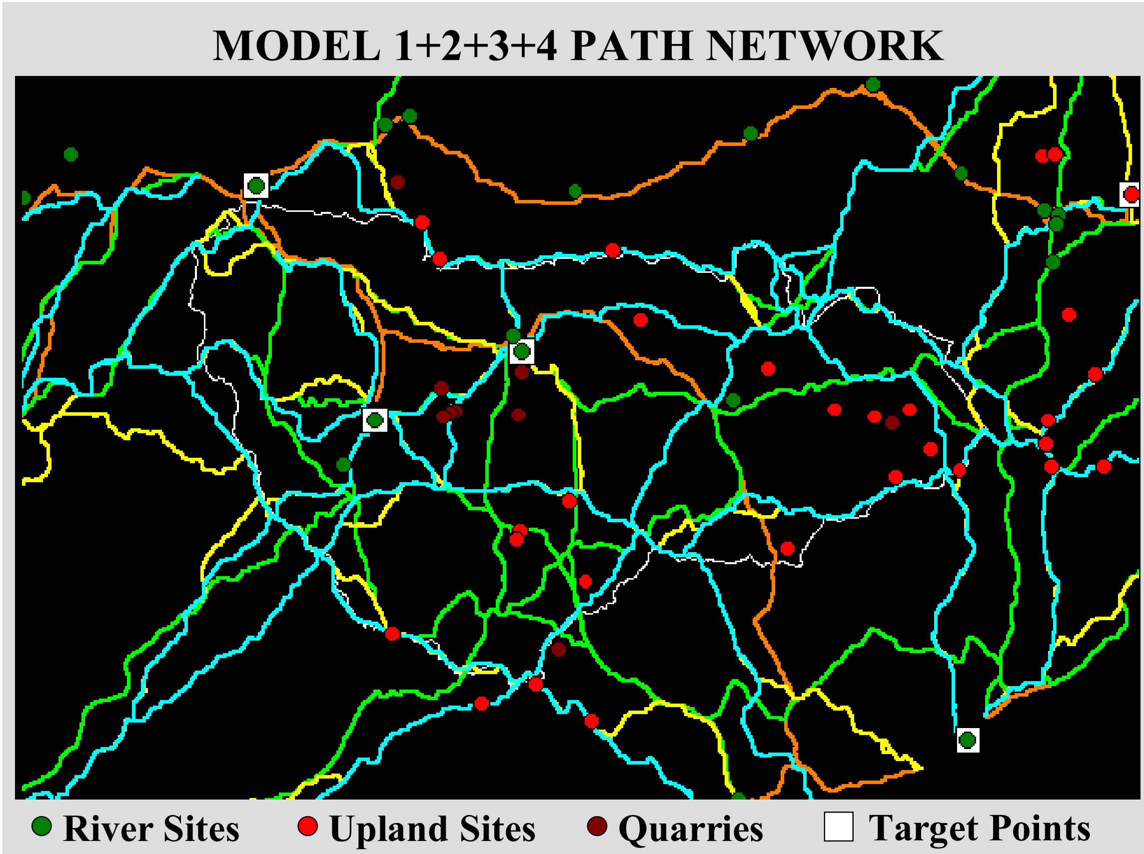


Figure 4.11: Combined Least-Cost Path Networks from All Four Friction Models.
Except for several outliers toward the eastern end of the watershed (to be discussed later), note the strong correspondence of combined paths with archaeological sites. Orange lines represent Path Network 1; green lines = Network 2; yellow lines = Network 3; blue lines = Network 4.

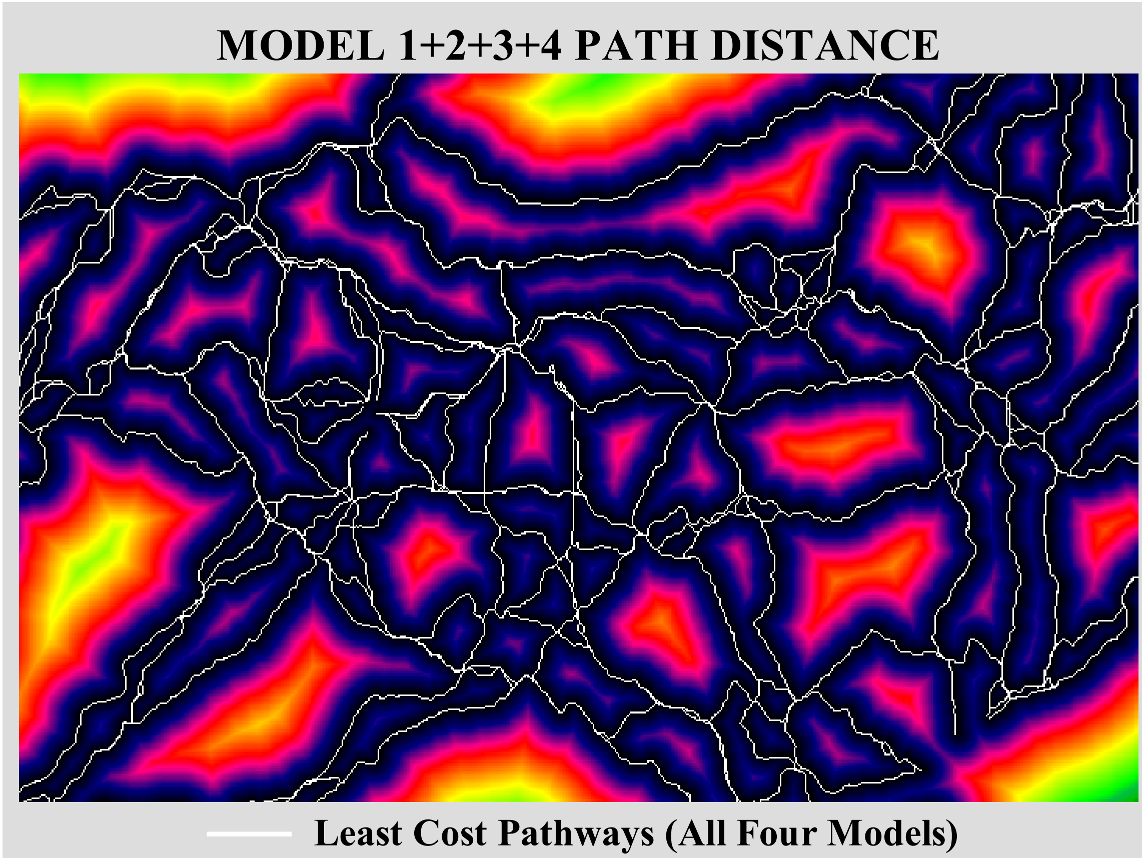


Figure 4.12: Distance Surface from All Four Path Networks.
All 4 pathway networks were combined and used as the feature from which to generate a distance surface. Blacks and blues are close to the pathways, while yellows and greens are farthest away.

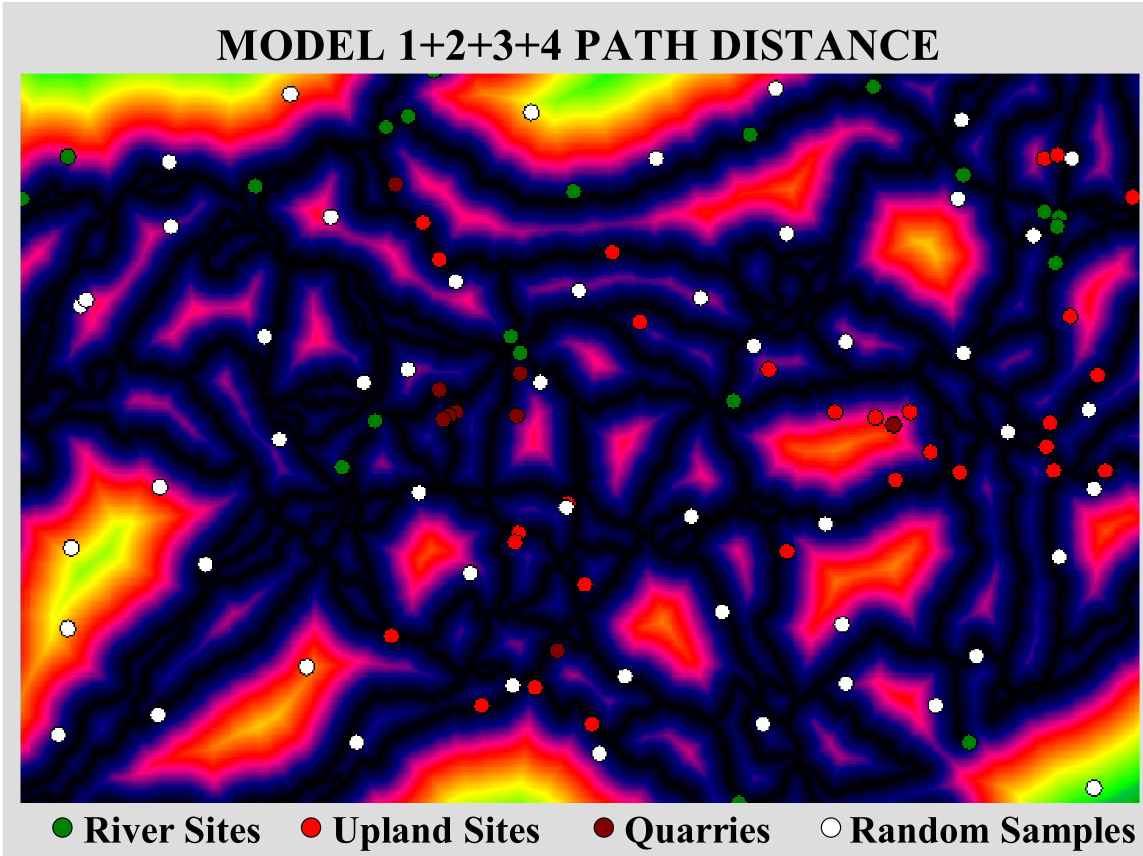


Figure 4.13: All Site Distances vs. Random Stratified Sample Points. The mean distances of archaeological sites from all pathways are compared to the mean distances of a set of randomly generated points to assess the validity of pathway models. Blacks and blues are close to the pathways, while yellows and greens are farthest away. In this case, archaeological sites had a significantly lower mean distance from pathways than did the random points (p=.00054).

4.4.5 Model Evaluations and Network Selection

Archaeological sites near rivers and major streams are most closely associated with Model 1 pathways (p=0.01030). For upland sites, the combination of Models 2 and 4 accounts for the most variation (p=0.00103). The collection of all sites including toolstone quarries are most closely associated with a combination of Models 1, 2 and 4 (p=0.00049), although the difference between that combination and Model 1+2+3+4 (p=0.00054) is negligible.

A visual examination of a map window from the eastern portion of the combined pathway map reveals two interesting features (Fig. 4.14). First, a cluster of “orphaned” sites not associated with any pathway can be seen in the eastern portion of the Black Creek drainage. Second, a number of paths from Models 1, 2 and 4 intersect near the confluences of Black and Clover Creeks with Little River. The archaeological site nearby (Clover) has not been thoroughly investigated and likely extends onto private land (Isaac Barner, pers. comm., 2000).

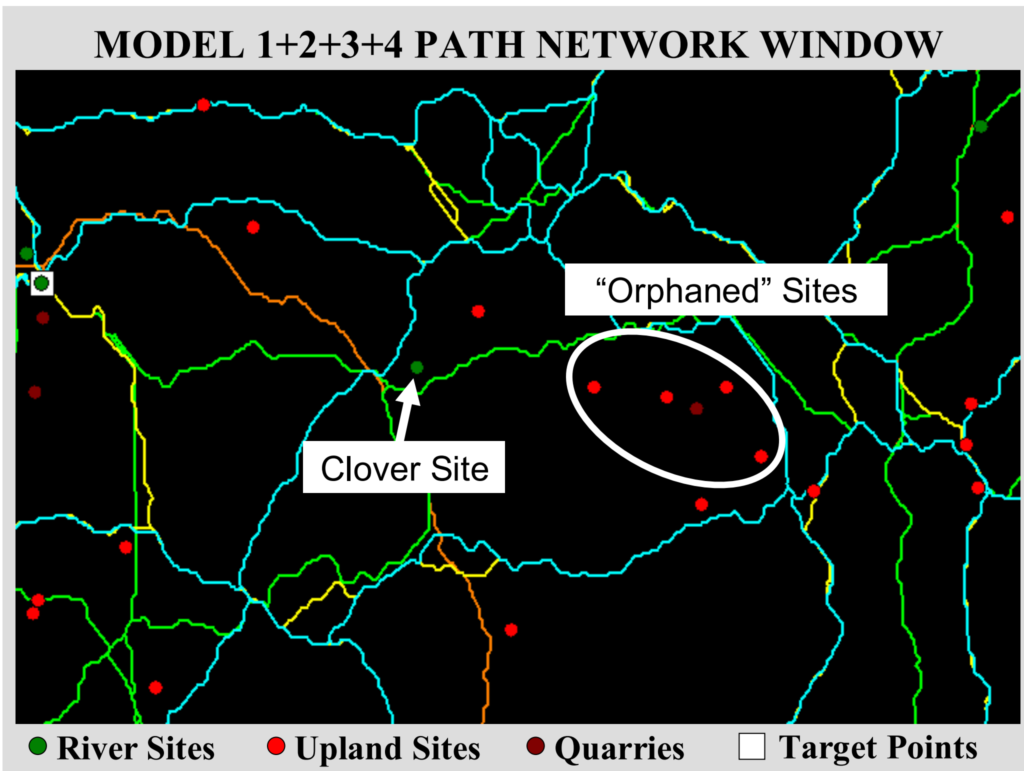


Figure 4.14: “Orphaned” Sites in Relation to the Clover Site.
This figure displays sites that were not spatially associated with modeled pathways. Note the intersection of several pathways near the Clover Site, an identified but unexcavated archaeological site.

Figure 4.15 is a 1946 aerial photo that contains the Clover Site area (rectangle). The light patches are mostly dry grasslands with some rock outcrops. Sinuous meadows and series of open patches can clearly be seen radiating out from the site in close proximity to hypothesized pathways. A closer look at the site (Fig. 4.15, inset) reveals an open meadow surrounded by parklands (open understory old-growth) and young, even-aged stands of dense timber. In addition, this site is on a relatively level bench above the river with good solar exposure, is close to several stream confluences, and is a short distance from a falls that forces salmon through a narrow shoot. These landscape features are all consistent with characteristics associated with many other significant archaeological sites.

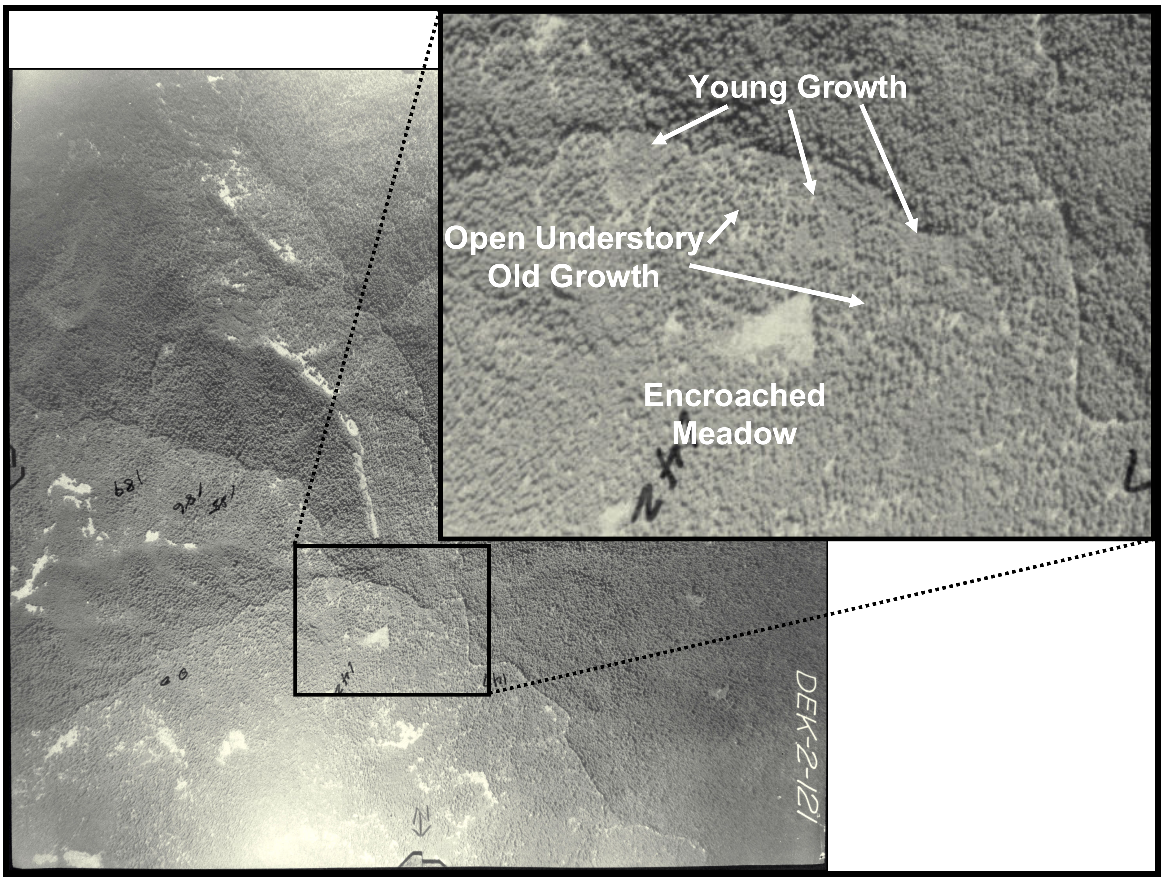


Figure 4.15: 1946 Aerial Photo of Clover Site Area.
The upper window surrounding the Clover site reveals an area that appears to have been much more open in the past. In the larger photo, many patches of encroached meadows embedded in the forest matrix are evident. Note especially the series of meadows on the ridges leading away from the site. *Note: In order to protect the location of the site, photos may or may not be oriented with north at the top of the figure.*

Given the evidence suggesting that the Clover area may have contained an important Native American site, I created a cost surface and ran pathways from there to distant sites to the east. All of the paths took the same routes as the original network except for the path to the easternmost target site (Snowbird). That path (Fig. 4.16, pink line) follows the meadows visible to the left of the rectangle in Fig. 4.15 along the Clover Creek-Upper Little River divide. It continues right past the cluster of orphans and joins the paths running along the Umpqua divide.

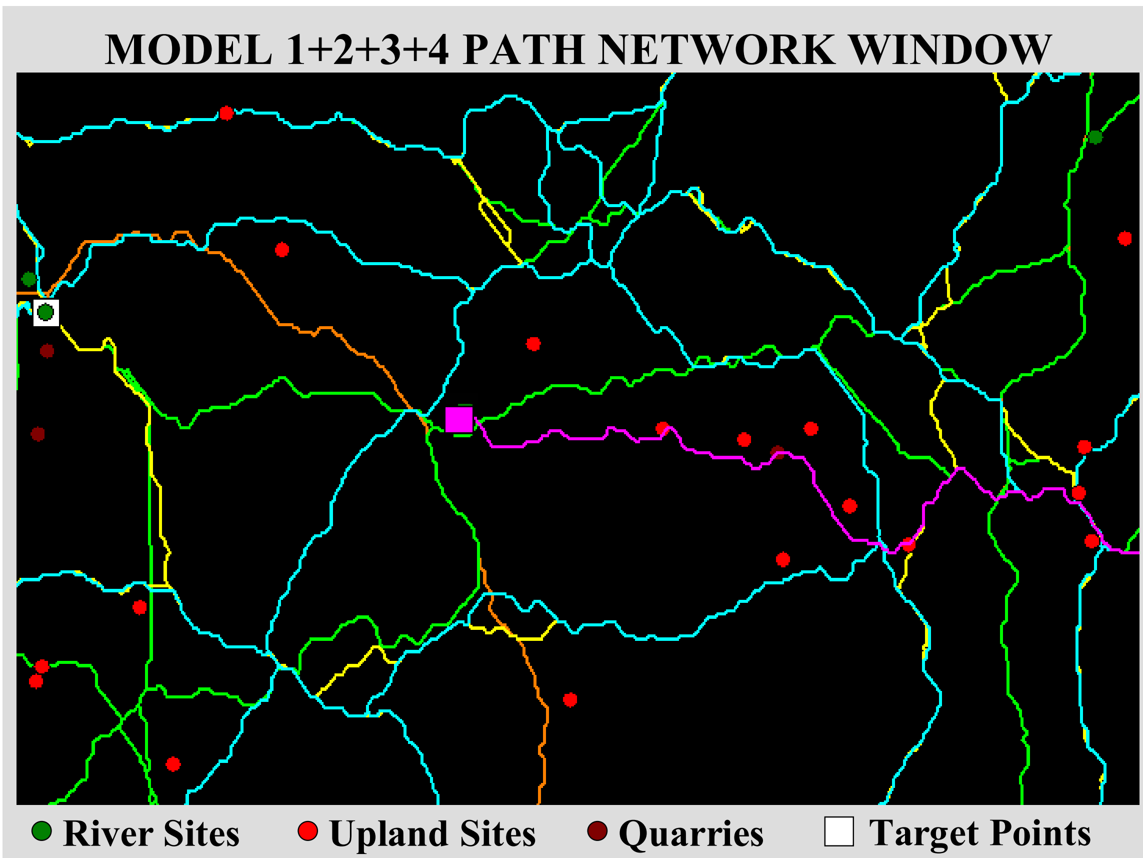


Figure 4.16: Clover Site Pathway.
The pink pathway was generated using the Clover site as a target point. This path corresponds closely with the “orphaned” sites circled in Fig. 4.14.

I added this path to the Model 2+4 upland network and again t-tested mean distances from upland sites vs. randomly generated points. Probability values increased in significance by an order of magnitude from p=0.00103 to p=0.00012. When the new Clover path was added to the Model 1+2+4 network and analyzed for proximity to all sites (with the Clover site removed from the analysis to avoid autocorrelation), p values again dropped an order of magnitude from p=0.00049 to p=0.00005. As noted above, these probabilities are very conservative because even though the Clover site fell very close to several pathways, it was removed before analysis along with other target sites to avoid autocorrelation bias.

Since the travel network that combines the pathways from Models 1, 2, 4, and the Clover to Snowbird path comes the closest to the most independent archaeological sites, this network was chosen for subsequent spatial analyses. For analysis with upland habitats, the Model 1 pathways were removed from the network.

The pattern of these modeled pathways fits the corridor, yard and mosaic pattern common to indigenous landscapes in many parts of the world (Lewis and Ferguson, 1999). It is also reflected in early sketches (see 2.16) and in the following quote from S.C. Bartrum, first Umpqua National Forest Supervisor, writing about conditions in 1899 on what is now the Umpqua National Forest:

> There were no trails into the interior of the Reserve, only a very few short cattle trails close to the Reserve boundary line. There was of course the old Indian trails, indistinct and impassable in many places, *routed to reach the apex of all high points*, presumably for observation purposes, regardless of location and grade, grades vary from level to 35 or 40 percent, and some too steep for horse travel." (my italics)

4.4.7 Potential Uses of Travel Pathway Modeling

Even with a very incomplete cataloging of archaeological sites, the modeling above created pathways that are strongly spatially associated with known archaeological sites. These specific pathway maps may be useful to archaeologists in the Little River area who may want to use them to prioritize their sampling efforts. The modeling and validation methodologies should also have robust applications in other areas.

Use of these modeling techniques also makes possible the development of testable hypotheses in landscape archaeology studies. For example, the intersection of several pathways at the Clover Site (Fig. 4.14), lead me to hypothesize that this was an important site. Pathway modeling using this site as a target node produced a path that passed very close to the “orphaned” sites not intersected by the original models (Fig. 4.16), adding more support to the hypothesis. Further site level analysis is now justifiable to fully test the hypothesis.

The following sections use the pathways that resulted from this modeling effort to test landscape level hypotheses concerning the spatial relationship between historic human activity and fire-maintained habitats.

4.5 HISTORIC OPENINGS AND ARCHAEOLOGICAL FEATURES: SPATIAL RELATIONSHIPS

Many meadows and other historic habitats are pryogenic, both supporting frequent light fires and being maintained by them. Evidence presented in this and in previous chapters suggests that historic fires were more frequent but less severe during aboriginal times than in subsequent cultural phases. If indigenous humans played a significant role in maintaining meadows and parklands, then these habitats should be spatially associated with archaeological sites and with the least-cost pathways connecting them.

4.5.1 Testable Hypotheses

After gathering, organizing and assessing the available data, I developed these testable hypotheses:

> ***H1. Historic openings are significantly spatially correlated with upland archaeological sites.***

> ***H2. Historic openings are significantly spatially correlated with least-cost travel networks among archaeological sites.***

4.5.2 Data and Methods

The GIS layer used for mapping historic openings used in this analysis was created by the North Umpqua Ranger District from a set of aerial photos made in 1946 (Fig. 4.17). Polygons were digitized around habitats within the Little River watershed that were judged by eye to be *water*, *rock*, *wet meadow*, *dry meadow*, *"broken canopy"* (parklands), and *hardwoods* (Ray Davis, UNF Wildlife Biologist, pers. comm.). Because only habitats within the Little River AMA were mapped, I used a tight map window around the watershed for the following analyses.

Historic Openings and Archaeological Sites: The same archaeological site layer used in the previous analysis was also used here to assess the spatial relationship between historic openings and archaeological sites. However, sites associated with rivers and major streams were not analyzed because (1) the number of river sites was so small (n=6), (2) sites close to rivers have experienced more disturbance due to Euro-American agricultural practices, and (3) openings in riparian areas tend to become re-vegetated more quickly due to their milder micro-climates and thus would be under-represented in 1946 aerials (see Fig. 4.15, and note the "young growth" along Little River).

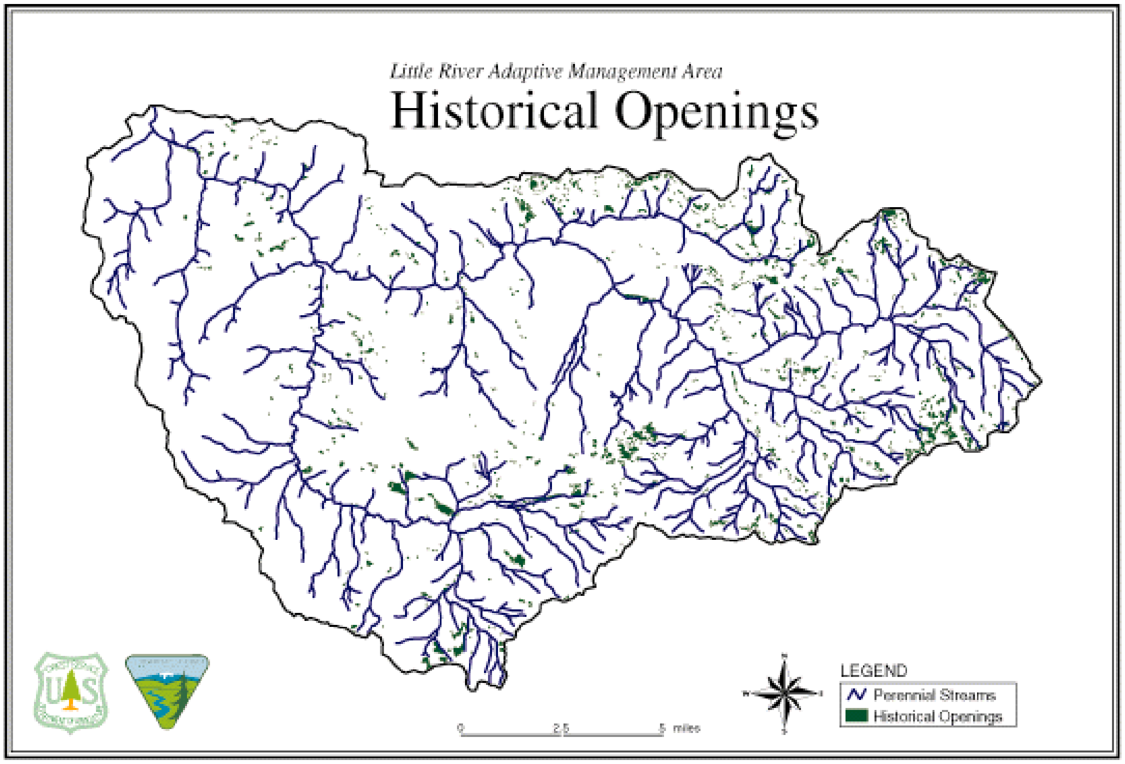


Figure 4.18: Historical Openings Digitized From 1946 Aerial Photos. "Historical openings" mapped by Ray Davis and colleagues at the UNF North Umpqua Ranger District from a set of 1946 aerial photographs. The same GIS layer used to make this map was obtained from the Forest Service and used to analyze the spatial relationship between upland archaeological sites and unique habitats in the Little River watershed.

To look for a spatial relationship between upland archeological sites and historic habitats, I first used Idrisi's DISTANCE module to construct distance surfaces from all meadows; all meadows and parklands; all meadows, parklands and hardwoods; and all meadows, parklands, hardwoods and rock (Fig. 4.18). Next, I used the EXTRACT module to first record the set of minimum distances from each archaeological site to the closest habitat polygon, and then to record the set of distances from a randomly generated set of points to the closest habitat polygon. Finally, I used t-tools to test for statistical differences in mean distances between sites and random points.

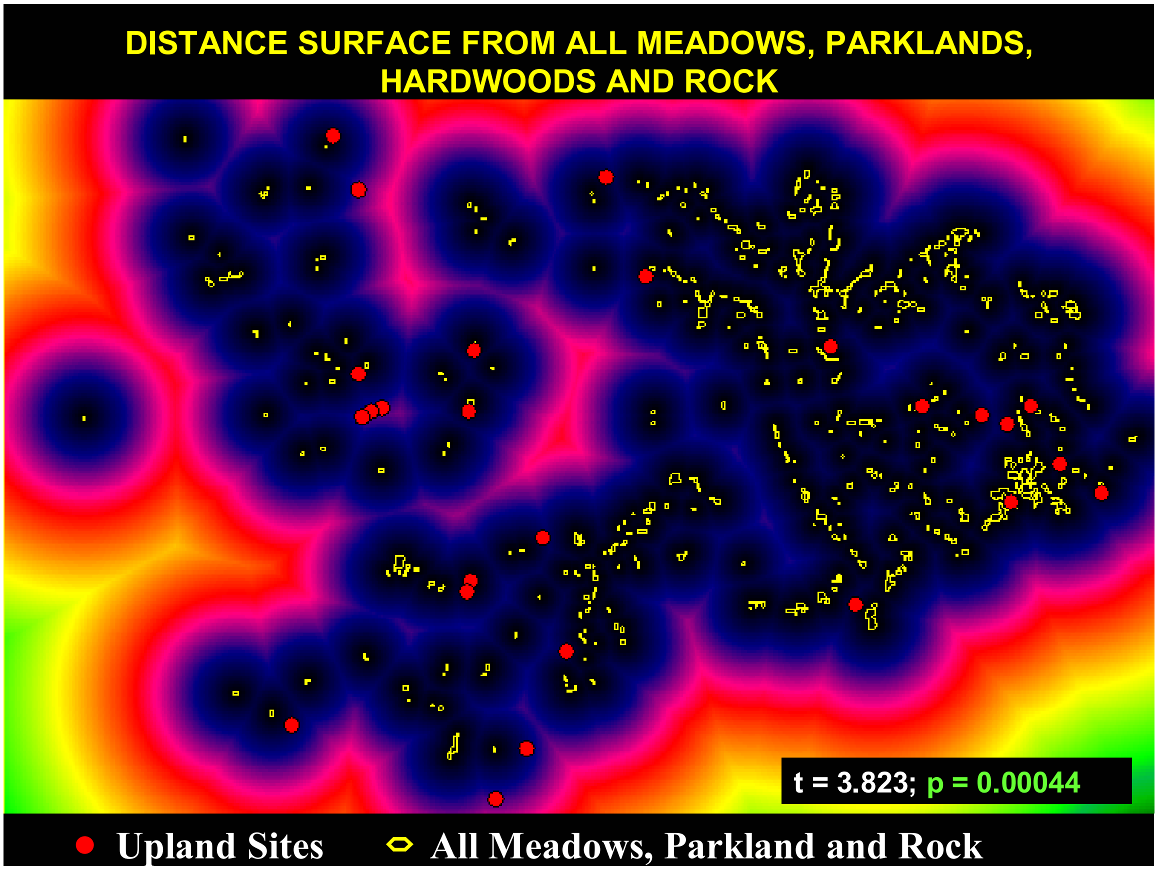


Figure 4.19: Association Between Upland Archaeological Sites and Historic Habitats.
Blacks and blues are close to habitats, while yellows and greens are farthest away.
Upland archaeological sites are far more likely to be spatially associated with meadows, parklands and rock outcrops when compared to a set of random points (p = .00044).

Historic Openings and Travel Pathways: Because the travel network composed of paths from Models 2+4 had the most significant spatial association with *upland* archaeological sites, this network was used for the analysis outlined below.

To determine the strength of the spatial relationship between historic habitats and the travel pathways modeled in the previous section, I used only the wet and dry meadows from the same historic habitats GIS layer displayed in Fig. 4.19. Using travel networks 2+4 and 1+2+4 described earlier in this chapter, I generated another set of distance surfaces using Idrisi's DISTANCE module. I then extracted minimum distance values for each habitat polygon and compared their mean to the mean of a similar number of Idrisi-generated stratified random points (Clark Labs, 2002) using t-tools. Since the North Umpqua Ranger District's photo analysis GIS layer for meadows was dominated by habitats in the eastern portion of the Little River watershed, I used a mask for creating random points that eliminated those parts of the watershed for which no meadows were identified.

4.6 RESULTS AND DISCUSSION

4.6.1 Historic Openings are Associated with Upland Archaeological Sites

Federal law and professional ethics make acquisition of spatial archaeological data difficult, and many sites are undoubtedly undiscovered or unreported. Thus, only 18 sites were used in this analysis. These limitations notwithstanding, the above analysis indicates that historic meadows are still much more likely to be found near archaeological sites than a similar number of random points.

When distances from upland archaeological sites to all meadows (wet and dry) are compared with distances to random points, t-tested means differ significantly ($p=0.00408$). Although the addition of hardwoods and parklands to the distance surface did not increase the strength of this association ($p=0.00471$ and $p=0.00463$, respectively), that may be more a function of the difficulty of mapping those stands from 1946 aerials, therefore yielding small sample sizes.

With the addition of the category "rock", the strength of the association jumps dramatically ($p = .00044$) (Fig. 4.18). This may suggest that the shelter and toolstone offered by rock formations were strong attractors of native peoples. It may also mean that the thin soils often associated with rock outcrops and ridge lines were easier to maintain as corridors than other landscape features, or that upland meadow soils are too poor to support forests at all.

This last of these three alternatives seems the weakest. The vast shrinkage in the area of native meadows and savannas on the Umpqua due to the in-growth of cohorts of young trees (see Chapter 2) when the region was reportedly becoming drier (Whitlock and Knox, 2002) suggests that soils rarely prevent forest establishment in the Little River Watershed.

Whether indigenous peoples were attracted to rock outcrops and created meadows around them, or whether meadows were easier to maintain on the soils associated with rock outcrops, the historic pattern is clear: indigenous people, meadows and rocky places were strongly associated across the upland landscape in the Little River watershed.

It is possible that the archaeological record is spatially biased by commercial logging. Cultural resource surveys were increasingly mandated toward the end of the 20th century, forcing the federal agencies to send archaeologists to proposed timber sale units. This caused most agency specialists to spend a disproportionate amount of their time surveying the higher, steeper ground being logged at the time (the flatter, more accessible sites having been logged before cultural surveys were federally required). A systematic survey for cultural sites in the Little River watershed would help to establish the extent and direction of this potential bias.

In addition to gaps in the archaeological record, the historic habitat GIS layer used in this analysis also appears to be incomplete. Figure 4.20 is one of the 1946 aerial photos from which the layer was created. The three known archaeological sites labeled on this image are clearly associated with meadow habitat, yet those meadows do not appear on the North Umpqua Ranger District habitat GIS layer, most likely because this area is private land and at the opposite end of the watershed from National Forest land.

All of the data issues outlined above would tend to *decrease* the strength of the associations between archaeological features and historic openings. Even so, there is still a strong association between known upland archeological sites and mapped historic meadows.

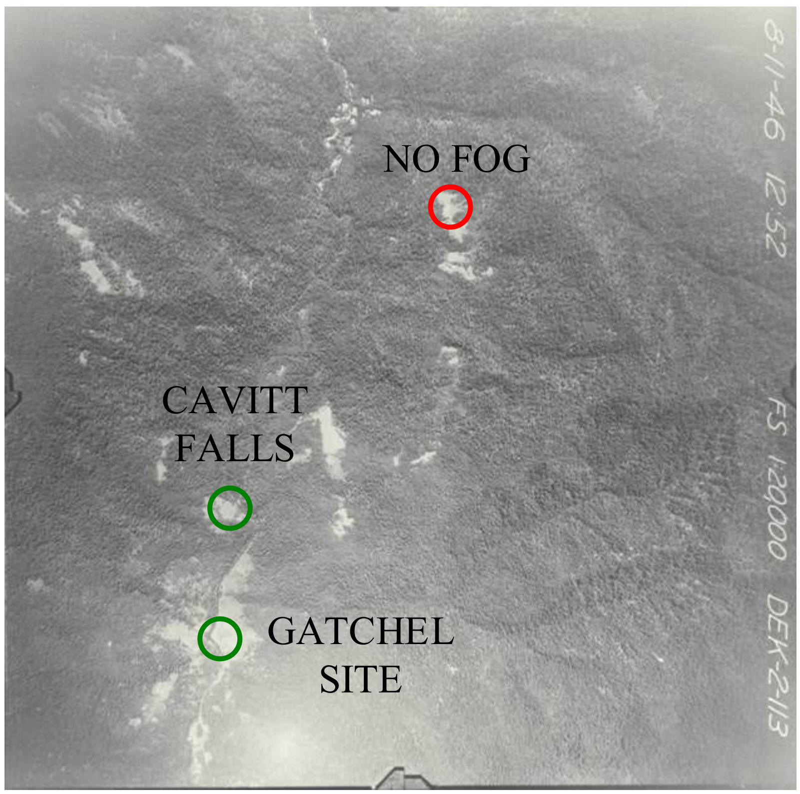


Figure 4.20: Sites Associated with Un-mapped Openings.
These archaeological sites are clearly associated with open habitat in 1946 – but these openings are *not* recorded on the USFS GIS layer. The addition of openings from the west side of the Little River Watershed to the N. Umpqua historic habitat GIS layer would have considerably strengthened the statistical match between archaeological sites and historic openings.

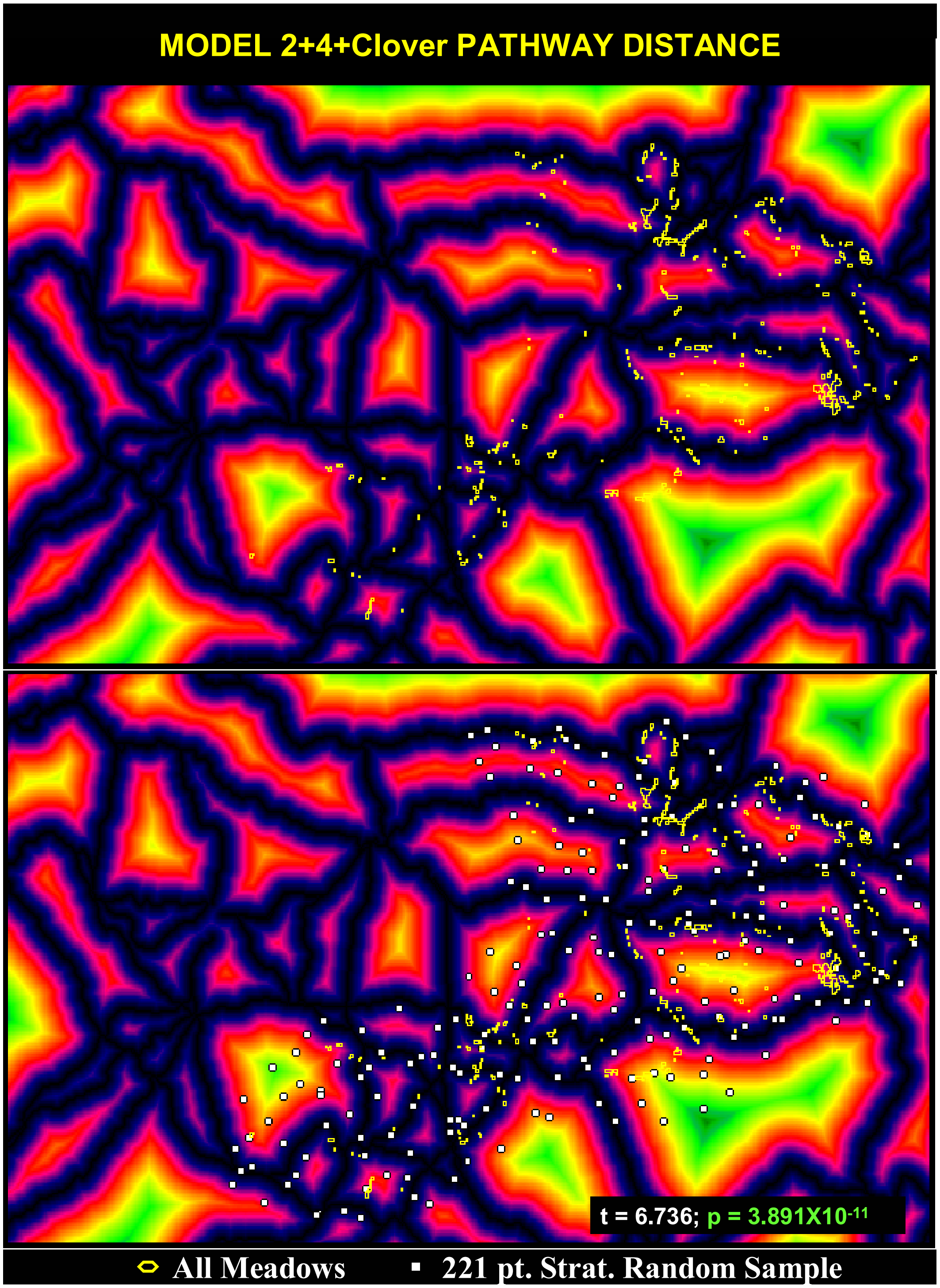


Figure 4.21: Association Between Travel Pathways and Historic Habitats. Yellow polygons are meadows interpreted from 1946 aerial by the North Umpqua Ranger District. White points are a stratified random sample of the portion to the watershed that had mapped meadows for statistical comparison. Meadows are strongly spatially associated with modeled travel pathways.

4.6.2 Historic Openings are Associated with Travel Pathways

The spatial relationship between meadows and least-cost travel networks is striking. When meadow distances from Model 1+2+4 pathways are compared with random distances, means differ dramatically ($p=5.708 \times 10^{-9}$). When distances from historic meadows to upland pathways alone (Model 2+4) are compared to random points, the association strengthened even further ($p=3.891 \times 10^{-11}$) (Fig. 4.21).

Such extraordinarily high p-values caused me to re-examine the analysis to look for potential bias or autocorrelation. I identified the following issues that could potentially bias these results:

First, since travel path Models 2 and 4 are drawn toward flat topography, they tend to follow ridges (see Sect. 4.4, this chapter). Ridges are more likely to have thinner, dryer soils than other geomorphological features and thus be less able to support forests. But Fig. 2.20 clearly shows a progression of tree growth on ridges for 63 years, and all but the wettest and driest meadows are currently being encroached by timber (Little River Watershed Analysis, 1995).

Second, wildfires tend to crown as they move upslope, making trees at the ridgelines more likely to be exposed to high severity fires. However, much evidence indicates that flat ground in river bottoms and on creek benches were once open parklands and grasslands as well (see Fig. 4.15 and Clover Site analysis below). These vegetation types would require (1) high intensity stand replacing fires to initially create these openings, and (2) frequent, low intensity fires to maintain them. These events are unlikely without human intervention because lightning strikes are less frequent in such topographic positions, and fires burning on flats in riparian areas are much less likely to crown in the first place (Agee, 1993). Thus, many lowland areas with young, even-aged timber stands such as those found at the Clover site may well be abandoned meadows that have simply regenerated faster than their upland counterparts, and were not mapped as openings in 1946. Moreover, the consistency of the corridor and yard pattern suggests a more systematic process than lightning across the landscape (Fig. 2.16).

Third, Indians had been officially removed from the Little River area over 90 years before the air photos used to map historic meadows were taken, so Indian influences on forest patterns by 1946 might be expected to have been minimal. But historic reports cited above indicate that burning by Indians continued into the early 20th century. Moreover, the parts of the landscape least likely to be abandoned by native peoples were the mountain trails and camps that were least likely to be used by Euro-Americans.

No single line of evidence for indigenous use of landscape fire developed thus far is by itself a “smoking gun”, but taken together they consistently reinforce the findings of previous chapters: that the Indians of the Umpqua Basin had a strong hand in the management of their landscapes. Indigenous people favored gentle ground near streams and rivers for fishing camps and village sites, and ridgeline trails for traveling through the mountains. Systematic, low-intensity fires maintained grass, forb and brush species that provided food and fiber to indigenous cultures. The type and pattern of aboriginal fire is reflected in the corridor and yard pattern at the landscape level, and in the open understory stands (Fig. 4.15) and meadow habitats associated with archaeological sites at the stand level.

CHAPTER 5: DISCUSSION AND MANAGEMENT RECOMMENDATIONS

5.1 INTRODUCTION

The results of investigations carried out in this dissertation indicate that the forests of the Little River watershed in southwest Oregon have undergone dramatic changes in pattern and process at multiple spatial scales, and that both ancient and modern humans have had important impacts on their landscapes.

In Chapter 1, I posed two research questions that provided a framework for developing and testing hypotheses concerning the causes and magnitude of landscape change in the Little River watershed:

> ***1) How have ecosystem conditions changed through time in southwestern Oregon?***
>
> ***2) How have culture-driven and climate-driven processes contributed to ecosystem change in southwest Oregon?***

Answers to the first question and part of the second can be found in historical records, archaeological evidence and ecological data from the Little River watershed and the surrounding region. These were used to converge on a picture of an indigenous landscape in which a mix of lightning and small, frequent, low intensity Indian-set fires produced a forest matrix dominated by uneven-aged stands with open understories (Chapter 2). A corridor and yard pattern of openings (Lewis and Ferguson, 1999) was spatially associated with archaeological sites and the ergonomic pathways connecting them (Chapter 4), and were likely the result of more systematic burning than in the matrix.

Culture-driven landscape reconfiguration is evident in the sequence of changes described in Chapter 2 (Table 5.1). The corridor, yard and mosaic arrangement created by systematic landscape burning has been converted to a patchwork matrix of overstocked, even-aged plantations with embedded patches of old-growth (much of it at historically high densities) and other legacy habitats.

Patterns of climate-driven effects on the landscape, however, are less obvious. Analyses presented in Chapter 3 found no significant linear relationships among precipitation index, the percentage of trees scarred annually, or yearly tree recruitment from 1590 to 1820. However, from 1850-1950, weak to moderately significant correlations were observed between all of the pairs, with fire having the strongest effect on tree recruitment. Although significant serial correlation exists to some degree in all three datasets, we used cross correlations on year-to-year differences (rather than absolute values) and again found no significant correlations between scarring and tree recruitment at any lag during aboriginal times (Fig. 3.11 a), while after 1850, several significantly correlated lags are evident, including one between the percentage of scarring in one year and regeneration in the following year (Fig. 3.11 b).

The lack of discernable patterns in the data during aboriginal times, but the significant correlations between precipitation, fire and regeneration after 1850 suggests two possibilities: either (a) the data are flawed and/or the appropriate analyses have not yet been tried (see Sections 3.2 and 3.4), or (b) systematic, indigenous landscape fires overrode precipitation effects and obscured a climate signal until human-set landscape fires became increasingly uncommon in the early to mid 1900s (CVS, 1995). The results of the analyses in Chapter 2 and 4 are all consistent with the second possibility.

CHANGES IN FOREST CONDITIONS
CHANGES IN FOREST STRUCTURE
• ***Old-growth matrix with grassland patches → early seral matrix with old-growth patches.***
• ***Multi-cohort stands → even-aged stands.***
• ***Decrease in large trees at stand and landscape levels.***
• ***Increase in stand densities.***
• ***Fire tolerant species → fire intolerant species.***
• ***Decrease in native structural and biotic diversity at stand and landscape levels.***
CHANGES IN FIRE PATTERNS
• ***Many small → few large.***
• ***Frequent → Infrequent.***
• ***Low-intensity → high-intensity.***
CHANGES IN FOREST MANAGEMENT
• ***Corridor and yard maintenance → dispersed clearcuts.***
• ***Ridge and river intensive → whole landscape intensive.***
• ***Major disturbance agent from fire → logging.***
• ***Systematic ignition to systematic suppression.***
• ***Extensive management → Intensive management.***

Table 5.1: Landscape and Stand Level Trends in the Little River Watershed.
Summary of changes in landscape and stand level forest conditions from aboriginal times to the present.

It is also interesting to note that, although large spatial scale trends have been found in the interactions of temperature and precipitation with the numbers and sizes of post-aboriginal fires (McKenzie et al., 2004), no significant linear trend was observed between fire scar percentage and tree recruitment from 1920 (beginning of fire suppression) to 1981(end of tree ring record). This suggests that humans are again overriding precipitation, this time by *suppressing* fires.

Evidence that the indigenous people had an active hand in influencing the fire regimes that shaped their landscapes has important implications for current managers. Rather than a conversion of unmanaged land to managed lands, the changes witnessed in the last 150 years are more indicative of a change from one management regime to another, with a brief period of passive management in the late 1800s and early 1900s. The message to land stewards is clear: *taking no action will* ***not*** *tend to return the landscape to aboriginal conditions.*

I will provide evidence below to support the arguments that (1) going back to pre-European landscape conditions is no longer possible, and that (2) late 20th century management (passive and active) has increased stand densities, has decreased timber productivity, and has promoted large, intense wildfires. I will then argue that pre-Euro-American landscape dynamics represent the last known stable state of the Little River watershed, and as such represent the default conditions toward which to manage until experimental evidence proves otherwise. I then provide a set of landscape-specific suggestions for moving the Little River landscape back toward indigenous conditions while still meeting the "desired future conditions" set out in the Little River AMA Plan (1997).

5.2 ECOSYSTEM CHANGE IN THE LITTLE RIVER WATERSHED: CAUSES AND CONSEQUENCES

The historical and ecological evidence from the Little River watershed and from nearby forests presented in previous chapters documents a number of trends away from historical conditions (Table 5.1). Intensive agricultural and forestry practices in the Pacific Northwest have generated forest conditions that by most measures are well beyond indigenous ranges of variation for the Pacific Northwest at both the stand and landscape levels. For example, in the nearby Oregon Coast Range, Spies and Pabst (2004) paint the following picture:

> Forests and watersheds of the Oregon Coast Range have been altered by Euro-Americans since the days of Lewis and Clark. Coastal and interior valleys were cleared for agriculture in the 1800's while logging, grazing and wildfires impacted vast areas throughout the 20th century. Significant changes in biodiversity include loss of forested valley bottoms through conversion to agriculture and development, loss of large conifers and old-growth forest structure through conversion to relatively uniform conifer plantations, alteration of the structure and dynamics of riparian zones, and alteration of oak woodlands through removal of fire.

The authors conclude that current conditions are beyond historic ranges of variation. These changes appear to be mirrored in the Little River watershed. The causes and consequences of these striking shifts will be reviewed below.

In addition to the results from Chapter 2 and 4, and the findings of other research from the region, I cite the findings of the 1995 Little River Watershed Analysis (LRWA). This comprehensive document combined expert opinion from agency scientists and resource specialists with intimate knowledge of the local area, along with data from the watershed and from regional studies to draw a number of important conclusions concerning the ecological state of the watershed. The Little River Adaptive Management Area Plan (LRAMAP, 1997) is an extension of the LRWA, and "…sets a course for adaptive management following a shared vision of the desired future condition for federally administered lands located in the Little River watershed." Drawing on all of these sources, I will use the ecosystem reference parameters outlined in Chapter 1 as a framework for summarizing the causes and consequences of changes in fire behavior, forest matrix structure, corridor and patch characteristics, and management patterns in the Little River watershed.

5.2.1 Changes in Fire Patterns

Landscape fires in southwestern Oregon have gone from (1) being regular, frequent, and of low intensity, to (2) being irregular, infrequent, and of high intensity. A number of lines of evidence support these conclusions.

In the valley grasslands and savannas, evidence from fire scarred oak stumps supports the 1-3 year intervals noted in many settler accounts (see Chapter 2). Moreover, many upland meadows that are no longer being frequently burned are rapidly being encroached and overgrown by the surrounding forest. This has happened much more quickly in dry vs. wet meadows (LRWA, 1995).

As noted in Chapter 2, most of the upland tree regeneration that occurred during the transition from Indian occupancy to the present culture consisted of cohorts of younger, fire intolerant species in the understories of fire tolerant older stands (Fig. 2.22; Table 2.1). This suggests that the overstory developed in the presence of frequent, low intensity ground fires, and that the understory is a response to their absence. The LRWA concludes that "Today there is a trend toward a *low frequency, high severity fire regime*, which is characterized as a severe surface or crown fire that results in total tree mortality… Fire return intervals are long and *may not be cyclic*. …fuel loads are on a trend to becoming *well above normal levels* in Little River. Stand conditions present today are a precursor to heavier fuel loads" (my italics).

The LRAMAP notes that "Prior to affective fire control (pre-1940s) fires of moderate severity burned often, mostly as ground fires…" and concludes that

"Today's more intense fire regime can be tied to the amount and structure of live in deadwood fuels resulting from decades of effective fire exclusion." The LRWA cites some pointed statistics:

> Today, aerial retardant, helicopter delivery of water and people, educational prevention programs, 800 miles of open roads, fire engine capabilities, plus well trained and equipped fire fighters have all increased the ability to extinguish fires within the first 24 hours of their detection. Extreme weather and multiple starts in combination with delays in initial attack are what allow fires to escape under today's conditions. In the western United States today, 97 percent of all fires are contained to less than 1/4 acre; the other 3% make headlines.

Increases in the time between fires and the intensity of the blaze have apparently also been accompanied by an increase in the size of fires. The largest historic fires in the Little River watershed were calculated to be no larger than about 7,000 acres (Van Norman, 1998). This is significantly smaller than the recent fires on the Umpqua and in southwestern Oregon (see Chapter 2). Historical accounts by John Leiberg (1900) observed burns "chargeable to the era of Indian occupancy" that were "small, circumscribed fires…of frequent occurrence". The fact that Leiberg categorizes four to five thousand acre fires as "large ones" suggests that aboriginal fires were typically much smaller than recent fires.

In order for fire to be used as a landscape management tool to keep vegetation densities low, it must be used systematically (Lewis and Ferguson, 1999). A number of area pioneers observed Indians burning grasslands and forests in the fall, generating many low intensity fires (see Chapter 2 and 4). A consistent, targeted pattern of burning by the Indians of Little River would explain the historic corridor and yard pattern described in Chapter 2.

Aboriginal management fires were markedly different from the fire prescriptions used by current managers. During the last half of the 20th century, fire was used almost exclusively for slash disposal after clearcutting. Fires burning through the thick layer of limbs and cull logs typically left on logging units were often hot enough to remove much of the humus and create hydrophobic soils that exacerbated runoff and erosion (Smith et al., 1997). Thus, an endogenous system of extensive, low intensity landscape level fire used to promote diverse food and fiber resources and to maintain camps and trails has been replaced by an exogenous system of concentrated, high intensity site level burns designed simply to clear the site for the next uniform tree plantation.

5.2.2 Changes in Landscape Patterns

Historic sources and ecological data (see Chapter 2) chronicle dramatic changes in southwestern Oregon landscapes in the types, proportions, arrangements and sizes of landscape components. These changes were almost certainly driven by a shift in management practices and intensities across the landscape from the time of Indian occupancy to the present.

The pattern of “fire yards” and “fire corridors” (Lewis and Ferguson, 1999) superimposed on a mosaic of uneven-aged forest matrix (see Figs. 2.15, 2. 16, 4.15) has given way to the near complete conversion of native forest to rectilinear plantations on private and BLM lands (Fig. 2.9 and 2.17), and to the extensive “staggered setting” clearcutting of Forest Service lands (Fig. 2.19 and 2.20). The analyses of archaeological sites and travel corridors conducted in Chapter 4 strongly associate native people with the type of corridor and yard features seen in the historic drawings and photos referred to above. Therefore, rather than representing a conversion from an unmanaged landscape to a managed one, these changes in landscape pattern reflect the change from one management system to another.

Historic, ethnographic and ecological evidence all point to changes in the sources and patterns of ignition that generate landscape fires. Aboriginal landscape patterns were maintained by systematic ignition (see Chapter 2 and 4) while current landscape patterns are influenced most by logging and systematic fire suppression (Fig. 3.10). Lewis and Ferguson (1999) note the differences between lightning and human-caused fires:

> Fires and the resulting fire mosaics are caused by both natural events (almost always lightning) and (to varying degrees) scheduled human activities. There is, however, an important difference in magnitude between natural and anthropogenic mosaics, specifically… in the "pattern and scale of burned and unburned patches." Natural fire mosaics are characterized by larger, less frequent, but usually hotter burned stands of vegetation; human-made fire mosaics (at least those fire-maintained hunter-gatherers) entail smaller, more frequently, and more lightly burned patches of growth. These dissimilar characteristics result from the fact that natural and hunter-gatherer fires are set at different seasons and with different frequencies, and hunter-gatherer fires are set under essentially safer, managed conditions.

In addition to historic and ethnographic evidence, support for the hypothesis that Indians were actively creating and maintaining historic landscape patterns comes from other sources as well. Many flats (yards) were in an open condition when Euro-Americans first arrived. These are not landforms in which fires would be expected to crown and cause high-severity fires (Agee, 1993). Therefore, in order to explain the inordinate amount of openings on flat ground (especially in cool, moist riparian areas – see Fig. 4.15), different timing and intensities of landscape fires must be invoked than would be expected from lightning-driven fire regimes.

The consistency of the patterns of corridors and yards (Chapter 2 and 4) also suggests that they were maintained by a systematic agency. Although ridges are quite likely to experience high severity fires by virtue of their topographic position (Agee, 1993), the proportion of burned-off ridges evident in historic photos supports ethnographic and historical accounts of the use of fire for upland trail and game yard management.

Extensive, light burning management of the landscape during aboriginal times (Lewis and Ferguson, 1999; see also Figs. 2.10, 2.15, 2.16) has been supplanted by the intensive, mechanized practices of the industrial era (Fig. 2.9). The scale of late 20th century management is reflected in the changes in the proportions of landscape elements through time. Landscape reconstructions from 1946 aerial photos (LRWA, Fig. 2.14) show an increase in late seral vegetation from the time of Euro-American colonization until the dawn of industrial forestry that is then followed by a rapid decline in old-growth and a dramatic increase in early seral stands through the late 20th century. The Little River AMA Plan (LRAMAP, 1997) reports that:

> There has been a large decrease in late-seral (old) forest and a large increase in the early and mid-seral forest over historic conditions. Sixty percent of the land (both private and public lands) in the Little River watershed, which was primarily late-seral forest in the 1930s, has been harvested… The old-growth forest has decreased by as much as 50 percent in the watershed…

Figures 2.18-2.20 also show dramatic shifts from native forest matrix with embedded openings to a matrix of even-aged plantations with dispersed islands of old-growth. The LRWA notes that:

> … fragmentation of late seral habitat has been extensive resulting in large decrease of interior forest habitat. Historically, interior forest normally covered between 40 percent to 51 percent of the total area of the watershed. …today it covers 12 percent of the watershed, with much of it intersected by roads, which further decrease its quality.

The conversion of old-growth forests to plantations and the loss of interior habitat due to fragmentation (Fig. 2.17) have lead to changes in wildlife populations. The LRWA concludes that:

> As a result of forest harvest in Little River and throughout the region, wildlife populations have shifted from those that thrive in

> older forests to those populations that prefer younger forests and openings.

5.2.3 Changes in Matrix Structure and Function

The conversion of old-growth forests to even-aged, closed canopy plantations, the loss of the large woody structure, and the infilling of native, fire resistant stands with a younger, dense cohort of fire intolerant species have all contributed to changes in forest function and fire behavior. The loss of old-growth forests also means a concomitant decrease in large trees – as live old-growth, standing snags, coarse woody debris on forest floors and in-stream logs. Moreover, intensive resource management has lead to increases in soil compaction, degradation of water quality, and loss of biodiversity (LRWA, 1995).

Since much of this old-growth was uneven-aged (LRWA data, 1995; Van Norman data, 1998), its replacement with tree plantations has caused a dramatic increase in the proportion of young, even-aged stands across the landscape. Relative to terrestrial habitats, the LRWA notes that:

> In areas that have been managed for timber harvest, structure differs to varying degrees from that unmanaged stands of the same age. Over the last 50 years, harvest has altered residual levels of biologically important components (snags and downed logs) in the watershed… Generally, the main deviation is the lack of snags and logs in managed stands; these are typically left after natural disturbances. Other deviations are evident in the development of understory vegetation in harvested areas (natural stands) and fuels accumulations much higher than natural because of fire suppression.

Three recent studies in western Oregon have also demonstrated marked increases in the densities of stands since Euro-American colonization of the region (Tappeiner et al., 1997; Poage, 2000; Sensenig, 2002). These results and the fire history datasets used in previous chapters are reflected in the findings of the Little River Watershed Analysis that "Some late seral and mid seral stands appear to have changed from having mostly large trees to a structure that has a higher component of smaller trees…" (see Fig. 2.22). The LRWA goes on to state that:

> Today's current stands are more dense… Currently in young stands, most stand densities are a product of tree planting and natural regeneration… Forest management policies of the 1970s and 1980s encouraged planting at high densities to help ensure reforestation success. Forest Service records of harvest acres cut prior to 1970 show that high-density stands represent 30 percent of the "older" young growth stands (those stands that were harvested earliest), while 16 percent of these young stands are at a low stand density.

Again, the lack of systematic burning by indigenous land managers is likely a major cause of increasing forest densities beginning in the mid 1800s. These crowded conditions were subsequently promoted and maintained by increasingly efficient fire suppression efforts during the 20th century. The LRWA suggests that:

> Historically, ingrowth was controlled by fire. [Forests] experienced more frequent fire, had open understories, and fire tolerant species in the overstory… The exclusion of fire has not allowed forest understory densities to be kept in check.

There are a number of consequences of the historically high crowding of timber. The LRWA points out that "…as stand densities increase, the amount of available fuels increase, resulting in fire behavior that have higher intensities, even in normal weather conditions". This report notes that these conditions are unlikely to improve in the near future, with increasing consequences to area homeowners:

> Many private, industrial forest lands within the watershed are likely to be scheduled for harvest over the next 20 years. A trend towards increased fire hazard on private lands can be expected at least for the next two decades depending on the pattern and type of

> harvest treatment applied. In addition, the Cavitt Creek and Little River vicinities are experiencing a gradual trend of increased human population, so the interface with rural landowners and fire hazard may intensify.

The LRWA points to another consequence of the infilling of native forests:

> One source of competition comes from the coniferous understory that grows up underneath the canopy, often called ingrowth. If left unchecked, ingrowth can slow the growth of the stand as growing space becomes restricted and nutrients and water become limited…

Not only is timber productivity affected by increased stand densities, but the diversity of stands may also be seriously affected:

> Species such as sugar pine and ponderosa pine to not grow well when the understory becomes thick and dense. They began to experience stress, which makes them susceptible to infestations from mountain pine beetles, eventually causing mortality.

The lack of understory fire has undoubtedly also driven the shift from fire tolerant species to fire intolerant species demonstrated by the 1995 Current Vegetation Survey (CVS) data (Table 2.1). The LRWA notes that "In some stands, current stand densities have a multi-layered structure consisting of fire tolerant overstory species and fire intolerant understory species."

Recent management may also have exacerbated the decrease in native structural and biotic diversity at the stand and landscape levels. The LRWA notes that:

> In some early seral forests, there are more species than historically present, sometimes due to an influx of non-native species. In other early seral areas, species diversity has declined due to an aggressive program to control competing vegetation, lack of a seed source when the stand was cut, and planting mostly Douglas-fir following harvest.

Forest structure conversion has had concomitant effects on animal diversity as well. A number of species in all major taxa are well below historic numbers – many are federally listed as threatened or endangered, and many more were listed as “Survey and Manage” species under the Northwest Forest Plan (NWFP, 1994). Many mammal predators have been extirpated from the watershed, due in large part to recent management practices. For example, the LRWA notes that:

> Martens travel mainly through upland areas and ridge tops. They will only travel along closed canopy corridors and seldom venture more than 75 feet from the forest edge. Because of this, martens are very sensitive to clearcutting and forest fragmentation. Clearcutting also removes habitat needed by some of their main prey species, such as the red-backed vole and the Douglas squirrel.

In addition to its impact on terrestrial systems, the conversion of much of the matrix to younger stands has important consequences for the health of riparian and aquatic systems as well. Large wood, historically delivered to streams by old-growth riparian forests, is at historic lows. The LRWA notes that “Historical accounts from long-time residents of the Little River area indicated that in-stream wood accumulations used to be much more frequent in the main stem, as well as other fish bearing tributaries found throughout the basin”. As a result of riparian old-growth logging and deliberate removal of logs during “stream cleanout” operations during the 1950s and 60s, “…spawning areas in the mainstems, and possibly other areas, are in a degraded condition… aquatic habitat within the mainstem of Little River is vastly different today than it was before significant settlement and management activities took place within the basin”. The report also notes that research efforts conducted in other parts of the Umpqua National Forest report far greater amounts of large wood in roadless area streams than in managed areas.

Logging methods have had other far-reaching effects on ecosystems in the Little River watershed. Along with the changes in forest structure noted above, plantations are often characterized by extremely poor soil quality, with higher bulk densities and lower organic matter content then old-growth stands (Amaranthus et al., unpublished). The LRWA states that:

> Approximately 35,300 acres or 27 percent of the land in the watershed… has been harvested or had the site prepared for planting using tractors… Quite commonly, at least 20 percent of a tractor harvest unit will have soils that are detrimentally compacted; however, other places in the watershed have up to 80 percent of the ground within a tractor harvest unit compacted…

The report further notes the influence of soil compaction on runoff:

> In addition to impacts to site productivity, soil compaction can also increase overland water flow. Overland water flow will reach stream channels were quickly than if it were to infiltrate to the soil, increasing peakflows.

Not only do increased overland flows cause extreme stream flow fluctuations, but they tend to pick up more sediments along the way:

> Relatively high levels of fine sediment appear to be present in spawning gravels found within Little River and Cavitt Creek. While much of the sediment is a result of natural processes and geology, management activities have also contributed a large portion as well…

During winter rains, the casual observer can easily see the contrast in the muddy brown color of the Little River water flowing from heavily managed vs. the clear, green water from the less intensively managed North Umpqua drainage where the two rivers meet (Fig. 5.1).

Figure 5.1: Colliding Rivers: Little River Meets the North Umpqua.
Little River (left) carries a much greater silt load than the less intensively logged North Umpqua River (right) after a moderate rain in the spring of 2004.

5.3 DESIRED FUTURE LANDSCAPES

The transition from aboriginal management to industrial management has been accompanied by an influx of exotic species and the extirpation of native ones, the alteration of riparian functions through extensive roading and stream channel alteration, the loss of legacy structure and extensive soil compaction, a changing climate and a radically different set of demands for natural resources from the current culture. In short, the ingredients for restoring landscapes to their pre-Euro-American conditions no longer exist.

After reporting on dramatic landscape changes in the Oregon Coast Range, Spies and Pabst (2004) state:

> The challenge to conservation scientists, policy makers, managers and the public is to define a new vision for biodiversity…based on ecosystem dynamics and the current environmental and social capacity of the region.

While it is no longer possible to "restore" the forest to aboriginal conditions, it *is* possible to emulate indigenous ecosystem dynamics. A return to a "corridor, yard and mosaic" pattern is still possible in a warming climate. While a return to native dynamics for its own sake is not a compelling reason to change current management, there are some important ecological and social reasons for doing so.

5.3.1 The Last Known Stable State

I argue here that since material cultures often reflect their landscapes (e.g. bedrock mortars in acorn country; woven nets, weirs, and traps where salmon run), stable human cultures infer stable landscape resources. And since local material culture was stable for at least 2000 years in southwestern Oregon (Beckham and Minor, 1992), then the pre-Euro-American socioecological system represents the last known stable state.

If we desire a predictable suite of ecosystem goods and services that are comparable (but not necessarily equivalent) to those available to native managers, then historic ranges of ecosystem conditions represent reasonable management sideboards. Given that the historic landscape of the Little River watershed is to a great degree the product of active aboriginal management, it will take active management on the part of land stewards to recreate and maintain analogous conditions.

5.3.2 Landscape Restoration and the Current Culture

Demands for the types and quantities of resources from southwestern Oregon forests have changed dramatically with the transition from indigenous socioeconomics to the present industrialized culture. Management by a local economy for food, clothing and shelter has given way to managing for commodities that are converted to capital and largely exported from the landscape (Robbins, 1997). Burning and gathering activities have been replaced by cutting, hauling and remote processing.

From a pragmatic standpoint, efforts to restore indigenous patterns and processes to the Little River watershed must take current management culture into consideration. The Little River Adaptive Management Area was designated by the Northwest Forest Plan (1994) with the specific emphasis of "development and testing of approaches to integration of intensive timber production with restoration and maintenance of high quality riparian habitat." Toward this end, the Little River Adaptive Management Area Plan (1997) outlines a number of biophysical "desired future conditions" designed to meet that goal:

- **highly productive timber management areas**
- **landscape more resilient to wildfire and disease and insects**
- **a network of late-successional forest, with emphasis on riparian areas**
- **legacy habitat components left or developing in all stands**
- **diversity of native plant in wildlife habitats and populations**
- **riparian areas dominated by late-successional condition with increased levels of large in-stream wood**
- **water quality that meets Oregon Department of Environmental Quality standards**
- **sediment and flow regimes that result in high quality aquatic habitat**
- **increased populations of healthy, native fish and other aquatic organisms**

In addition, the Plan outlines a number of “social-economic” conditions. Most of them are beyond the scope of this discussion (public education, interagency funding efforts, public/private management collaboration, etc.), but two of them *are* applicable here:

- **sustainable and dependable harvest level**
- **improved and increased recreational opportunities**

In the following discussion, I will outline a set of management suggestions designed to meet the LRAMAP goals while moving the current Little River landscape toward the common features of the last stable state:

- **ridge and river corridors connecting yards and parks**
- **lower density, multi-cohort forest matrix**
- **frequent, low severity landscape fires**

I will then assess the compatibility of the Little River AMA Plan's "desired future conditions" with a return to indigenous landscape patterns and processes.

5.4 RESTORATION DIRECTIONS

The AMA Plan's "desired future conditions" and my management recommendations are both broad and general. The suggestions offered here are landscape-specific, and although they should have broad application to other southwestern Oregon landscapes, they focus on the specific conditions in the Little River watershed. They are intended only as examples of potential methods, not as part of a comprehensive landscape plan.

Most of the specific suggestions for moving the landscape in the desired direction have been thoroughly discussed elsewhere, e.g. thinning (Newton and Cole, 1987; DeBell, et al., 1997), uneven-aged management (Tappeiner et al., 1997; Lindenmayer and Franklin, 2002), value of large wood (Perry, 1994; Franklin et al., 1997), underburning (Perry, 1994; Agee, 1997; Lindenmayer and Franklin, 2002), fire effects on flora (Lotan et al., 1981; Agee and Huff, 2000), maintaining biodiversity (Hansen et al., 1991; Folk, et al., 1996), cutting systems (Cromak et al., 1979; Franklin and Forman, 1987; McRae, et al., 2001), sustainability and forest economics (Costanza et al., 1993; Perry, 1995; Amaranthus, 1997). The theory and practice is well developed, but it will be ultimately up to the current land managers in the Little River watershed to choose precisely the right site-specific prescriptions for creating and maintaining a stable forest environment.

A discussion of harvest engineering is beyond the scope of this work. However, intensive clearcut-plantation forestry has caused significant damage to Little River ecosystems including soil and water degradation, lowered terrestrial and aquatic diversity, and lowered timber productivity levels (LRWA, 1995). The argument that clearcutting mimics wildfires (Bonnicksen, 1994) has some serious weaknesses. McRae et al. (2001) found little similarity between the two types of disturbances in an exhaustive study of Canadian forest data. In the Little River watershed, all native stands in the two fire history datasets show some degree of fire scarring, and the large majority (92%) are uneven-aged. This suggests that fire behaved more as an intermediate disturbance agent (Perry, 1994), creating structurally diverse forest matrix, and not as a large, acute disturbance (Lindenmayer and Franklin, 2002). Alternative harvest systems that better emulate ecosystem dynamics need to be employed (McRae et al, 2001).

Recognizing the need to change burning practices in the Little River watershed, the LRWA recommends that "… the use of low intensity prescribed underburning should be increased in order to mimic natural fire". However, the newer methods of prescribed burning outlined later in the same paragraph do not appear to mimic indigenous burning practices:

> Broadcast burning is now conducted in the spring with fewer "hot" burns… Hand piling and burning to treat logging slash on federally managed land is expected to continue. Intense burns will continue to occur in piled areas, and while not over a broad area, all the soil organic matter is consumed, impacting the productivity of the site at the location of the burn pile.

More work is needed to develop and apply methods that more closely resemble the characteristics of native fire.

Forested landscapes can yield high quality of life values along with high quality wood products. Places to relax, play and meditate may be designed into easily accessible parts of the landscape. Aesthetic sensibility and recreational opportunity need to be recognized and designed into the management regime. Nassauer (1995) suggests that local landscapes communicate local cultural values. She cites references that indicate that savanna and parkland stands offering “prospect/refuge” configurations are intrinsically pleasing to humans of all cultures (Ulrich, 1993). Heavily managed stands can be visually buffered with feathered edges, non-linear contours and other innately pleasing forms (Wilson, 1993).

5.4.1 Toward Indigenous Landscape Patterns

The history of a landscape is intertwined with the history of its peoples; one needs to know both before one can really understand either. In order to generate accurate reconstructions of indigenous land use patterns, one must have access to reasonably complete archaeological data. However, systematic surveys for archaeological evidence are rarely undertaken. Such a survey is needed in the Little River watershed to refine and re-validate the modeling developed in Chapter 4.

Even with unavoidable data gaps, the indigenous landscape patterns of the Little River watershed reconstructed with currently available archaeological data and historic documentation fit a pattern consistent with Lewis and Ferguson’s “corridor, yard and mosaic” pattern. The aboriginal travel pathways modeled in Chapter 4 demonstrate the strong association of archaeological sites with ridge and river corridors, and with meadow “yards” and open understory forest “parks”. These reconstructions suggest that ridges and rivers were important travel corridors for indigenous peoples (and probably many other species as well). Wherever these corridors come close to flat or gently sloping topography, historic open meadows and open understory old-growth forests are likely to be found, suggesting that they were maintained through human agencies.

These two major types of corridors were interwoven into the aboriginal landscape and tended to be found along major ridgelines (usually dividing sub-watersheds) and river corridors (including some large, perennial streams). In addition, the two basic patch types (yard and park) were usually joined by one or the other type of corridor. The restoration, maintenance, and/or re-creation of these landscape elements will first require careful surveying and mapping of vestigial historic landscape features. Historic habitats that are likely to contain the legacy propagules for their characteristic vegetation mix need to be prioritized for early restoration efforts.

Ridge line meadow systems may be restored (or created) by first thinning existing stands to open up the forest understory. To increase fire resistance, thinning should target the smallest diameter (most flammable) trees (Perry et al., 2004), and mature, fire resistant trees should ideally be left in the canopy. Flats along ridgelines and river bottoms (including any perennial streams) may also be thinned if necessary and maintained with frequent, light burning. Thinning will likely remove much more volume from river benches than ridgetop yards because of the superior growth conditions found in most riparian areas (Fig. 4.15).

Although more field-based research is needed to assess the effectiveness of various wildlife corridor designs (Lindenmayer and Franklin, 2002), a landscape configuration that provides a network of dispersal corridors (both forest and meadow) will help sustain gene flow among populations (Noss and Cooperrider, 1994) (Fig. 5.2). Maintaining stream side vegetation will also serve to provide habitat for the majority of wildlife species that use riparian areas at some point in their life cycles (Naiman et al, 1993; Machtans et al., 1996).

Fuel breaks may be designed into the pattern to damp the spread of crown fires. Meadows and parklands sited on the ridges would naturally form shaded fuel breaks where fire is most likely to crown (Agee, 1997) and spread to neighboring stands. Shaded fuel buffers using fire resistant hardwoods (Perry, 1994) may also be designed into the landscape, especially oak, madrone and maple. Decommissioned midslope roads could be managed as a fuel breaks to slow wildfires that tend to crown as they move upslope. Other woody and/or herbaceous species with value as browse or habitat for wildlife species could be included in the mix, thereby boosting diversity.

The reshaping of the landscape toward historic conditions must include a thorough analysis of the resources and risks found at the wildland/urban interface. As more homes are built in the forest, more are threatened by the wildfires that are now carried by the historically high fuels loads of the surrounding forest. Therefore, it makes sense to concentrate early restoration efforts on the W/U Interface. Just as indigenous managers did for centuries, the maintenance of open, low-fuel defensible spaces around homes and communities needs to be aggressively pursued.

Despite the best efforts of fire managers, prescribed or lightning sparked fires will inevitably jump into the crown and kill patches of trees. This will also mimic indigenous processes in two ways. First, research conducted by Umpqua National Forest staff have found evidence that small patches of “snag forests” may have composed around 6% of the matrix and may have had important effects on biodiversity (Ray Davis, UNF Wildlife Biologist, pers. comm., 2005). Second, fire killed stands will supply pulses of large wood to streams, and can have rapid, positive responses. The LRWA notes that:

> The one exception to the overall lack of instream wood in the mainstem of Little River is in reach 6, where trees killed in a 1987 fire have recently fallen into the channel, resulting in a much larger amount of in-stream wood [by over 3 times that of any other reach].

The foregoing discussion suggests that emulating the pre-European landscape configuration will meet a number of the AMA Plan goals. It will produce an initial yield of logs from initial thinning operations. It will produce a network of forests and openings that will create connectivity and promote biodiversity. Fire breaks can be built into the landscape to damp the spread of crown fires. High quality recreational opportunities can easily be incorporated into the pattern.

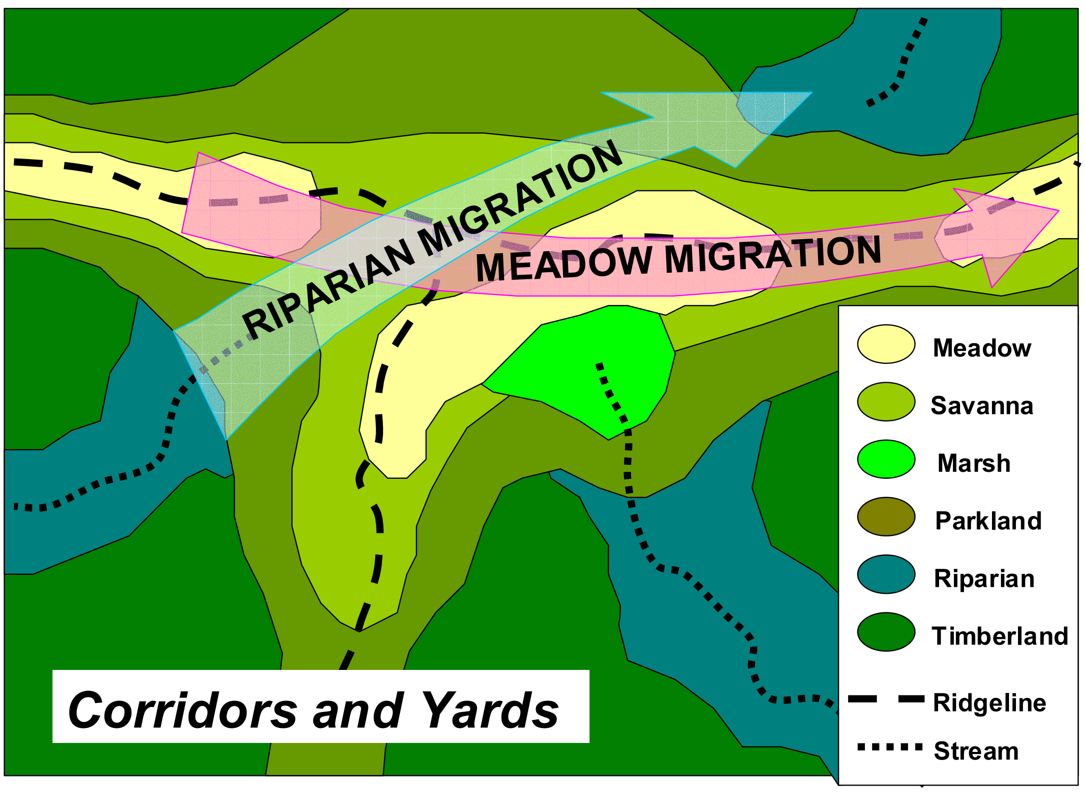


Fig. 5.2: A Hypothetical Configuration for Designing Corridor and Yard Landscape Configurations.
This figure illustrates a generic configuration for a ridge system that provides migration corridors to multiple species.

5.4.2 Toward Indigenous Matrix Structure

The aboriginal Little River matrix (mosaic) consisted of more open, uneven-aged forests than at present (Chapter 2). Ecological and historical evidence document an increase in stand densities from two sources. First, native stands with widely spaced, fire tolerant overstories became increasingly infilled in the late 1800s and early 1900s. Second, recent practices have converted much of the remaining primary forests and converted them to closely spaced tree plantations. The resulting dense stands are less resistant to diseases and pests (Goheen, 1995; Schowalter, et al., 1997), and are more fire-prone (LRWA, 1995) -- even-aged plantations are especially flammable (WEEP Report, 2003). The LRWA makes this observation accompanied by a warning:

> Today, many dense young stands are in need of treatment. Since 1980, clearcut harvesting on public lands within the watershed has generated over 11,000 acres of land that is or will soon be in need of density adjustments using pre-commercial thinning. Some young stands are passing the pre-commercial thinning stage and have not been thinned. These stands will soon come into the commercial thinning stage. Delays in needed pre-commercial thinning operations can slow down growth to the point of stagnation. High densities will increase a tree's height to diameter ratio… and blowdown (or stem breakage) is likely to occur.

In order to increase the resilience of both types of stands to fire and pests, an aggressive thinning program followed by a systematic burning regime is needed. Again, the precise prescriptions for these activities will need to be determined on-site after a rigorous reconstruction of the range of native stand conditions.

Under-burning may be employed whenever safe and wherever needed to maintain or enhance desired habitat with the pattern and timing of historic fires guiding schedules. The use of frequent, light fire to underburn stands will tend to select the more fire tolerant species (e.g. ponderosa pine and Douglas-fir) to form future fire resistant overstories. Fire may also be periodically used in thinned stands to keep shade tolerant understory tree seedlings from becoming (re)established, and to improve wildlife habitat and recreational opportunities. Moreover, prescribed fire may be used to maintain existing stands of pines, hardwoods, huckleberries and other remnant fire dependent plant communities.

For the ecological reasons outlined above, thinning prescriptions should be designed to accelerate the production of large trees (Newton and Cole, 1987; Lindermayer and Franklin, 2002) and be monitored as part of the adaptive management strategy of the AMA (NWFP, 1994). Along with their ecological values discussed above, large diameter logs have a high monetary value because of the proportion of high grade, knot-free wood they contain. As fine-grained old-growth lumber becomes increasingly scarce, products milled from sustainably grown mature timber will fetch increasingly higher prices. Moreover, the most fire resistant species in the Little River drainage (Douglas-fir, ponderosa pine, sugar pine) are also the most economically valuable.

The Little River AMA goal of the “integration of intensive timber production with restoration and maintenance of high quality riparian habitat" may seem somewhat mutually exclusive to those who have witnessed the last half century of forest management. However, the Little River AMA Plan provides a definition of intensive management that may contain the key to reconciling these two goals: “Intensively managed forest stands are those that are managed to obtain a high level of timber volume *or quality* (my italics)”.

Simply put, large, quality logs are worth far more than the equivalent volume of small diameter, plantation grown logs. Value is added to the product through the work of local land stewards. Just leaving cohorts of trees in long rotations ensures a better price for the future timber. Where topography and transportation make it feasible, pruning may be employed to begin producing high-value, clear wood at an earlier stage in the tree’s development.

Again, all of these suggestions support the AMA's "desired future conditions". An emphasis on large wood makes both ecological and economic sense. When grade is emphasized over volume, high monetary value is accrued with less biomass removal. Increased large wood delivery to streams will improve water quality, improve aquatic habitat, and help shore up beleaguered fish stocks, thereby boosting another valuable commodity. Thinning stands increases their resistance to pests and fire, and provides a supply of logs to local mills. Since the fire tolerant tree species in the Little River watershed are also the most valuable, a shift toward fire tolerant trees has double benefits. And the use of frequent, prescribed fire keeps the forest in an "intermediate disturbance" regime that promotes biodiversity (Perry, 1994).

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