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THE MENDOCINO CHAPARRAL

A PROBLEM IN RESOURCE MANAGEMENT

APPROVED BY

DISSERTATION COMMITTEE

DEDICATION

To my beautiful little girls,

KIRSTIN LEANNE AND MARDISS ALICIA,

who have given me constant encouragement-

"Daddy, when are you going to finish that stupid

'dishertashun' so we can go to Disneyland?"

and

to my wife, GWENDOLYN DOLORES

who has been a continuing inspiration

to succeed in this endeavor even after a vow by me,

ten years ago, that this is something that

I would <u>never</u> want to do!

The fulfillment of a graduate education is a demanding process that only those who have endured can fully appreciate. I apologize to our families and all our friends who have been shunted aside while I have been engaged in my education. I am especially saddened that during the dozens of trips into the Mendocino Chaparral I, of necessity, could not take the time to visit genuinely compassionate life-long friends: MR. RUFF BURCH and his wife, LELA, and MR. LEO FLOOD. Despite the fact that they are now gone, I shall have many pleasant memories of them. I wish only that I had had more opportunity to visit them in their waning days.

ACKNOWLEDGEMENTS

My initiation to academic Geography occurred in 1958 at Chico State College, Chico, California, at which time I was inspired by the superb teaching and spirited enthusiasm of Dr. David W. Lantis. It was he who provided me with the inspiration for a career in Geography.

I am especially grateful to my advisor, Dr. James M. Goodman for his willingness to aid in the formulation, research and the culmination of this dissertation problem. He has dedicated his time and energies to this research in a manner far exceeding his actual obligation; for that reason I am indebted and very grateful to him.

The assistance of others is also gratefully acknowledged. I wish to thank Dr. Ralph E. Olson, Dr. Harry E. Hoy, Dr. Nelson R. Nunnally and Dr. Joe B. Schiel for their constructive criticisms. Dr. David Ott (Department of Mathematics, Southern Oregon College, Ashland, Oregon) has provided many hours of his time in aiding me in this research.

A note of special thanks is directed to Mr. Ray Crane and the Board of Directors of Crane Mills, Corning, California. It would have been virtually impossible to have engaged in the field research necessitated by this problem without the financial assistance provided by Crane Mills. I hope eventually that this endeavor will yield a dividend to Crane Mills.

I am grateful to our families who have lent logistical and financial support. Without them this research could not have been completed. I am immensely proud of my father, Kenneth Curran, for his ability to "jeep jocky" on exceptionally steep ground in his 78th year and of my mother, Elizabeth A. for letting him do it! I also thank Gwen's parents, Quinton C. and Melba T. Bailey, for providing moral and financial assistance, and to Earle G. and Rachel A. Curran for the use of their pickup camper during a very crucial period.

I thank students, Mr. Ray Cook for aiding me in field research and Mr. Richard Box for his talents in drafting some of the diagrams in this study. A note of appreciation is in order for the Administration at Southern Oregon College, Ashland, Oregon, for their cooperation.

Finally, I am indeed pleased that this has been a family endeavor. It has been one in which Gwendolyn D. has aided me tremendously with her constant encouragement to succeed in this task. Her comments on the manuscript, and her aid with the mechanical aspects in the preparation of this dissertation have been extremely helpful.

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ABSTRACT

THE MENDOCINO CHAPARRAL

A PROBLEM IN RESOURCE MANAGEMENT

In northern California, the Mendocino National Forest is comprised of forest lands and chaparral brush. These brushfields, known as the Mendocino Chaparral, are a small portion of California's chaparral vegetation. Presently, there is no management plan for chaparral brushlands. The Mendocino Chaparral located along the eastern face of the Coast Range mountains was selected for research study in the hope of developing applicable land management techniques. It is hoped that as a result of resource management planning the Mendocino Chaparral will become a viable resource.

The Mendocino Chaparral has a potential for hazardous wildfire. Rampant wildfires result in deterioration of water and wildlife resources, in acceleration of downslope movement of earth surface materials and in transmission of wildfire into adjacent coniferous forests.

The nature of the Mendocino Chaparral is assessed as a function of a mix of environmental factors that influence fuel volume in

a temporal and spatial context. A general linear model has been utilized to analyze the influence of time since wildfire burn and the effect upon fuel volume from selected spatial variants: altitude, slope and directional orientation. A predictor equation is employed to ascertain the volume of expected fuel after specific growth periods and combination of spatial variants.

Management decisions based upon modular output can be implemented in specific units and sub-units in the Mendocino Chaparral. Planning recommendations can be based upon the particular combination of spatial variants that occur in the unit or sub-unit. The mix of combinations may be ascertained vicariously through the analysis of simple measurements garnered from 7.5 minute topographic maps. The primary management recommendation involves the inclusion of prescribed burning to reduce the fuel volume, hence, a reduction in the propensity for potentially destructive wildfire in the Mendocino Chaparral.

Primary resource benefits will accrue as a result of prescribed burning. These benefits include enhancement of water resources, rejuvenation of wildlife habitat, and increased seasonal use of the Mendocino Chaparral for recreational purposes. Ancillary benefits include: the reduction in the number of instances in which wildfire spreads from chaparral brushlands into adjacent coniferous forests, the maintenance of a higher moisture content in fire susceptible vegetation throughout a larger portion of the year, and the reduction of accelerated erosion of earth surface materials.

THE MENDOCINO CHAPARRAL

A PROBLEM IN RESOURCE MANAGEMENT

CHAPTER I

INTRODUCTION

Chaparral is a term used to describe a type of woody vegetation commonly found in regions characterized by droughty summers and rainy winters. Chaparral vegetation occurs in several regions in the world in which the Dry-Summer Subtropical climatic type exists. Generally this kind of scrub vegetation is referred to as being of the Mediterranean type. Considerable areas in Southern Europe and Northwestern Africa are occupied by scrub communities referred to as maquis or garrigue (Eyre, 1963, p. 126; Polunin, 1969, pp. 354-358; Gleason and Cronquist, 1964, pp. 388-400). Similar areas of sclerophyllous shrubs are found in Australia, South Africa, Chile and California.

Several explanations for the origin of the term chaparral have evolved; however, the most plausible is its derivation from the Spanish word, <u>chaparro</u>, meaning an evergreen oak (Sampson and Jesperson, 1963, p. 3). The term chaparral is applied to any dense impenetrable growth of rigid or thorny shrubs or dwarf trees.

THE PROBLEM

This dissertation evaluates the resource potential of a portion of California's chaparral brushland and the role of prescribed burning in its management. Many facets of use for the chaparral are extant -- the major emphasis herein will be to ascertain the place of fire in the management of chaparral brushlands as a resource. An investigation of the role of fire influences will yield insights instructive to the management of chaparral lands. Records of the incidence of wildfires are utilized to delineate specific sites where recovery stages of chaparral species may be studied within a time framework spanning approximately the last fifty years.

The actual behavior of fire in chaparral brush, and the potential for fire under given circumstances are inadequately understood. A means of predicting potential fuel volume for wildfire on the basis of local chaparral brush characteristics and environmental conditions will be of considerable utility. Federal agencies which are responsible for the management of chaparral brushlands have no means of ascertaining the actual wildfire potential of hundreds of square miles of chaparral vegetation.

In addition to the dearth of specific knowledge concerning wildfire hazard in chaparral brushlands there is a pitifully meager data base upon which to evaluate the resource potential of chaparral brushlands. At the present time it is indeed difficult to envision chaparral brushlands as a functional element in the realm of California's resources. The intent of this investigation is to analyze their potential and to formulate specific management recommendations.

A modular design has been developed which facilitates the assessment of the resource potential for one of California's landscapes -- the Mendocino Chaparral of Northern California. It will be suggested that Mendocino Chaparral should be subjected to periodic prescribed burning as a measure for enhancement of its resource potential.

RATIONALE

In the mid 1960's California became the nation's most populous state with almost twenty million people. Present trends indicate that California's population will experience continued growth (Rogers, 1965, p. 1). At the present time the majority of California's population is concentrated in Southern California. It appears that Northern California's population is rapidly growing as displaced urban dwellers relocate in more sparsely populated rural areas.

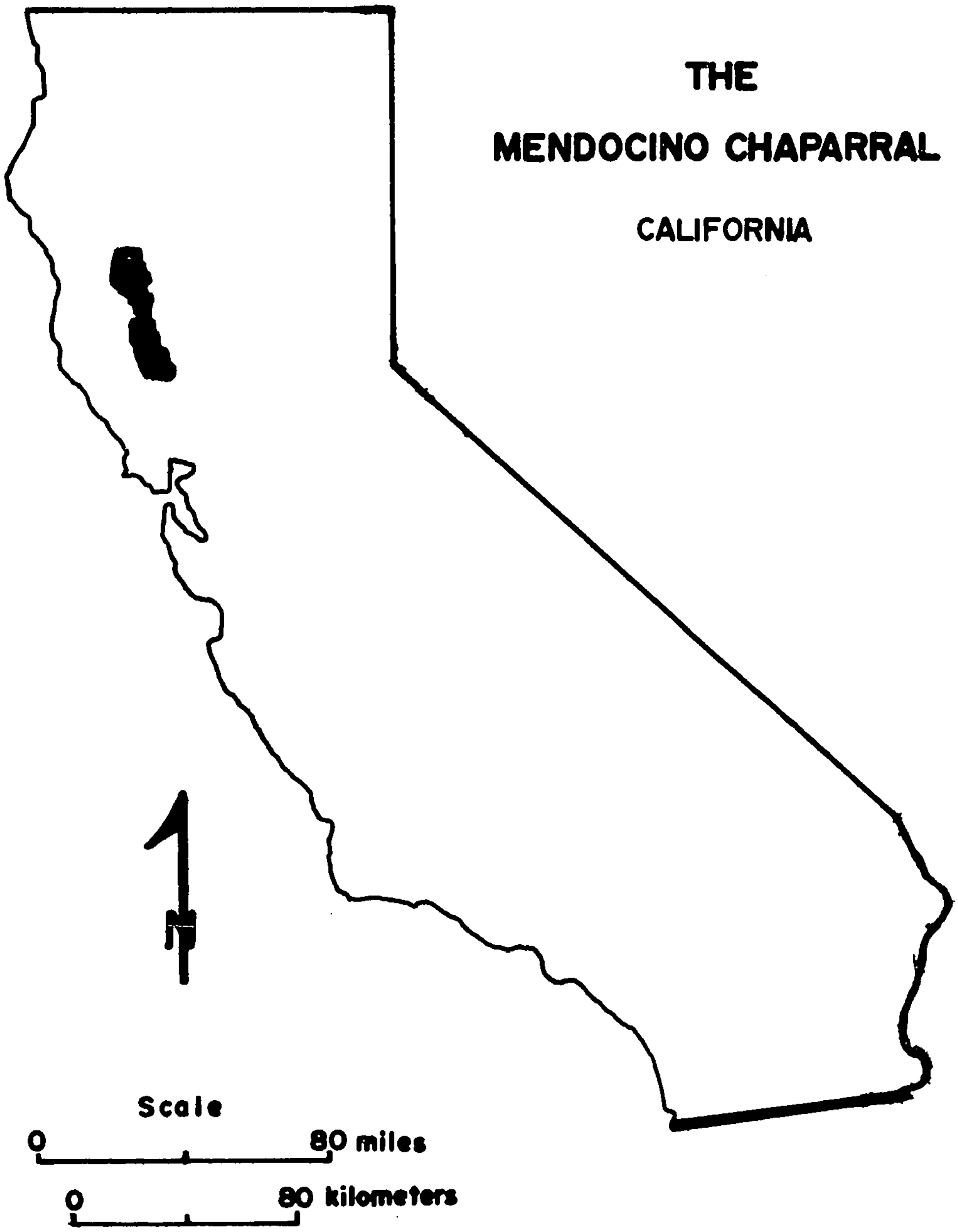
Planning for the orderly development of California's remaining potential resources is of critical importance. The environmental attributes of California's remaining open spaces must be thoroughly appraised before further population growth occurs. Obviously this does not necessarily mean that chaparral brushlands must be appraised as possible areas of residential relocation although that may eventually occur. However, it does mean that more people will be seeking recreation areas on public lands which heretofore have not been utilized in this manner. Perhaps the main prohibition for use of chaparral brushlands will be the inherent hazardousness of wildfire and all of its attendant debilitation to land resources.

Chaparral vegetation is of little direct economic value at present. Inadvertently it serves as a watershed protector, but it is not managed to maximize its utility for water resources. Providing wildlife habitat is another function of chaparral, yet again there is no definitive management plan. There is a certain element of beauty in the chaparral wilderness setting that is not always fully appreciated. Perhaps in the future chaparral brushlands will be regarded as a place for recreation, and their unique wild beauty will lend them a functional resource value.

THE RESEARCH AREA

The Mendocino National Forest is located in the Coast Range of Northern California (Figure 1). Chaparral brushlands along the east face of the Coast Range Mountains have been chosen as a focus for investigation for several reasons. First, significant land management research has not been initiated here except in the immediate area of the Grindstone Canyon Chamise Conversion Project (U.S. Forest Service, 1958, pp. 1-35). This USFS project is concerned

FIGURE I


THE
MENDOCINO CHAPARRAL
CALIFORNIA
N
Scale
0
80 miles
0
80 kilometers

with the means of converting chaparral brushlands into grasslands for cattle grazing. Project objectives are to evaluate cost-benefits and conversion techniques which destroy brush by mechanical or chemical means, or some combination of these. Jay R. Bentley (1965, p. 10), a student of techniques of brush conversion, concludes that since most of California's chaparral brushlands are situated on steep terrain with shallow, rocky soils, only on selected sites can brushfields be effectively converted to a new, more desirable plant cover. Second, the majority of these lands are entrusted to the stewardship of the Federal Government; hence, they are "public lands". Third, this area is in a state of semi-isolation. Presently there are no all-weather east-west highways for a distance of 177 km. crossing this segment of the Coast Range. Secondary macadam and dry-weather roads provide only limited seasonal access. A few such roads are maintained as avenues of access westward to the higher mountains for utilization by the timber industry and for fire protection. Fourth, there presently is no significant economic activity situated wholly within the chaparral brushlands. Human utilization is basically limited to seasonal recreational activities. Fifth, this research project has developed from a deep personal interest in the Mendocino Chaparral as a result of boyhood years of exploration there. There is a definite dearth of literature concerning this region. A great deal of personal satisfaction will be derived with the completion and publication of this research.

CONTEMPORARY LAND USE

Chaparral brushlands in the Mendocino National Forest are characterized by passive land use. These lands yield surface runoff water which is a very valuable commodity for contemporary Californians; however, there is no viable management plan designed with the objectives of increasing water yield or water quality. Undoubtedly, Mendocino Chaparral could be managed very profitably solely for water resources.

A few head of cattle are ranged in those parts of the Mendocino Chaparral which are best suited for this purpose. Unfortunately, there is very little of the region that can be profitably used for livestock. The vagaries of environmental conditions combine to result in highly variable grazing seasons from year to year. Livestock ranchers residing in the foothills of the Coast Range can not depend upon chaparral ranges except in a rather tenuous way. It is probable that livestock ranching will remain a risky endeavor.

Many forms of wildlife, especially deer and associated predators, are residents of the chaparral. During the latter part of the 19th Century, and for the first few years of the 20th century, deer herds were decimated by market hunters (Burcham, 1956, p. 63). If the meat was not sold, deer were slaughtered for their hides. Buckskin was sold to foothill and Sacramento Valley ranchers for making harness.

Today there are only a few deer in the Mendocino Chaparral because of the decadent condition of most brushfields. Brush more than thirty years old is unpalatable to browsing animals as well as being very low in nutrients (Biswell and others, 1952, p. 6). Potentially the chaparral may be capable of supporting a dynamic deer herd if the brush is occasionally rejuvenated.

Human utilization of the Mendocino Chaparral is very limited. There are scarcely a dozen permanent habitations in the entire study area. A few persons have seasonal residences, but since a large majority of the land is owned by the Federal Government there will continue to be only limited seasonal residential usage. However, camping, hunting and fishing do occur to a limited extent, and if managed properly the Mendocino Chaparral could accommodate a significantly large expansion of these pursuits.

ENVIRONMENTAL FACTORS

A thorough appraisal of environmental factors in the Mendocino Chaparral must be accomplished prior to the application of the interaction model. The assessment of the interrelationships which occur between environmental components is requisite to an accurate application and analysis of modular output.

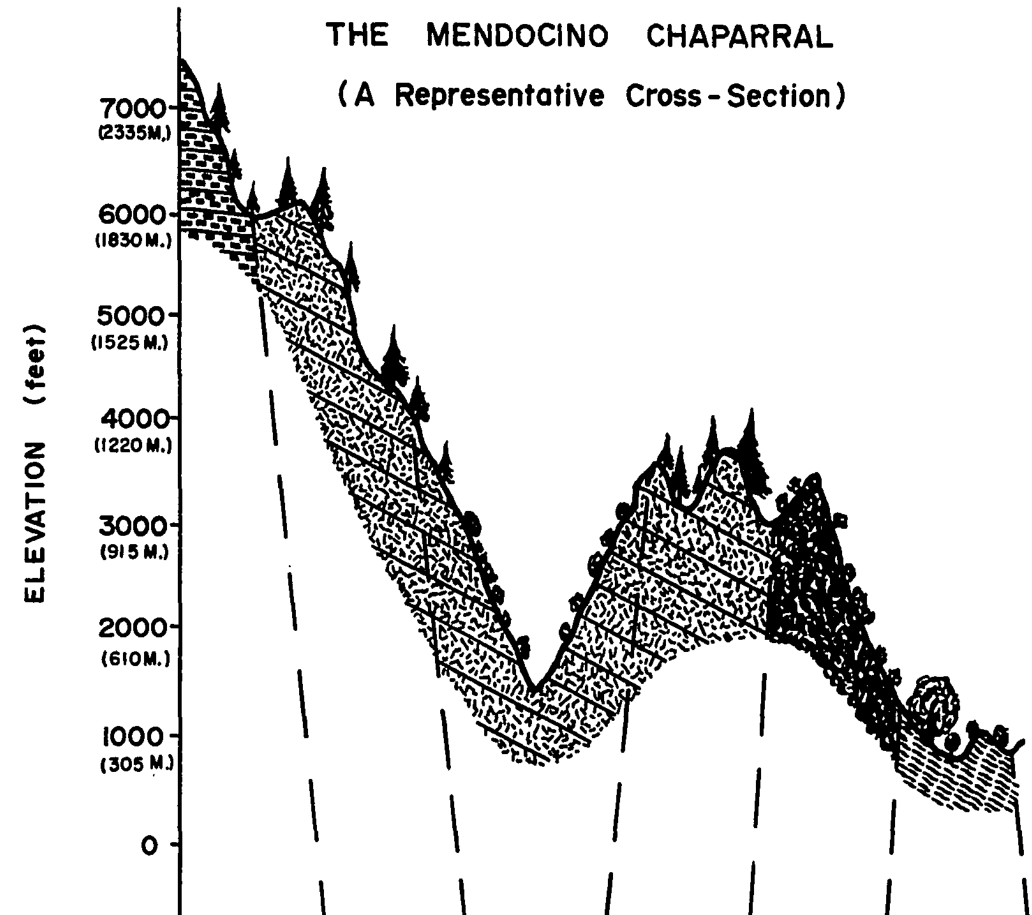
Basically, the problem is to discover which physical factors influence the volume of fuel produced in the Mendocino Chaparral. At the same time it is imperative to maintain a simplistic approach. Simplicity is a desirable feature in that it will facilitate an application of management principles by moderately trained technicians. With this as a major consideration the research project is designed to include only those variables which are thought to influence biomass. These variables might be surrogates for complex landscape interdependencies. The several spatial variables which have been selected as inputs can be garnered from available topographic maps; this data can be manipulated to fulfill the requirements of the research design.

Landforms -- one of the more important facets of the physical landscape -- affect vegetation types and quite probably vegetation volume through the influence of altitude, slope, and directional orientation. Arrangement of the landforms influences climatic patterns which in turn may affect species, types and distribution of chaparral vegetation. Finally, steepness of slope is important because of the effect it has upon surface materials, especially soils (Figure 2).

LANDFORMS

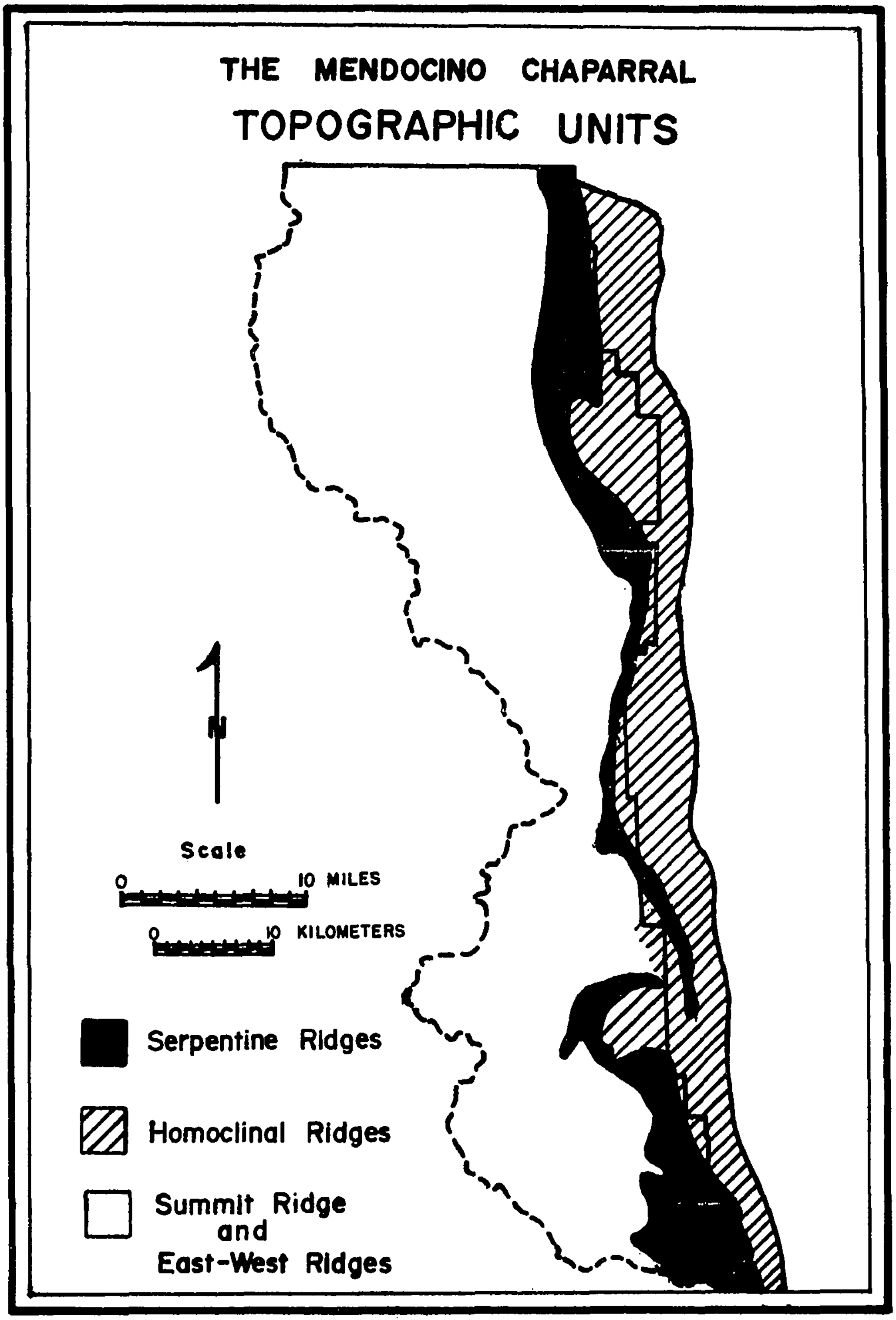
Three distinctly different topographic units exist in the research area (Figure 3). The most westerly portion of the study area includes the summit ridge of the Coast Range and major east-west ridges joined to it. Immediately east of these ridges is a chain of prominent ridges composed of serpentine emplaced along the Stony

FIGURE 2



DOMINANT SOILS	Neuns	Masterson Sheetiron	Maymen Los Gatos Parrish	Sheetiron Josephine	Henneke Stonyford	Lodo Millsap
PARENT MATERIAL	Meta-Volcanics	Schistose Sedimentary Rocks			Serpentine PillowBasalt	Shale
NATURAL VEGETATION	Conifers	Mixed Conifers	Mixed Shrubs	Mixed Conifers	Mixed Shrubs	Oaks Grasses Shrubs
LAND USE	Timber Watershed Recreation	Timber Watershed Recreation	Watershed Wildlife Recreation	Timber Watershed Recreation	Watershed Wildlife Recreation	Range

FIGURE 3


THE MENDOCINO CHAPARRAL
TOPOGRAPHIC UNITS
N
Scale
0 10 MILES
0 10 KILOMETERS
Serpentine Ridges
Homoclinal Ridges
Summit Ridge
and
East-West Ridges

Creek Fault. Farthest east and transitional to the Sacramento Valley, are a series of homoclinal ridges and intervening valleys.

Summit and Major East-West Ridges

Situated along the western margin of the study area, the summit ridge of the Northern Coast Range trends along the north-south line from near Clear Lake, California, to the junction of the Coast Ranges with the Klamath Mountains (west of Redding, California) -- a distance of about one-hundred and ninety km. The ridge extends to maximum elevations slightly in excess of 2,440 m. Several mountain peaks along the summit of the range are approximately 1,830 m. The general crest of the range is about 1,375 to 1,525 m. Some of the highest peaks situated along the summit ridge display some evidence of Pleistocene alpine glaciation as far south as Snow Mountain (Irwin, 1960, p. 55), (Figure 4).

Long ridges branch from the main summit of the coast range, and occasional prominences along the ridges appear as "peaks" that are disassociated from the main summit ridge. Pacific, Trough Spring, Open, Felkner, Alder Springs, Log Springs and Raglin all are major ridges that extend eastward from the main summit ridge. In several instances these ridges are 19 km. to 24 km. in length and parallel one another until truncated (by the Stony Creek Fault) at the eastern edge of the Coast Range. Ridge summits sometimes are very flat from 0.40 km. to 0.80 km. across their top. In some places, however, they are but a few meters wide -- scarcely enough for a narrow, unimproved road.

Some ridges, such as Log Spring Ridge, maintain a rather uniform elevation throughout their entire length. Log Spring Ridge extends eastward from the flank of 2,023 m. high Anthony Peak at the summit of the Coast Range, to its termination 24 km. distant at Commissary. About 1.5 km. east of the summit of Uhl Peak, at Government Flat, the elevation of the ridge is 1,769 m. while at its terminus the elevation is 1,522 m. Goat Hill, 17.7 km. east of Government Flat, rises to an elevation of 1,819 m. which is slightly higher than the ridge top where it joins the crest of the range (U.S. Department of the Interior, Anthony Peak, 1952).

Sizable stream drainage basins are situated between each of the major ridges. Within these basins many short, narrow ridges plunge to canyon bottoms. Therefore, each major drainage basin is composed of a series of lesser basins enclosed by secondary ridges. Secondary ridges are steep-sided, and sometimes they are characterized by nearly precipitous slopes. Their summits are very narrow and seldom are they level for any appreciable distance.

Small drainage basins are found along the very steep faces of main ridges, which were truncated as the result of nearly vertical displacement along the Stony Creek Fault. Headward erosion has resulted in the formation of small basins where stream action is attacking the very steep and rugged eastern face of the Coast Range. Salt Creek, for example, falls more than 915 m. in approximately 4.8 km.

Topography is controlled to a great extent by geologic factors. The Coast Range summit ridge, like the main ridges extending eastward from it, is composed of weakly metamorphosed Franciscan rocks. The most commonly found metasediment is quartz-mica schist (Dondanville, 1958, p. 9). Prominences along major ridges are places where the schist outcrop has resisted weathering.

Slopes are ordinarily steep except for the narrow ridge crests. In some places massive solifluction scars have resulted in the formation of slopes of 60 percent to 80 percent. Where the mass of material has come to rest a bench is formed in which there is a rapid change in slope. It is not uncommon to find slopes of 15 percent to 30 percent in areas characterized by this type of general activity.

Most of the topography in the area of quartz-mica schist is characterized by slopes in excess of 30 percent. In part this is due to the stabilization of ridge crests by resistant materials. However, in addition there has been rapid vertical downcutting by practically all streams. Ultimately this results in advanced mass wasting along canyons and gully sides. Many streams have rapidly cut their channels and they have become so rugged that it is practically impossible to traverse their courses.

Serpentine Ridges

Immediately east of the schistose rocks is a narrow band of serpentine rocks. Throughout the zone of serpentine steepness of slope is a prevailing characteristic which probably is directly related to basic geologic events. Serpentine occupies an area of once active crustal movement along the Stony Creek Fault. This high-angle thrust fault probably extends deep into or through the earth's crust (Dondanville, 1958, p. 9). The zone of movement is occupied by slicken-sided lenses of serpentine introduced into the fault zone either as a cold intrusion or as a thick plastic smear (Page, 1966, p. 270). As a result of this, serpentine ridges occur as topographic highs along the contact with the schistose rocks (Figure 5). Massive down-slope slippage of serpentine has occurred resulting in jumble of serpentine colluvium which masks its contact with Sacramento Valley sediments (Raymond, 1962, p. 13).

Within this zone occasional outcroppings of volcanic rocks, diabase and greenstone occur (Willis, 1962, p. 12). Outcroppings usually occur where they have been exposed as the result of active downcutting by stream action. Hence, many streams are in precipitous gorges bordered on both sides by resistant igneous materials (Figure 6).

Figure 5. -- Serpentine ridges occur as topographic highs along the geologic contact with schistose rocks

Figure 6. --Precipitous gorge along Grindstone Creek

Homoclinal Ridges

Landforms associated with Sacramento Valley sediments are markedly dissimilar to the serpentine ridges just described. Basically, these sediments have been diastrophically deformed resulting in the formation of a series of north-south trending homoclinal ridges (Dondanville, 1958, p. 2). These ridges are composed of steeply dipping conglomerate or sandstone beds which are resistant to weathering and erosion. Intervening valleys occur where softer sandstones and mudstones have been weathered and eroded. The resulting topography is a series of arcuate ridges which are several miles in width and which tend to parallel the Coast Range Summit ridge (California Department of Natural Resources, Geologic Map of California, 1969). Ridge crests rise steeply 90 to 150 m. above valley floors. Only the extreme western portion of this topographic unit is included within the research area (Figure 2).

The very rapid mid-Pleistocene uplift of the Northern Coast Range resulted in a greatly steepened mountain front. Numerous masses of slide rock broke loose resulting in landslide scars and huge accumulations of slide debris (Hinds, 1952, p. 157). Irwin (1960, p. 56) comments that these debris flows are the foremost mode of degradation. Debris consists of sheared and jumbled masses of graywacke, shale, serpentine, greenstone and glaucophane schist (Hinds, 1952, p. 157). Slopes from which such flows have occurred usually are grass covered and largely devoid of brush and trees (Figure 7).

The study area is characterized by mountainous terrain, in which generally steep slopes are found. Very rugged topography with slopes of 35 to 50 percent are not uncommon. In many places slopes of 65 to 70 percent were measured in the field with a Brunton pocket compass. It is little wonder that there is such pronounced mass wasting throughout the study area. Many slopes display the evidence of significant mass wasting in the past, and more of the same activity may be expected in the future.

CLIMATE

Topography is an important climatic control in the study area. The main summit ridge of the northern Coast Range is an effective barrier to the eastward movement of maritime air masses. Mountainous areas east of the main summit ridge -- as well as foothills along the western margin of the Sacramento Valley -- are in the rain shadow of the Coast Range. Coffin (1955, p. 23) discovered that only well developed storms of December, January and February produce appreciable amounts of precipitation along the east front of the mountains.

Near the summit of the Coast Range -- at 39° N. latitude -- average annual precipitation is estimated as being approximately 190 cm. Stonyford, which is situated near the southeastern corner

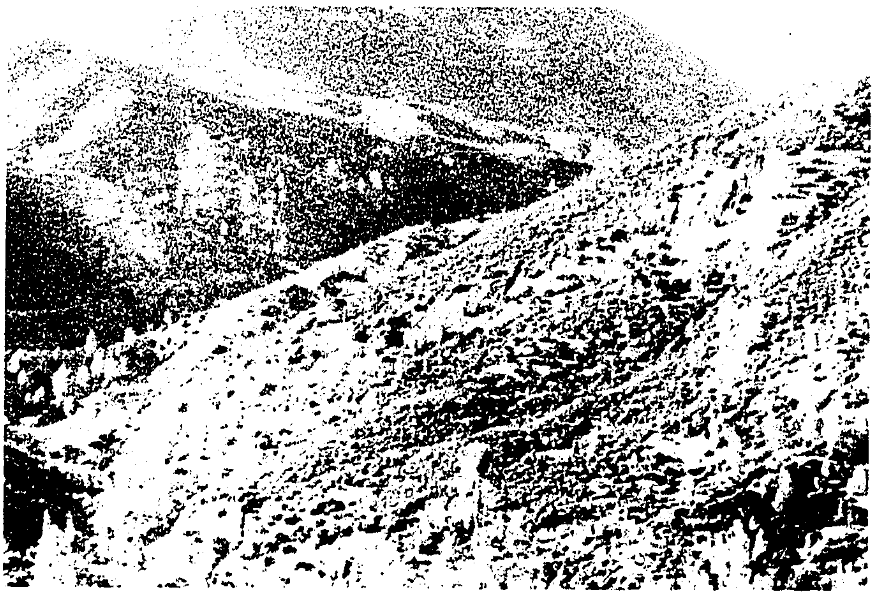


Figure 7. --Slopes on which mass wasting has occurred usually are grass covered and largely devoid of brush and trees

of the study area, receives an average annual precipitation of 48 cm. Monthly maximum precipitation occurs in January (Coffin, 1955, p. 23_c). Prevailing weather is characterized by "periods of storminess separated by periods of clear or partly clear weather (Coffin, 1955, p. 4)."

Summers are quite dry. Subsidence of air from oceanic high pressure results in prevailing clear skies throughout the high-sun season. Occasional buildup of cumulus clouds does occur, but precipitation seldom is an accompaniment. Lightning can result from these dry thunderstorms which tends to increase wildfire potential (Melendi, 1972). Most thunderstorms are concentrated along the main summit ridge of the Coast Range; hence, lightning strikes associated with them ordinarily are in areas of coniferous forest rather than in the Mendocino Chaparral.

Daytime temperatures can be in excess of 40 degrees C. during the period June through October. At the same time there is virtually no precipitation. The combination of these two factors results in a summer season which is characterized by extreme fire danger. Prevailing winds display a highly seasonal pattern. During winter, winds sweep across northern California, generally from the south as air flows toward low pressure cells moving from over the Pacific Ocean (Coffin, 1955, p. 28).

Northerly winds predominate during the warm season as a result of subsiding circulation associated with the North Pacific anticyclone. During the summer months desiccating north winds can occur when severe droughty conditions already are in existence. North winds may persist for several days in succession with windspeeds of twelve to twenty km. per hour and with gusts of twenty-five to thirty-five km. per hour (Melendi, 1972).

Occasionally during the summer westerly winds of marine origin flow into the study area. The Coast Range acts as a barrier creating a reservoir of marine air to the west. At times this air spills over the crest of the Coast Range and roars eastward down the large stream basins. Adiabatic heating helps to produce a blast of warm, relatively dry air funnelling down the canyons. The wind velocity is increased even more as the air is constricted at the mouths of the canyons -- a condition that intensifies extant conditions of maximum evaporation in conjunction with high temperature and summer drought. Weather patterns of this sort tend to raise fire danger ratings to critical levels -- as relative humidity is extremely low and potential evapotranspiration is very high.

SOILS

Soils in the Mendocino Chaparral present a very limited potential for usage other than for the production of natural vegetation. Shallow, infertile soils are dominant throughout the area. When the additional effects of steepness of slope, low water retention and a generally impoverished condition are considered, it is apparent that future soil use is limited to conditions approximate to their present use (Appendix 1).

Most brushland soils have been subjected to continued, but slight, sheet erosion. A predominance of steep to very steep slopes has enhanced the downslope transportation of smaller soil materials (U.S. Department of Agriculture, Soil Survey of Colusa County, 1968; Soil Survey of Glenn County, 1968; Begg, 1965; Soil Survey of Tehama County, 1967). Subsequently, gravel and cobble materials are concentrated in surface horizons. Practically all of the soils within the study area are described as either stony clay loams or gravelly loams. Accumulation of coarse surface materials has resulted in the formation of soils which are characterized by rapid permeability, moderately rapid permeability or moderate permeability in the surface horizon (Begg, 1965, p. 19).

Occasional gullying of some soils is found to occur on steep slopes. However, primarily due to the dense vegetation cover throughout the study area gullying has not occurred to an appreciable extent. Government soil scientists concur that wildfire removal of the chaparral cover could result in accelerated erosion and critical gullying (See soil surveys for Colusa, Glenn and Tehama Counties).

Perusal of Table 1 reveals that the chemical reaction of most soil types is either neutral or slightly to moderately acid -- a condition which is to be expected in soils that are characterized by good to excessive drainage or good drainage. Available water holding capacity generally is low -- varying from about 0.5 dm. to 1.0 dm. -- depending upon the particular soil type (Soil Survey of Glenn County, 1968, p. 67).

The predominant vegetation cover for most soil types is an association of various chaparral shrubs. Sheetiron and Josephine soils are the only ones having a vegetation cover which is dominated by a mixture of conifers. These two soil types are transitional at an intermediate position between lower altitudes dominated by chaparral vegetation and higher altitudes comprised of coniferous forests. Only that portion of these two soil types which is transitional between the two major vegetation associations is included in this study.

Soil fertility is rated only as fair for all soil types -- except the Henneke stony clay loam (which is rated as very poor). Storie Index ratings are low for all soils (Table 1). A rating of 10-19 signifies that soils in this class are of restricted use for cultivated crops as the result of a variety of limiting factors (Appendix 1). Soils which are rated less than 10 are nonagricultural and totally unsuited for cultivation (Begg, 1965, p. 7).

Land which is incapable of cultivation may be utilized for grazing. However, none of the previously described soil types support vegetation suitable for grazing. Grazing capability in Mendocino

TABLE 1

SOIL CHARACTERISTICS *

Soil Type	Perme-ability	Reaction	Parent Material	Drainage	Erosion	Fertility	Vegetation Cover	Storie Index	Grazing Capability
HENNEKE Stony Clay Loam 10-30%	Per.	Neut.	Serp. Rocks	G	1	VP	C	12	VL
HENNEKE Stony Clay Loam 30-5-%	Per.	Neut.	Serp. Rocks	R	1	VP	C	6	VL
HENNEKE Stony Clay Loam 60-65%	Mod. Per.	Neut.	Serp. Rocks	R	2	VP	C	3	VL
SHEETIRON Gravelly Loam, Shallow 30-5-%	Rap.	Mod. Acid	Sch. Sed. Rocks	G	O	F	M	11	--
LOS GATOS Gravelly Loam 30-5-%	Per.	Mod. Acid	Sch. Sed. Rocks	R	1	F	C	10	--
MAYMEN Gravelly Loam 30-50%	Per.	Sl. Acid	Sch. Sed. Rocks	R	1	F	C	8	--

TABLE 1 (continued)

LOS GATOS Gravelly Loam 50-65%	Mod. Per.	Mod. Acid	Sch. Sed. Rocks	R	1	F	C	6	--
MAYMEN-LOS GATOS Gravelly Loam 30-65%	Mod. Per.	Sl. Acid	Sch. Sed. Rocks	R	1	F	C	6	--
MAYMEN Gravelly Loam 50-65%	Per.	Sl. Acid	Sch. Sed. Rocks	R	1	F	C	5	--
MAYMEN-PARRISH Gravelly Loam 30-65%	Mod. Per.	Sl. Acid	Meta. Sed. and Sed. Rocks	R	2	F	C	5	VL
STONYFORD Gravelly Clay Loam 50-65%	Per.	Neut.	Basalt and Serp. Rocks	R	2	F	C	4	VL
MAYMEN Gravelly Loam 50-65% Eroded Very Shallow	Per.	Mod. Acid	Sch. Sed. Rocks	G	0	F	C	3	VL
SHEETIRON Gravelly Loam 30-50% Med. Deep	Rap.	Mod. Acid	Sch. Sed. Rocks	G	0	F	M	11	VL

TABLE 1 (continued)

JOSEPHINE Gravelly Loam 30-50%	Per.	Sl. Acid	Sch. Sed. Rocks	R	2	F	M	13	L

SOURCE: Eugene L. Begg, Soils of Glenn County, California, p. 19.

* See Appendix for explanation of abbreviations.

Chaparral is described as either very low or simply incapable of producing forage for cattle. Carrying capacity is defined as the number of hectares per cow per year. Rangeland with a very low carrying capacity requires in excess of 15 hectares per cow per year (Begg, 1965, p. 7).

Various environmental factors are responsible for the impoverished nature of soils in the study area. However, unfavorable features which appear to be most important are steepness of slope with subsequent shallow, rocky soils; and low fertility.

THE CHAPARRAL

Cooper (1922, p. 7) describes chaparral brush as:

> ... a shrub community dominated by many species belonging to genera unrelated taxonomically, but of a single constant ecological type, the most important features of which are the root system which is extensive in proportion to the size of the plant, dense rigid branching and preeminently the leaf which is small, thick heavily cutinized and evergreen.

Generally this type of vegetation is referred to as broad-sclerophyll, which includes a variety of genera and species. However, some exceptions occur, for example, *Adenostoma fasciculatum* (chamise) has short needle-like leaves rather than the broad-sclerophyllous leaf-type (McMinn, 1964, p. 7).

Broad-sclerophyllous forests are found along the Pacific Coast of North America -- ranging from Southern Oregon to Baja, California (Cooper, 1922, p. 21). Within this region broad-sclerophyllous forests and climax chaparral are in very close habitation "... in that they overspread the same range occupying area of comparatively slight physical differences (Cooper, 1922, p. 25)".

Climax chaparral shrub, as indicated by Adenostoma fasciculatum (chamise), is the dominant plant community from Northern Baja, California to about 41^{o} N. latitude in Northern California (Cooper, 1922, p. 26). Northward from there broad-sclerophyllous forest becomes the dominant vegetation, however, some chaparral species continue to occur as understory shrubs.

Wieslander and Gleason (1954, p. 3) recognize California brushlands as belonging to five cover types. The most extensive of these is chaparral shrub which occupies 3.4 million hectares in the California Coast Ranges and Sierra-Cascade foothills. The other four types of vegetation include woodland, woodland-grass, coastal sage and desert, none of which are under direct consideration in this study. The woodland-grass association adjoins the chaparral along the eastern margins of the study area and woodland (broad-sclerophyllous forest) is found northward from the Mendocino Chaparral.

Chaparral is the dominant type of vegetation along the eastern side of the North Coast Range at altitudes of less than 1,375 m. Coniferous forests, valued for their timber production, predominate above this altitude; however, even there inclusions of mountain chaparral are found to occur.

Occasionally narrow strips of coniferous forest extend to altitudes considerably lower than where they are ordinarily found. Usually such strips are situated on the north faces of very steep ridges or are found to occupy narrow stream canyons where more mesic conditions ensue. Occasionally conifers are found at elevations as low as 450 m.

Most chaparral is shrub-form vegetation, although it may become tree-like where a number of environmental factors are very favorable. For example, _Umbellularia californica_ (California laurel) and _Aesculus californica_ (California buckeye) may occur as either a shrub or a tree (Cooper, 1922, p. 21). Sometimes it is difficult to discern the difference between the large tree-like forms of chaparral and a broad-sclerophyllous forest. However, the broad-sclerophyllous forest ordinarily includes some species of trees such as varieties of _Quercus_ (oak), _Acer_ (maple), and _Arbutus menziesii_ (madrona) which are not ordinarily associated with chaparral shrubs.

Southward facing Mendocino Chaparral brushfields -- which have been undisturbed for a minimum of fifty years -- can become essentially impenetrable by man as well as some of the larger species of wildlife, including deer, bear and mountain lion (Figure 8). In many places the brush is so dense that a person must crawl on hands and knees following the path of least resistance in order to penetrate it. In stands of old-growth brush sometimes one is forced

Figure 8. --Impenetrable wall of chaparral brush

Figure 9. --Old growth chaparral brush is difficult
to penetrate

to walk on top of the dense mat, and at times one may find oneself several feet above ground level (Figure 9). Ceanothus cuneatus (wedgeleaf ceanothus), in a dense tangle, is by far the most difficult to traverse of any species. C. cuneatus is a very rigid plant with branches that culminate in sturdy spine-like twigs. Several individual plants in proximity to one another tend to become interlocked and unyielding. Moving upslope in such a tangle is virtually impossible. Arctostapholos spp. (manzanita) also can be very difficult to penetrate. Manzanita is the largest of the chaparral species found occupying south facing slopes. Individual plants may reach a height of more than four meters and a diameter of three to five meters. Where several bushes grow in proximity to one another, passage is seriously restricted.

Chamise, the most common inhabitant of south facing slopes, ordinarily is more easily traversed than the larger more rigid species of brush. Individual plants rarely are more than 2.5 meters high and usually only about one-half the diameter of their height. Despite the fact that chamise is rigid, it can be pushed aside to allow passage and seldom does it grow in an interlocking tangle such as do other species.

Northward facing slopes also are densely vegetated. Several species of the genus Quercus are commonly found as well as manzanita, Garrya fremontia (Fremont silktassel) and a variety of other shrubs. The tendency toward more mesic conditions on north slopes results in much larger maximum size of individual plants. Ordinarily north slope vegetation is not as difficult to penetrate as is the dense tangle of south slope brushfields. Species of Quercus and manzanita grow high enough that often one may walk beneath dense canopy.

Significant differences exist between Mendocino Chaparral brushlands and chaparral in other parts of California. In a study of chaparral succession in Southern California, Hanes (1970, p. 35) noted seventy-eight shrub species of which Adenostoma fasciculatum was most frequently encountered. Quercus dumosa and Ceanothus crassifolia were other species often observed (Hanes, 1970, p. 36).

Field observations in the Mendocino Chaparral have yielded some similarities and dissimilarities with Southern California chaparral. Adenostoma fasciculatum is the dominant chaparral species found in the study area while several species of Ceanothus, Arctostapholos and Quercus are of other genera commonly found there. (For a general discussion of chaparral vegetation see: Jepson, 1925; Munz and Keck, 1959). Fewer than one-fourth as many shrub species are found in the Mendocino Chaparral as Hanes recorded in Southern California. Only eighteen species of chaparral brush occur in the study area (Table 2).

Numerous factors are responsible for the fewer number of

TABLE 2

MENDOCINO CHAPARRAL SPECIES *

Scientific Plant Name	Common Plant Name	Sprouter or Non-sprouter	Over-All Browse Value				
			Cattle	Horses	Sheep	Goats	Deer
Adenostoma fasciculatum	Chamise	Sp.	4-5	5	2-3	2-3	2-3
Aesculus california	California buckeye	Sp.	4	5	3-4	3-4	1-2
Arctostopholos glandulosa	Eastwood manzanita	Sp.	5	5	5	4-5	4-5
A. patula	Greenleaf manzanita	Both	5	5	4-5	4-5	3-4
Ceanothus cuneatus	Wedgeleaf ceanothus	Ns.	4	5	2-3	2-3	3
C. integerrimus	Deerbrush	Both	2-3	3	1-2	1-2	1-2
Cercocarpus betuloides	Western Mountain Mahogany	Sp.	2	2-4	1-2	1-2	1
Erodictyon californicum	California yerba santa	Sp.	5	5	4-5	4-5	3-4
Garrya fremontii	Fremont silktassel	Sp.	4-5	5	2-3	2-3	2-3
Heteromeles arbutifolia	Toyon	Sp.	5	5	4-5	2-3	2-3
Quercus chrysolepis	Canyon liveoak	Sp.	5	5	5	5	3-4
Q. dumosa	California scruboak	Sp.	4-5	5	4	2-4	1-2
Q. kellogii	California black oak	Sp.	2-4	4-5	3-4	3-4	1-2

TABLE 2 - (continued)

Scientific Plant Name	Common Plant Name	Sprouter or Non-sprouter	Over-All Browse Value				
			Cattle	Horses	Sheep	Goats	Deer
Q. wislizenii var. frutescens	Scrub interior live oak	Sp.	4	5	3-5	3-4	1-2
Rhus diverslobia	Poison-oak	Sp.	4-5	4	4	4	3-4
R. trilobata	Squaw bush	Sp.	4-5	5	4	4	3-4
Umbellularia californica	California bay	Sp.	3-4	5	3-4	3-4	2-3

1 = excellent 2 = good 3 = fair 4 = poor 5 = useless

* Adapted from Sampson and Jesperson, <u>California Range Brushlands and Browse Plants</u>, pp. 146-148

species in the Mendocino Chaparral. First, latitude with its attendant influence on climate probably is the most significant reason. As previously noted Cooper observed that a definitive change in sclerophyllous vegetation occurred at approximately 41° N. latitude in California. Largely as the result of latitudinal position Northern California chaparral is transitional between areas which display seasonal xeric qualities and areas which are mesic climates.

Southern California vegetation displays an opposite kind of transition. Species of plants belonging to the chaparral association border upon regions characterized by increasingly xeric conditions -- both southward and eastward. Vegetation there occupies a zone of climatic transition between a sub-tropical climate and semi-arid or arid climate.

Secondly, altitude is an important limiting factor. In the study area terrain dominated by chaparral brushlands is found to occur at an altitude under 1,200 m., whereas in Southern California Hanes' (1970, p. 34) study suggests maximum altitude for continuous chaparral shrub cover to be approximately 1,525 m. South-facing brushfields in the Mendocino Chaparral are almost pure stands of chamise, extending from about 485 m. to about 770 m. Above this level increasing amounts of wedgeleaf ceanothus and manzanita are intermixed with the still dominant chamise. Occasionally, brushfields at higher altitudes encompassing several hundred hectares are almost evenly divided between two species -- Adenostoma fasciculatum and Ceanothus cuneatus (Figure 10).

Altitude appears to be a less important determinant of species types on north facing slopes. There the same species of chaparral brush are observed from low altitude to high altitude. Main differences occur simply as an expression of changes in the volume of woody material rather than in changes of species types.

Third, all of the study area is situated east of the crest of the north-south trending Coast Range. Mendocino Chaparral is in the rain-shadow of the highest Coast Range peaks. Precipitation decreases in amount from west to east and with a decrease in altitude.

Fourth, soil types are decidedly different in the study area than those found in Southern California. Steep slopes ordinarily possess thin, rocky soils which display at least some sheet erosion and gullying. Soils occupying gentle slopes are not only deeper and characterized by less sheet erosion and gullying, but they also have better water retention capabilities.

Henneke soils, which have been derived from serpentine parent material, are infertile because there is a very low ratio of calcium to magnesium (Soil Survey of Glenn County, 1968, p. 32). Vegetation typically occupying Henneke soils is impoverished looking, and nowhere on these soils does it yield the same volumes that it does on soils derived from metasedimentary, metavolcanic or sedimentary rocks.

Ceanothus jepsonii is an indicator shrub which is very useful in the determination of the location of Henneke soils. In no other place in the entire study area was *Ceanothus jepsonii* observed to grow except in areas characterized by serpentine parent material. Chamise brush is seldom found to occur on Henneke soils, but if it does occur ordinarily it is only in marginal proximity situated along the geologic contact of serpentine and schistose sedimentary rocks. Easily discerned patterns of vegetation distribution occur as a result of this (Figure 11).

Finally, no discussion of the chaparral would be complete without at least some comment upon the utility of chaparral brush. Sampson and Jesperson (1963, p. 3) have rated the overall browse value of chaparral species for livestock and deer (Table 2). Chamise, the most commonly found shrub in the study area is rated poor to useless for horses and cattle but as good to fair for sheep, goats and deer. Bissell and Weir (1957, p. 479) tested the total digestible nutrient content of chamise sprouts and seedlings. Their research revealed that its value as a feed for sheep and deer was only slightly less than that of alfalfa. Wedgeleaf ceanothus is rated poor to useless for horses and cattle but again good to fair for sheep, goats and deer. *Cercocarpus betuloides* (western mountain mahogany) which is found at various sites throughout the research area is rated

Figure 10. -- Occasionally, brushfields at higher altitudes are almost evenly divided between two species -- Adenostoma fasciculatum and Ceanothus cuneatus

Figure 11. -- Sparse vegetation occurs on Henneke soils derived from serpentine, and dense vegetation occurs on soils derived from metamorphic rocks

as good to excellent for both livestock and deer. Mountain mahogany has the highest overall rating of any chaparral species native to the research area. On the contrary, the two species of manzanita found here are ranked as poor to useless as browse for either livestock or deer.

CHAPTER II

THE RESEARCH PROBLEM

In the opening statements of this research study it was noted that chaparral vegetation is of little direct value at the present time. It would be enlightening to view the Mendocino Chaparral in a historic context. Mendocino Chaparral brushlands were once included in a pioneer economy but gradually were phased out as the twentieth century progressed.

Since the abandonment of the Mendocino Chaparral by early settlers these lands have been withdrawn from direct utilization and placed under the control of the United States Forest Service. Public policy, as administered by the U. S. F. S., has been one of only marginal management. Basically that policy is one of total wildfire exclusion which has resulted in the formulation of land management practices such as the fuel-break system. A few select areas have undergone the conversion of vegetation types from chaparral to grassland. However, the majority of the Mendocino Chaparral area is only passively managed.

The possible deleterious effects of wildfire are an important consideration in the management of the Mendocino Chaparral. It is possible that the resource potential of the Mendocino Chaparral may be greatly enhanced upon the implementation of a more intensive management plan while at the same time the deleterious effects of wildfire may be greatly reduced.

The preceeding subjects will be considered in the first parts of Chapter II. The final pages will be devoted to the statement of the main research hypothesis and four supportive hypotheses.

THE MENDOCINO CHAPARRAL

Chaparral brushlands located in the research area are largely controlled by the Federal Government. Curiously enough, the U.S. Forest Service was charged with the responsibility of administering chaparral brushlands even though these lands are ordinarily incapable of forest production. When the Mendocino National Forest was instituted in 1907 the Forest Service was directed to engage in the task of managing mountain lands for their yield of "timber and water" (The Mendocino National Forest, Administrative Files). Naturally the mountainous areas of coniferous forest were to be managed for their yield of timber, and as the demand for timber products has increased forest management techniques have been intensified. However, since Mendocino Chaparral has long been considered as having only marginal utility no comprehensive management plan has evolved.

Prior to the creation of the Mendocino National Forest the chaparral brushlands were used by homesteaders. The resource base was impoverished and only favored spots throughout the brushland areas could support a single homestead family if there was ample spring water for domestic use and perhaps a glade that could provide some pasturage for a few domestic livestock. Remnant apple trees often are all that remain to mark the homesites of these early-day pioneers. Except for the few sites which became patented land claims, the majority of the chaparral brushlands remained in the public domain. Homesteaders from the Sacramento Valley and adjacent coast range foothills utilized the brushlands for pasturage of goats and cattle (Burcham, 1956, pp. 62-64). Goats browsed the brushfields the year round while cattle ranged only seasonally. These settlers had arrived at the custom of occasionally igniting the brushlands during the Fall season to improve the browse capabilities for domestic livestock during the following spring and summer seasons (Whitlock, 1970). Near the turn of the twentieth century the demand for mohair decreased and goat husbandry in the chaparral very rapidly declined as a result of the changing economy. Homesteaders in the chaparral were forced to move, and the use of the chaparral brushlands for livestock grazing became entirely seasonal.

Despite the fact that the Forest Service was charged with controlling the Mendocino Chaparral for its water resources there has been no comprehensive management plan to increase either water yield or water quality. In essence, the brushlands have been only marginally managed, perhaps in part because of the policy of fire exclusion. Fire exclusion policies were adopted by the U.S. Forest Service to protect watersheds from the deleterious effects of wildfire which ordinarily is directly associated with subsequent acceleration of erosion. Rather than controlling and managing the vegetation in watersheds it has been protected. The effects of a dense vegetation cover with a capability for evapotranspiration of huge quantities of water have not even been considered. It is simply assumed that total protection of the chaparral will yield maximum water. Additionally, the aspect of water quality has not been thoroughly examined except to contend that it radically deteriorates as the result of wildfire. Hence, for the last sixty-five years public policy has been one of fire exclusion in the Mendocino Chaparral.

Even since the multiple-use concept has been instituted in the management of public lands it has not been applied to the Mendocino Chaparral in any kind of concerted effort. Besides its yield of water the chaparral can support a variety of animals and birds. It can provide some forage for livestock, and it has a potential for recreation.

Numerous wildfires have occurred despite the policy of fire exclusion, and several of these fires have burned over tens of thousands of ha. Fire records maintained by the U.S. Forest Service allege that most wildfires have been deliberately ignited by livestock ranchers (The Mendocino National Forest, Administrative Files). Many ranchers and conservation groups have lobbied for a change in the total fire exclusion policy of the U.S. Forest Service, but on a policy level the Service is still adamantly opposed to change.

The fact remains that no comprehensive analysis or management plan has been instituted in the research area for the chaparral brushlands controlled by the U.S. Forest Service. Major emphasis is placed upon fire exclusion because of the supposed damage to watersheds and the danger of fire spreading into valuable timberlands adjacent to the chaparral brushlands. There can be no viable comprehensive management plan until the potential of the chaparral brushlands is fully assessed. Further, it is herein contended that until a comprehensive management plan is developed the resource potential of chaparral brushlands is being grossly underestimated. Ineffective piece-meal programs are the norm. Two of these will be briefly considered in the following section.

Fuel Breaks

The U.S. Forest Service is on the verge of implementing a massive fuel-break system to reduce potential fire hazard. Basically, the fuel-break system is a program of action in which fuel -- chaparral brush -- will be cleared in a strip at least one hundred meters wide along ridge tops throughout the Mendocino Chaparral (Figure 12).

In most instances the brush will be mechanically treated -- that is crushed with a bulldozer and then burned after it has had sufficient drying time. The cleared strip will be planted to hardy types of shallow rooted perennial grasses. Grasses will stabilize surface soil materials and at the same time will reduce fire hazard. During the hot, dry summer season grasses are susceptible to fire, but the smaller volume of fuel in comparison to brush results in less hazardous and less costly suppression (Figure 13).

The fuel-break system is only a stop gap measure which is the treatment of the effects of mismanagement of chaparral brushlands. Dodge (1972, p. 141) contends that "... fuel breaks do not eliminate the problem of fuel accumulation, they merely divide it up." Ridge tops have been selected as places of embattlement. Absolutely no attempt has been made at developing an assessment of the resource potential of those chaparral brushlands surrounded by fuel-break and in no way will those areas be protected from fire. The fuel-break system simply is a measure designed to prohibit the possibility of a single massive conflagration. Neither can the system prevent the occurrence of numerous wildfires with subsequent "damage" in any number of areas contained by fuel-breaks.

Not only does the fuel-break system simply treat the effects of a problem rather than its causes, it also is a short term investment. Unless fuel-breaks undergo periodic chemical treatment chap-

Figure 12. -- Fuel-breaks in the Mendocino Chaparral

Figure 13. --A fuel-break planted to grasses to reduce wildfire hazard by reducing fuel volume

arral species will rapidly reinvade them. A great deal of persistence will be needed if the grasses planted in the breaks are to become permanently established. Programs of fertilization and reseeding plus chemical treatment to prohibit reincroachment of chaparral species will need to be financed and implemented. Finally from an aesthetic viewpoint the fuel-breaks are a temporary man made monstrosity impressed upon what essentially is a wilderness landscape.

Chamise Conversion

The Mendocino National Forest has invested some funds in the conversion of chamise chaparral to grasslands -- the aim of which is the solution of some chaparral brushland management problems. As a result of this program the U.S. Forest Service recognizes the potential of some areas of chaparral brushlands and has become involved in the conversion of brush to grassland. Factors such as water yield, grassland range quality, fire control and rejuvenation of wildlife habitats are enhanced by such a program. Unfortunately only a small percentage of the total area of chaparral brushlands has a combination of physical factors favorable to conversion (Bentley, 1965, pp. 7-9). At the present time only those areas characterized by soils capable of producing grasses have been managed in accordance with this plan. Conversion sites that have been chosen for treatment are ones with relatively deep soil and which occur on slopes of less than 40 percent (Figure 14).

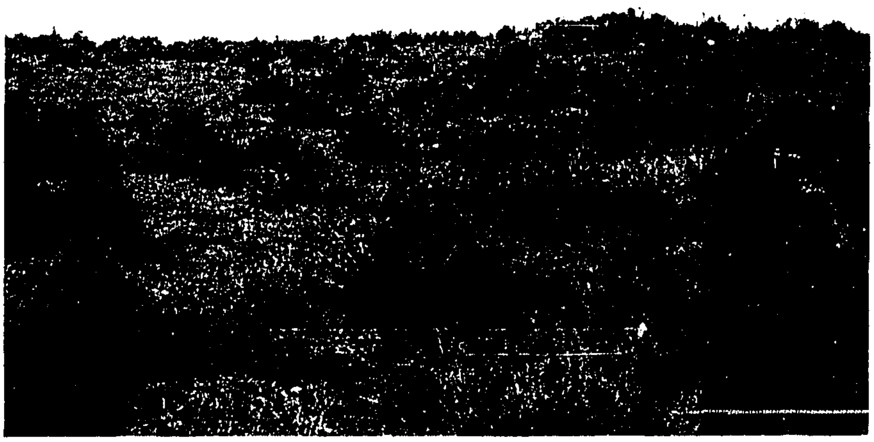


Figure 14. -- Brush conversion sites are in areas with relatively deep soil and on slopes of less than 40 percent

In the last decade approximately 1,000 ha. of chaparral brushlands have been converted into grasslands in the Grindstone Basin Project (The Mendocino National Forest, Administrative Files). Indeed this is a very meager start when one considers the fact that there are many thousands of hectares of chaparral brushlands in the Mendocino National Forest in need of treatment. An overwhelming majority of the chaparral brushlands can not be treated and converted into grassland because either the topography is too steep or the surface is too rugged. These many thousands of acres of chaparral brushlands which are incapable of conversion into grasses present a level of fire potential which is practically beyond description.

WILDFIRE AND CHAPARRAL

The role of wildfire in the distribution of chaparral brushlands is widely acknowledged. Chaparral species apparently must be adapted to recovery after burning because of the inevitability of occasional fire in such dense, woody vegetation which is periodically subjected to extreme drought. The seasonally droughty climate, in conjunction with the high density of the vegetation cover, makes chaparral one of the most fire-susceptible vegetation types in the world (Lewis, 1961, p. 13). Catastrophic wildfires occur in chaparral brushlands in various parts of the globe, especially in those areas where the amount of dry woody material has maximized and where the incidence of prolonged summer drought has resulted in drastic reduction of the moisture content of the chaparral shrubs (Zinke, 1961, p. 21).

Abundant scientific literature exists on the succession of chaparral species in areas which have been subjected to wildfire and also in areas where wildfire either has not occurred or has not occurred recently. Many of these studies have been in Southern California where human population densities are high in proximity to chaparral brushlands. For instance, Hanes (1970, pp. 27-51) discussed succession after wildfire burns in Southern California. Sampson and Jesperson (1963, p. 3) described the character of California range brushlands and browse plants and alluded to the problems of management of chaparral brushlands.

The most comprehensive treatment of chaparral plant succession in Northern California is that of Sampson in 1944. Ramifications of wildfires are discussed in his study -- not only as to the types and kinds of change in actual vegetal succession, but also the changes in site conditions which result from wildfire. Sampson (1944, pp. 58-62) pointed out the importance of wildfire to both sprouting and non-sprouting species of chaparral brush.

The 1961 conference on Southern California Wildland Research Problems dealt with the ecology of chaparral brushlands (Man, Fire and Chaparral, 1961). The consensus of conference participants was that adequate knowledge about the successional pattern of Southern

California chaparral had been accumulated; however, the problem that remains unsolved is that of proper management of the chaparral brushlands.

Under given circumstances the actual behavior and potential for wildfire in chaparral brush is inadequately understood. One of the major problems is the inability of estimating fuel volumes. Other important factors which must be thoroughly appraised before the propensity for wildfire burning may be adequately predicted include physical properties such as the dimension of the fuel particle, the arrangement of fuel particles, the moisture characteristics of the fuel and its chemical properties.

Countryman and Philpot (1970, p. 1) observed that energy from burning fuel is the primary force affecting fire behavior in wildland fires. They concluded that several physical factors affect the rate at which energy is released in the fuel bed (fuel bed refers to those spatial factors which effect fire behavior) and that the greater the energy release the more difficulty involved in curtailing a wildfire. For example, two areas with identical fuel volumes may display radically different behavior during wildfire simply due to differential arrangement of fuel particles.

The proportion of fuel particles of various dimensions in the fuel bed is a determinant in the rate of energy release of a wild-land fire (Chandler, 1957, p. 28). Small particles are enveloped with air;

therefore seldom is there a lack of oxygen which is necessary in the combustion process. Larger materials require a much greater length of time in which to release their potential energy. Wildfires occurring in chaparral brushlands usually do not consume live material greater than 1.5 centimeters in diameter (Countryman and Philpot, 1970, p. 4). The proportion of fine fuels becomes highly critical in assessing the potential for fire. Most chaparral brushlands are characterized by vegetation with a greater proportion of fine fuel volume than of coarse fuel volume because chaparral brush species have several stems and many branches.

Investigation of a typical chamise chaparral brushfield in Southern California revealed that 61 percent of fuel weight, 65 percent of fuel volume and 96 percent of the surface area of chamise is in fine fuels (Countryman and Philpot, 1970, p. 4). In an experimental prescribed burn in chaparral brush, Green (1970, p. 4) noted that 70 percent of all live-green fuel was consumed by fire; however 85 percent of the green chamise brush burned. An obvious conclusion is that brushland areas in which chamise is the dominant species are potentially hazardous wildfire sites.

Arrangement of fuel particles is of course very difficult to describe. The spacing, or compactness of particles in the fuel bed affects the supply of oxygen to each particle. If the fuel particles are very small combustion will be retarded if they are also closely spaced. However, if the particles are arranged in space so that each particle is surrounded by sufficient air for its complete combustion and yet close enough so that the combustion of one will ignite one or more others, then the rate of combustion may be explosive (Countryman and Philpot, 1970, p. 30).

The moisture content of the fuel is dynamic and difficult to assess in the field, but it significantly modifies wildfire potential. Severe seasonal drought has been referred to earlier as an environmental characteristic of geographic areas dominated by chaparral brushlands. Chaparral brush ordinarily commences new growth sometime between late January and early March. Between March and May new growth has a very high moisture content -- sometimes exceeding 200 percent of the dry weight equivalent of the plant (Countryman and Philpot, 1970, p. 10). During the summer months the moisture content of living parts of brush plants is generally declining until a minimum is reached in September or October. It is during this period of very low moisture content of living fuels that fire danger is most hazardous.

The volume of dead fuel also must be considered. Dead fuel occurs as the result of the dying of a plant or as the accumulation of litter on the ground surface beneath living plants. Chamise and _Ceanothus cuneatus_, which are the two most commonly found chaparral species in the Mendocino National Forest, seldom have any measurable litter accumulation. Other larger leafed species such as Arctostapholos (manzanita) and Quercus (oak) have up to six cm. of litter accumulation. Presumably in some instances litter would tend to increase the energy yield of a fire, but more importantly it serves as a medium for the transmission of fire. The fuel moisture content of dead fuel is primarily dependent upon atmospheric conditions and can change very rapidly in response to changes in humidity and temperature. This is especially true of chamise brush because of the dominance of fine fuel. The moisture content affects the flammability of dead materials; hence it affects fire potential.

Chemical characteristics of a fuel also may affect the rate at which it burns. Some plants contain high energy ether extractives consisting of waxes, oils, fats and terpenes. Countryman and Philpot (1970, p. 10) found that ether extractives account for 8 to 12 percent of foliage weight and from 3.4 to 8.8 percent of woody material weight in chamise brush. During combustion of chamise the ether extractives are volatilized, in which state they are highly flammable. Laboratory tests for the heat values of these ethers yielded a measurement of 17,000 B. T. U. per pound of foliage and 24,000 B. T. U. per pound of small twigs. For individual plants the energy yield ranged from 83,000 to 9,200 B. T. U. per pound (Countryman and

Philpot, 1970, p. 15). It can be concluded that ether extractives are responsible for creating energy levels high enough to desiccate green fuels which ultimately results in the increased capacity for their consumption by wildfire. Brushfields which are characterized by a large proportion of fine fuels are potentially explosive wildfire environments.

Old growth chaparral brushfields which are particularly susceptible to wildfire create deleterious environmental effects as a result of that burning. Occasionally uncontrolled wildfires burn thousands of acres at a time. The effects of these holocausts on wildlife is largely a matter of conjecture; however, it is known that in some instances many animals have perished. At the very least there may be the disruption and dislocation of existing animal populations.

High soil temperatures destroy microorganisms in the soil. Destruction of functioning biological elements in the soil can cause a serious debilitation in the rejuvenation of that soil following wildfire. When organic matter in the soil is destroyed there is a deterioration of soil structure in which both the water-storing and water-transmitting properties of the soil are reduced (De Bano, and Rice, 1971, p. 329).

Soil scientists have discovered that fire can result in the formation of extremely water repellent soils. Water repellency can occur in unburned areas as well as in those areas subjected to burning;

however, in unburned areas water repellent layers are near the surface. De Bano (1969, p. 12) discovered that in unburned soils the maximum concentration of hydrophobic substances is in the upper part of the soil profile immediately below the litter layer. Smaller amounts of leachate may be moved below the litter layer by infiltrating water.

High temperatures during burning result in the vaporization of chemical constituents of the fuel. As previously noted the energy released in the combustion of plant ethers results in high temperatures. During fire, temperatures as high as 1,100 degrees C. have been recorded in the fuel bed (De Bano and Rice, 1971, p. 329). Temperatures within the soil are significantly less due to the low conductivity of the soil. At five centimeters below the surface during fire maximum temperatures range from 150 degrees C. to 20 degrees C. Differentials in temperature between the soil surface and depths of several centimeters are very significant. Vaporized ethers move downward in the soil profile where they are cooled and condensed on soil particles. After a fire has swept through a brushfield condensed vapors produce a water repellent layer below the soil surface. "The depth and thickness of the water repellent layer depends upon the intensity of the fire and the nature and amount of vegetation present" (De Bano and Rice, 1971, p. 330).

Water repellency affects both the stability and the productivity of soils. Severe water repellency can alter soil-moisture relationship and impair vegetation growth (De Bano, 1969, b, p. 11).

Soil erosion apparently is related to water repellency. Precipitation can infiltrate quite rapidly into dry wettable soils. Initially the intake may be high and then decrease over a period of time. However, the much slower infiltration rate of water-repellent soils can produce an erosion problem. Suppose that the surface is wettable, but that underneath that there is a water repellent layer. When the soil above the water repellent layer becomes saturated water flows laterally between the two layers (De Bano, b, p. 11). If this occurs on terrain characterized by steep topography downslope movement of surface materials results in the contribution of significant amounts of debris in stream channels (De Bano and Rice, 1971, p. 328).

It appears probable that in areas where hydrophobic soils exist that some plant species may have adapted to water repellency whereas an invading plant would have difficulty in becoming established. Perhaps sprouting species of plants are particularly well suited for areas characterized by water repellent soils. The plant's root structure and crown are not destroyed even during the hottest wildfire; hence, they may begin growing immediately after aerial portions have been destroyed by fire. Sampson (1944, p. 2) found that burning did not destroy or materially thin out sprouting forms of chaparral.

Plumb (1961, p. 2) studied the effects of an extremely hot wildfire in Southern California where sprouting of chamise brush was observed within 10 days after the holocaust.

Laboratory tests conclusively showed that of the several chaparral species commonly found to dominate brushfields, chamise caused the most severe water repellency. Decreasing repellency was associated with other shrubs; however, it was enough to produce a layer in which the infiltration of water would be seriously impeded (De Bano, 1969, b, p. 14).

FIRE AND CHAPARRAL MANAGEMENT

Considerable controversy exists as to the degree that natural vegetation has been altered by fire. Some specific types of vegetation have evolved largely as the result of recurrent wildfire spanning a history extending back over the last few thousands of years. Sauer (1956, pp. 46-69) has considered the long range effects of fire upon native vegetation. He reasons that "naturally" occurring wildfires resulting from such phenomena as lightning or volcanic activity, coupled with man's use of fire as a tool in driving game and clearing land have altered vegetation patterns. Dansereau (1957) considers the same possibilities in a discussion of the role of fire. Stewart (1951, p. 319) contends that American Indians almost universally used fire as a tool to improve their ability to obtain foodstuffs. Burcham (1957) has cited historical accounts of early Spanish and American explorations of California in an effort to reconstruct patterns of natural vegetation pre-dating Occidental occupance of California. Contrary to many authors, Burcham supports the thesis that burning of chaparral brushlands in California has occurred largely since Occidental occupance. Eastman (1972, p. 12) quotes statistics for a 22-year period from 1945-1966 in which lightning ignited 64 percent of all wildfires in national forests while the remainder were ascribed to man. Each year thousands of fires are started by lightning -- perhaps as many as 10 thousand to 15 thousand (Eastman, 1972, p. 12).

It is reasonable to assume that large brushland areas in pre-Columbian America were periodically subjected to wildfire. In view of this the total fire exclusion policy of public land management agencies seems to be a mistake. It appears logical to conclude that fire is an integral element of the natural environment.

Mutch (1970, p. 1046) argues that some plant communities which have a readily available energy source are highly flammable, which results in frequent wildfires. The accumulation of fuels over long periods of time under a policy of total fire protection eventually leads to very destructive fires.

> Wildland fires must be studied and managed as integrated events associated with the ecosystem. The vegetation brings certain properties to the ecosystem that conditions the fire history, and the fire history determines in part, the maintenance, regression, or succession of plant communities (Mutch, 1970, p. 1050).

Periodic wildfires have burned chaparral vegetation and the fact that many chaparral species are vigorous sprouters may indeed indicate that these plants are adapted to survival in a fire environment. Even non-sprouting species of chaparral brush require fire to enhance their reproduction. Their seeds have extremely hard shells which crack and open as the result of scarification and weakening that occurs during high temperatures. Germination and establishment of seedlings is usually prolific following heat treatment.

The long-term effect of fire exclusion is unknown because the fire exclusion policy has been pursued only during this century. Undoubtedly it will result in the decadence of vegetation and the accumulation of dead materials. It has been previously noted that the volume of dead fuels definitely is a fundamental controlling factor in the behavior of a wildfire. Living fuels are more difficult to ignite -- at least as compared to dead fuel. It appears obvious that more disasterous wildfires are certain to occur in the future as the proportion of dead to living fuel increases. Dodge (1972, p. 141) notes that small fuels contribute most to fire intensity and rate of spread. Large fuels cause the fire to persist. He concludes that "... the critics of control burning fail to recognize the differences between high-intensity wildfires that do destroy everything and low intensity fires that may cause little or no damage". In view of these factors a logical decision would be to manage chaparral brushlands so that a minimum of dead material is present.

In 1959 Burcham (p. 180) noted that insufficient research has been "... directed specifically toward developing sound applications of planned burning to wild land management (and) probably none has been centered on the use of fire to achieve wild land management goals". Green (1970, p. 1) found that one of the major factors which has caused the reluctance to use fire as a management tool is the risk of escape which converts a prescribed burn into a wildfire. Weather conditions and fuel characteristics which are suitable for prescribed burning also are conducive to wildfire. However, burning can be accomplished during favorable conditions -- especially in the spring when daytime temperatures are high and nighttime temperatures are low.

A major problem of burning in spring is that the moisture content of brush is then at its highest. It has been found that a dessiccant, cacodylic acid can be broadcast sprayed on designated areas to reduce fuel moisture in preparation for a prescribed burn (Green, 1970, p. 2). Standard phenoxy chemicals such as 2,4-D; 2,4,5-T or a mixture of the two will dessicate leaves and small twigs. Carpenter et. al. found that prescribed burning of untreated manzanita does not effectively clear the vegetation. After spraying brush with a mixture of phenoxy chemicals and diesel oil all manzanita brush including stems in excess of two inches were consumed in a prescribed burn one year later (Carpenter and others, 1970, p. 4).

The implications of this discussion are obvious. It is becoming increasingly apparent that fire can be a valuable tool in the management of chaparral brushlands. Several basic questions need to be analyzed before specific management recommendations can be specified. First, at what critical level shall fuel volume be manipulated? Second, what relationships exist linking fuel volume to spatial variants of surface configuration (slope, altitude and directional orientation) and the time required to achieve specific fuel volumes?

This study uses a system of data collection which provides information concerning the recovery of fuel volume following chaparral wildfires. It is intended that the research techniques herein used will yield fundamental data upon which basic management decisions can be developed to enhance the utility of chaparral brushlands. Discovery of those factors that will enable land managers to reduce the explosive conflagration of chaparral brush while at the same time increasing its viability as a resource are the intended objectives of this endeavor. Mutch would concur with these objectives since he has stated that:

> The ability to accurately assess plant community changes, and fuel changes, that result from resource management, total fire protection, prescribed fire use, or wildfires, will provide one scale for evaluating management practices (Mutch, 1970, p. 1050).

THE RESEARCH HYPOTHESIS

The main research hypothesis of this study is:

> The evolution of Mendocino Chaparral brushlands is dependent upon select environmental factors acting within a time dependent system such that fuel volume will significantly vary thus resulting in variance in wildfire potential.

Managers of public lands heretofore have not attempted an objective analysis of the influences of environmental factors upon fuel volume. As a consequence of this a policy of total fire exclusion has evolved because of the fear of environmental deterioration after a wildfire. The folly of this logic is readily apparent. If the volume of fuel increases with age then the potential for wildfire also will increase. Chaparral brushlands in which the vegetation has matured not only has a greater volume of fuel than young maturing stands, but it also has a buildup of dead fuel. A condition such as this is fraught with the danger of the occurrence of a wildfire such as has never before been witnessed. A wildfire of gigantic proportions could result in severe environmental damage. For instance, suppose that tens of thousands of acres of brush are consumed by a wildfire in September. Water repellent soils would develop because the energy level of such a fire probably would be extremely high. With the onset of the cool rainy season it is possible to foresee a condition of heavy, extended precipitation in which there subsequently would be rapid runoff and massive areas of soil slip and landform modification. The irony of this circumstance is that fire has been totally excluded simply to ensure against this possibility; while in reality total exclusion of fire has resulted in conditions in which the chaparral is highly vulnerable to uncontrollable wildfire.

Periodic prescribed burning is a tool for reducing the volume of fuel which potentially will support wildfires. At the same time it will greatly reduce the risk of occurrence of mass wildfire and it's deleterious effects.

An understanding of the factors contributing to the volume of fuel in the Mendocino Chaparral is fundamental to the development of a management plan which includes prescribed burning. Perhaps the most important factor affecting fuel volume is the time element. It seems safe to assume that fuel volume will increase with increased time. However, what is not clear is whether or not that increase is a uniform continuum or whether there are distinct volume levels which may be associated with the age of the chaparral. If the volume of fuel accumulates at non-uniform rates then this might indicate the most desirable time for prescribed burning to prevent a fuel buildup.

What other factors affect the volume of fuel produced? Are the spatial variants of surface configuration such as a slope, altitude and directional orientation important determinants of volume?

A plausible approach to the investigation of these factors would be the development and application of an interaction predicting model. The model should be designed in such a manner that with the inputs of growth time and the simple variants of configuration that a prediction of fuel volumes encompassing various levels and combinations of inputs will be yielded.

SUPPORTIVE HYPOTHESES

Research hypotheses will be analyzed and tested with a statistical model. The expression of both quantitative variables and qualitative variables included in the design of the model facilitate the assessment of those factors that result in increased volume of fuel. Testing of the main research hypothesis requires the consideration of several supportive hypotheses which should yield insight into the primary problem of potentially hazardous fuel accumulations in chaparral brushlands.

The following supportive and null hypotheses will be tested:

H_{01} The volume of fuel produced in a Mendocino Chaparral brushfield is not related to the time since the last wildfire burn.

H_{11} The volume of fuel produced in a Mendocino Chaparral brushfield increases with time since the last wildfire burn.

H_{21} The volume of fuel produced in a Mendocino Chaparral brushfield decreases with time since the last wildfire burn.

H_{02} Altitude has no affect upon the volume of fuel produced since the last wildfire burn in the Mendocino Chaparral.

H_{12} The volume of fuel produced in the Mendocino Chaparral increases with an increase in altitude.

H_{22} The volume of fuel produced in the Mendocino Chaparral decreases with a decrease in altitude.

H_{03} Differences in slope have no affect upon the volume of fuel produced in the Mendocino Chaparral.

H_{13} The volume of fuel produced in the Mendocino Chaparral increases as differences in slope occur.

H_{23} The volume of fuel produced in the Mendocino Chaparral decreases as differences in slope occur.

H_{04} The volume of fuel produced in the Mendocino Chaparral is not related to directional orientation.

H_{14} The volume of fuel produced in the Mendocino Chaparral increases as a result of directional orientation.

H_{24} The volume of fuel produced in the Mendocino Chaparral decreases as a result of directional orientation.

CHAPTER III

METHOD OF ANALYSIS

The statistical model utilized and analyzed in this research problem is an integral part of this dissertation. In this chapter the general linear model is designed to accommodate input data which includes the variants of configuration, altitude, slope and directional orientation. Four levels of burn years, spaced at approximately fifteen year intervals, have been selected for data collection.

STATISTICAL DESIGN

A general linear model is employed in the analysis of this research. The factorial design of the model chosen for this experiment facilitates the investigation of the main effects of various factors and their interactions. Presumably the effects of several of a variety of environmental parameters may be tested with the application of this model (Mendenhall, 1968, p. 86).

The first step in the research calls for the identification of factors that are to be measured and tested for main effects and interactions. Since the model is proposed as the basis for planning it is contended that the less complicated the observed data and the more easily it is observed and interpreted the greater will be the utility of this research. Explicitly as a result of this reasoning easily measured environmental factors are chosen for analysis. The factor of primary concern is simply the number of years elapsed since a wildfire burn occurred in the area to be investigated. Only areas of verifiable wildfire burn history in the last 55 years (1917-1972) are chosen for analysis (The Mendocino National Forest, Administrative Files).

Basically, the intention is to consider the time since the last wildfire burn as a main effect, and to analyze differentials in the cubic volume of fuel as a function of time since burn. In addition, altitude, slope and directional orientation are assessed because of their probable effect upon the expected volume of fuel. Undoubtedly numerous other environmental factors could be measured and analyzed with this kind of experiment, but it would indeed be difficult to utilize several that are as easily assessed. It is intended that this model will be applied by land management agencies and it is desirable that non-technical field procedures be instituted which are directly applicable by management technicians.

Four levels of burn years are used yielding a numerical expression of time since burn of 55, 40, 24 and 13 years respectively. The environmental facets observed in the field are altitude, slope and directional orientation; each facet is interpreted at two levels. Sample sites are described as being at an altitude of either above or below 762.5 m. Two classes of altitude are in this way delineated -- one from mean sea level up to 762.5 m. and one above 762.5 m. In actuality the ranges of the two classes are from the lower altitudinal limits of chaparral brushlands at about 350 m. to the upper altitudinal limits of chaparral brushlands at about 1,220 m. Out of a total of 246 sample sites from four burn areas, 135 sites occur at an altitude in excess of 762.5 m. and 111 are found at an altitude of less than 762.5 m. On the basis of field observations it is noted that compositional changes in the proportion of various chaparral species tend to occur in an altitudinal range from about 670 m. to 850 m. Hence, an approximate mid-point value of 762.5 m. is chosen as the line of evaluation between the two altitudinal classes.

Each of the two other environmental factors is also classed into two levels. Slope is categorized as belonging to a class of either less than 40 percent or more than 40 percent. This particular dividing point is a logical choice since it has been found that mechanical treatment of chaparral brushfields on slopes in excess of 40 percent becomes prohibitively expensive (Bentley, 1965, p. 10). Slope classes are grouped as follows: 137 exceeding 40 percent and 109 are less than 40 percent.

Finally, exposure is divided into two classes. All slopes situated from northwest to southeast are classed as northerly; all slopes situated from southeast to south to northwest are classed as southerly. This arrangement is chosen because the effect of directional orientation is not simply an east-west bifurcation. For example, slopes oriented from northwest clockwise to southeast are more closely associated with conditions characteristic of north slopes than of south slopes; souteast facing slopes clockwise to northwest are characteristic of south facing slopes. All exposures, therefore, from 315 degrees to 135 degrees are designated northerly while all exposures from 135 degrees to 315 degrees are designated southerly. One-hundred-forty-four sites are oriented south and one-hundred-two are oriented north.

Admittedly the designation of two levels for each environmental factor is less desirable than specific measurement of each factor. However, one of the features of the general linear model is that there must be an observation for each possible combination and level of factor (Mendenhall, 1968, p. 91). The design of this research model is such that this allows for thirty-two possible combinations. It would be very difficult to analyze a design that could well result in hundreds of possible combinations. Even if such a design could be analyzed the chance that the experimental region does not have a particular combination of level and factor is greatly increased. Hence, again simplicity of design is a desired feature increasing the chance of investigating several sample sites with recurring factor combinations.

Another decidedly favorable feature of the factorial design is that both quantitative and qualitative variables may be analyzed. No doubt the model would be more effective if all levels of factors were strictly quantifiable. In this research, even though the three environmental factors selected have been delineated on the basis of quantifiable limits they ultimately must be considered as qualitative factors (Mendenhall, 1968, p. 57). Logically one might expect this since the classes for each level include a wide range of possible values. For example, one percent slopes and thirty-nine percent slopes are grouped in one class. Altitude and directional orientation also are grouped into classes. Therefore, the only truly quantitative input is the time interval between successive burns, and all other variables are qualitative inputs.

The linear trend model that has been employed in this research study is:

$$\begin{aligned} y = {} & \beta_o+\beta_1x_1+\beta_2x_1^2+\beta_3x_1^3+\beta_4x_2+\beta_5x_3 \\ & +\beta_6x_4+\beta_7x_1x_2+\beta_8x_1x_3+\beta_9x_1x_4+\beta_{10}x_1^2x_2 \\ & +\beta_{11}x_1^2x_3+\beta_{12}x_1^2x_4+\beta_{13}x_1^3x_2+\beta_{14}x_1^3x_3 \\ & +\beta_{15}x_1^3x_4+\beta_{16}x_2x_3+\beta_{17}x_2x_4+\beta_{18}x_3x_4 \\ & +\beta_{19}x_1x_2x_3+\beta_{20}x_1x_2x_4+\beta_{21}x_1x_3x_4+\beta_{22}x_1^2x_2x_3 \\ & +\beta_{23}x_1^2x_2x_4+\beta_{24}x_1^2x_3x_4+\varepsilon \end{aligned}$$

Where y = the value of the cubic volume of vegetation from a sample site; x_0 = is a dummy variable; x_1 = time since burn; x_2 = altitude; x_3 = slope; x_4 = directional orientation; $B_0 + \ldots + B_{24}$ are the interaction coefficients of terms; and where ε is the estimation of error.

Values for the B terms are ascertained by obtaining the product of a 25 x 32 matrix (Figure 15). In referring to Figure 15 it should be noted that there are four different levels of x_1. They are -35, -20, -4, and 7. These values are measured from an arbitrarily chosen year -- namely 1952. Hence, -35 refers to burn year 1917; -20 refers to burn year 1932; -4 refers to burn year 1948; and 7 refers to burn year 1959. The rationale for arbitrarily choosing 1952 rather than 1972 is that the latter is outside the experimental region. Time levels outside the experimental region cannot be predicted with reliability.

Again, while referring to Figure 15 note that variables x_2 (altitude), x_3 (slope), and x_4 (directional orientation) are coded as either +1 or -1. Altitudes coded as -1 are those found to occur at less than 762.5 m., and +1 are those found to occur at an altitude in excess of 762.5 m. Slope is coded in the same manner where -1 denotes slopes of less than 40 percent and +1 denotes those slopes of greater than 40 percent. Directional orientation is coded as either south which is -1 or north which is +1.

The general factorial design includes a predictor equation

FIGURE 15 MATRIX

	Time Since Burn			Altitude	Slope	Directional Orientation	INTERACTION TERMS																	
X_0	X_1	X_1^2	X_1^3	X_2	X_3	X_4	$X_1 X_2$	$X_1 X_3$	$X_1 X_4$	$X_1^2 X_2$	$X_1^2 X_3$	$X_1^2 X_4$	$X_1^3 X_2$	$X_1^3 X_3$	$X_1^3 X_4$	$X_2 X_3$	$X_2 X_4$	$X_3 X_4$	$X_1 X_2 X_3$	$X_1 X_2 X_4$	$X_1 X_3 X_4$	$X_1^2 X_2 X_3$	$X_1^2 X_2 X_4$	$X_1^2 X_3 X_4$
1	-35	1225	-42875	-1	-1	-1	35	35	35	-1225	-1225	-1225	42875	42875	42875	1	1	1	-35	-35	-35	1225	1225	1225
1	-35	1225	-42875	-1	-1	1	35	35	-35	-1225	-1225	1225	42875	42875	-42875	1	-1	-1	-35	35	35	1225	-1225	-1225
1	35	1225	-42875	-1	1	-1	35	-35	35	-1225	1225	-1225	42875	42875	42875	-1	1	-1	35	-35	35	-1225	1225	-1225
1	-35	1225	-42875	-1	1	1	35	-35	-35	-1225	1225	1225	42875	-42875	-42875	-1	-1	1	35	35	-35	-1225	-1225	1225
1	-35	1225	-42875	1	-1	-1	-35	35	35	1225	-1225	-1225	-42875	42875	42875	-1	-1	1	35	35	-35	-1225	-1225	1225
1	-35	1225	-42875	1	-1	1	-35	35	-35	1225	-1225	1225	-42875	42875	-42875	-1	1	-1	35	-35	35	-1225	1225	-1225
1	35	1225	-42875	1	1	-1	-35	-35	35	1225	1225	-1225	-42875	-42875	42875	1	-1	-1	-35	35	35	1225	-1225	-1225
1	-35	1225	-42875	1	1	1	-35	-35	-35	1225	1225	1225	-42875	-42875	-42875	1	1	1	-35	-35	-35	1225	1225	1225
1	-20	400	-8000	-1	-1	-1	20	20	20	-400	-400	-400	8000	8000	8000	1	1	1	-20	-20	-20	400	400	400
1	20	400	-8000	-1	-1	1	20	20	-20	-400	-400	400	8000	8000	-8000	1	-1	-1	-20	20	-20	400	-400	-400
1	-20	400	-8000	-1	1	-1	20	-20	20	-400	400	-400	8000	-8000	8000	-1	1	-1	20	20	20	-400	400	-400
1	-20	400	-8000	-1	1	1	20	-20	-20	-400	400	400	8000	-8000	-8000	-1	-1	1	20	20	-20	-400	-400	400
1	-20	400	-8000	1	-1	-1	-20	20	20	400	-400	-400	-8000	8000	8000	-1	-1	1	20	20	-20	-400	-400	400
1	-20	400	-8000	1	-1	1	-20	20	-20	400	-400	400	-8000	8000	-8000	-1	1	-1	20	-20	20	-400	400	-400
1	-20	400	-8000	1	1	-1	-20	-20	20	400	400	-400	-8000	-8000	8000	1	-1	-1	-20	20	20	400	-400	-400
1	-20	400	-8000	1	1	1	-20	-20	-20	400	400	400	-8000	-8000	-8000	1	1	1	-20	-20	-20	400	400	400
1	-4	16	-64	-1	-1	-1	4	4	4	-16	-16	-16	64	64	64	1	1	1	-4	-4	-4	16	16	16
1	-4	16	-64	-1	-1	1	4	4	-4	-16	-16	16	64	64	-64	1	-1	-1	-4	4	4	16	-16	-16
1	-4	16	-64	-1	1	-1	4	-4	4	-16	16	-16	64	-64	64	-1	1	-1	4	-4	4	-16	16	-16
1	-4	16	64	-1	1	1	4	-4	-4	-16	16	16	64	-64	-64	-1	-1	1	4	4	-4	-16	-16	16
1	-4	16	-64	1	-1	-1	-4	4	4	16	-16	16	-64	64	64	-1	-1	1	4	4	-4	-16	-16	16
1	-4	16	-64	1	-1	1	-4	4	-4	16	-16	16	-64	64	-64	-1	1	-1	4	-4	4	-16	16	-16
1	-4	16	-64	1	1	-1	-4	-4	4	16	16	-16	-64	-64	64	1	-1	-1	-4	4	4	16	-16	-16
1	-4	16	-64	1	1	1	-4	-4	-4	16	16	16	-64	-64	-64	1	1	1	-4	-4	-4	16	16	16
1	7	49	343	-1	-1	-1	-7	-7	-7	-49	-49	-49	-343	-343	-343	1	1	1	7	7	7	49	49	49
1	7	49	343	-1	-1	-1	-7	-7	-7	-49	-49	-49	-343	-343	-343	1	-1	-1	7	-7	-7	49	-49	-49
1	7	49	343	-1	1	-1	-7	7	-7	-49	49	-49	-343	343	-343	-1	1	-1	-7	7	-7	-49	49	-49
1	7	49	343	-1	1	1	-7	7	7	-49	49	49	-343	343	343	-1	-1	1	-7	-7	7	-49	-49	49
1	7	49	343	1	-1	-1	7	-7	-7	49	-49	-49	343	-343	-343	-1	-1	1	-7	-7	7	-49	-49	49
1	7	49	343	1	-1	1	7	-7	7	49	-49	49	343	-343	343	-1	1	-1	-7	7	-7	-49	49	-49
1	7	49	343	1	1	-1	7	7	-7	49	-49	-49	343	343	-343	1	-1	-1	7	-7	-7	49	-49	-49
1	7	49	343	1	1	1	7	7	7	49	49	49	343	343	343	1	1	1	7	7	7	49	49	49

which is alluded to above. The equation yields a predicted value for any point within the experimental region. Output from this equation can be thought of as a response surface which is the result of the specific combination of level and factors at a particular point (Mendenhall, 1968, pp. 52-55). The equation is as follows:

$$\hat{Y} = \hat{\beta}_o+\hat{\beta}_1x_1+\hat{\beta}_2x_1^2+\hat{\beta}_3x_1^3+\hat{\beta}_4x_2+\hat{\beta}_5x_3$$
$$+ \ldots +\hat{\beta}_{24}x_1^2x_3x_4+S = \sqrt{\frac{SSE}{39dof}}$$

where $\hat{Y}$ = the estimate of the volume of fuel at a particular point; x_1 = the time interval since burns; x_2 = altutide; x_3 = directional orientation; $\hat{\beta}_o \ldots +\beta_{24}x_1^2x_3x_4$ an estimation of the interaction of terms; and where $S = \sqrt{\frac{SSE}{39dof}}$ is the estimate of error for the predictor equation.

The predictor equation is particularly valuable in this research design for it enables an approximation of the volume of fuel that would be expected at any point in the experimental region for any particular combination of altitude, slope and directional orientation. Again, it is reiterated that values can be predicted only for those factors which occur under the response surface -- namely for the years 1917 through 1959. As previously noted the year 1952 is chosen as an arbitrary point from which to apply output generated by the model. Any one of numerous other years could have been chosen. For illustrative purposes only, let the reader suppose that 1972 rather than 1952 had been chosen as the referral year. Since this point is outside the limits of the experiment it must then be interpreted as an extrapolation of events which occurred prior to the last level of burn-year which was 1959. Undoubtedly this could be very misleading because the interaction of main effects at a point on the perimeter of the experimental region is likely to possess a larger variance than the interaction of main effects of a point situated somewhere well under the response surface (Mendenhall, 1968, p. 226). The reason for the inability to predict the nature of combinations of levels and factors outside the experimental region is that in essence there are only observations from one side of that point. The reliability of the prediction of a point situated back from the perimeter of the response surface is possible because there is a predictable trend on either side of that point. A 90 percent confidence limit has been placed around the predictions (Appendix 2).

The utility of this model goes beyond a simple prediction of fuel volume for the specified years since burn (- 35, - 20, - 4 and 7), The model is capable of predicting a fuel volume for any year between the temporal extremes of the investigation (- 35 and 7) and with any combination of environmental factors — altitude, slope, and directional orientation. Perusal of Figure 25 provides an indication of the value of the predictor equation. Years since burn are recorded along the X -axis and expected volume of fuel is recorded along the Y -axis. A point fixed by the crossing of the X intercept and the Y intercept suggests the volume of fuel to be expected at a given level and combination of factors. Hence, it becomes possible to obtain a predictive value for any level and combination of factors between 1917 and 1959.

Chaparral land management planning can be developed with the aid of graphed information. The trend of any line or the comparison of the trends of two or more lines provides insight into the various environmental facets which are extant at specified places. Hopefully, the final application of this experimental procedure will be the articulation of management units and subunits which will ultimately result in an enhancement of resources realization of chaparral brushlands.

THE DATA BASE

SELECTION OF BURNS

Four areas which were subjected to wildfire were chosen from which to obtain specific sample information concerning the Mendocino Chaparral. Vegetation sampling within burned areas provided specific compositional data and allowed comparisons of recovery of brush volumes both in a temporal and spatial context. Each of the chosen sites has a verifiable history of wildfire occurrence of at least once during the past fifty years.

Dozens of burns have occurred along the east slope of the Coast Range since 1900 (Figure 16). Wildfire records maintained by the U.S. Forest Service, Mendocino National Forest, Willows, California indicate that there was at least one major conflagration in each of the decades commencing with 1910 and culminating in 1960. No very large burns occurred in the 1960's; however, one did occur in 1971.

The 1971 wildfire burn is of relatively little value for purposes of this study, because it was controlled by aerial tanker attacks in which fire retardants were dropped. Most retardants are phosphatic fertilizers either in a liquid state or mixed with inert substances to produce a slurry (Chemicals for Forest Fire Fighting, 1963). It is difficult to ascertain in the field what effect these chemical mixes will have upon the re-establishment of the chaparral vegetation. None of the major burn sites chosen for this research were subjected to aerial bombardment of chemical mixes.

The variants of configuration, slope, altitude and directional orientation were sampled in each burn area. A requisite of the statistical model is the consideration of a complete range of variables in each burn area chosen for study.

The four areas chosen for study are spread along the east front of the Coast Range over a distance of approximately seventy km. Ideally, it would be desirable to choose burns that were spaced at exact time intervals, but of course this is controlled by the accidental occurrence of wildfire. Burned areas which were chosen for this research are separated by about 15 years. Inclusion of more than four burn years would result in an extension of modular computations which has been deemed unnecessary. If fuel volume can be predicted from four evenly spaced burn years there is little reason to include more burned areas.

The following burned areas were chosen for data collection. The Trough Spring burn (Figure 16) occurred in 1917 and it destroyed approximately 3,280 hectares of brush (The Mendocino National Forest, Administrative Files). In 1932, the Eagle Peak fire burned about 2,480 hectares of brush. The 5,280 hectares Red Bridge burn of 1948 included 2,176 hectares all previously burned in 1919. And finally, the Noel Spring Ridge burn of 1959 consumed approximately 400 hectares of chaparral vegetation.

The fact that chaparral brushlands totalling more than twenty thousand hectares burned at various intervals over the last fifty years should be indicative of the magnitude of the problem to be considered. Some of these wildfire burns have been sampled in order to garner specific data concerning the recovery of vegetation since each burn year.

Sampling Procedures

Topographic maps of the 7.5 minute series (1:24,000) provided the basis for delineation of burned areas which served as study sites. All sites selected are situated along the east front of the Coast Range in the Mendocino National Forest from a zone about sixty km. long and seven to twenty km. wide.

A method of sampling was employed that insured site selections that include an array of environmental factors. In each burned area selected for study that the spatial variants of altitude, directional orientation and slopes along with brush types were sampled. Every possible combination of factors must be found to occur in each burn year selected. To illustrate, suppose that in hypothetical burn A there are no north slopes. Hypothetical burn B might have north slopes but all altitudes are below 762.5 meters. These two levels of burn could not be analyzed with the model used in this research study, for all levels of burn <u>must</u> possess each possible combination of environmental factors.

Several sample sites were surveyed in each burn. The actual number of sites varied according to the size of the burn and its accessibility. Small burns, such as the Noel Spring Ridge burn of 1959, had approximately 40 sample sites whereas the Red Bridge burn of 1948 consisted of about 100 sample sites scattered throughout the 5,200 hectares of burned over chaparral.

Procedures for obtaining descriptive qualities of shrub cover as a quantitative expression of plant numbers and sizes have been effectively instituted by Bentley and others (1968; see also Lyon, 1968, pp. 115-118). An estimate of fuel characteristics is made by determining the volume of space occupied by each shrub (Figure 17).

Other facets of the sampling procedure are worthy of note. First, no sampling was undertaken near roads or tractor trails where the vegetation may have been disturbed or influenced by man's activity. This eliminated the possibility of recording "edge effects" which could jeopardize data analysis. Second, even though two types of coniferous trees do occur in the chaparral brush they were not included in computed volumes of fuel from a sample site. Ordinarily <u>Pinus sabiniana</u> (digger pine) occurs only sparsely. Greatest concentrations occur in the transition zone between chaparral and foothill grass-woodland vegetation. <u>Pinus attenuata</u> (knobcone pine) is aggressive after an area is burned and rather dense forests of these pines may cover several hundred acres. Even though numerous places populated with knobcone pine do occur along the east front of the Coast Range none were observed in the burned areas chosen for this study. Third, riparian vegetation was not considered in this research because it consists of trees rather than shrubs. Fourth, the researcher carefully watched for visible evidence of fire in the burned areas. The reasons for this are to corroborate the fire records obtained from the U.S. Forest Service and to refrain from sampling a site where the vegetation did not burn. Fifth, uniform procedures were

Figure 17. -- Chaparral shrubs are assumed to fill a cylinder

employed at all sample sites in all burned areas. It is imperative that uniform measurements are made since careless work can provide unfounded results.

The actual sites sampled were selected by the researcher upon the basis of a visual analysis of the vegetative characteristics. The researcher must be thoroughly familiar with chaparral vegetation to be able to select a site comprised of typical local conditions. Admittedly this system contains a subjective element. Cain and Castro (1959, p. 120) remark, "However, as we have emphasized in several places in this Manual, methodology in the study of vegetation is no substitute for judgement that arises from experience and even from a feeling that is not backed by objective data".

The sample site consisted of a circular plot with a radius of 3.61 m. A central point was selected from which the plot was measured. A bamboo wand 1.795 m. in length was used both to circumscribe the area for sampling vegetation and to measure the height and diameter of the vegetation. Vegetation was measured and recorded two wand lengths (a radius of 3.61 m.) from the center of the plot.

Each plant within the sample plot (occasionally group of plants) was measured with the wand which was marked into meters and tenths of meters. The height and crown diameter of each plant or group of plants was measured and recorded. Preferably each individual plant should be measured. Frequently, the vegetation was so intertwined that it was virtually impossible to measure each plant. In the event that this occurred the entire single species group was measured as a unit.

Equipment needed in addition to the measuring wand included: a Thommens altimeter; a Brunton pocket compass; and 7.5 minute series topographic maps. The altimeter was used to enable accurate marking of the sample site on topographic maps. Slope angle and directional orientation were ascertained through use of the Brunton pocket compass. Finally, it was imperative to have a four-wheel drive vehicle. Access by road to many of the burns was limited to very steep, rough, dry-weather tractor trails which are inaccessible to normal vehicular traffic.

CROWN VOLUMES

Procedures for the determination of crown volumes have been effectively used by other researchers. Bentley and others (1968, p. 1) assigned variegated vegetation into classes for determination of crown volumes. Crown volumes are computed by multiplying height of crown by area of crown surface (Figure 18). This technique yields an assessment of shrub cover which is expressed as a quantitative measure of the numbers of plants and their sizes.

Bentley and his colleagues trained observers to visually assess and assign vegetation volume to a specific category. They were

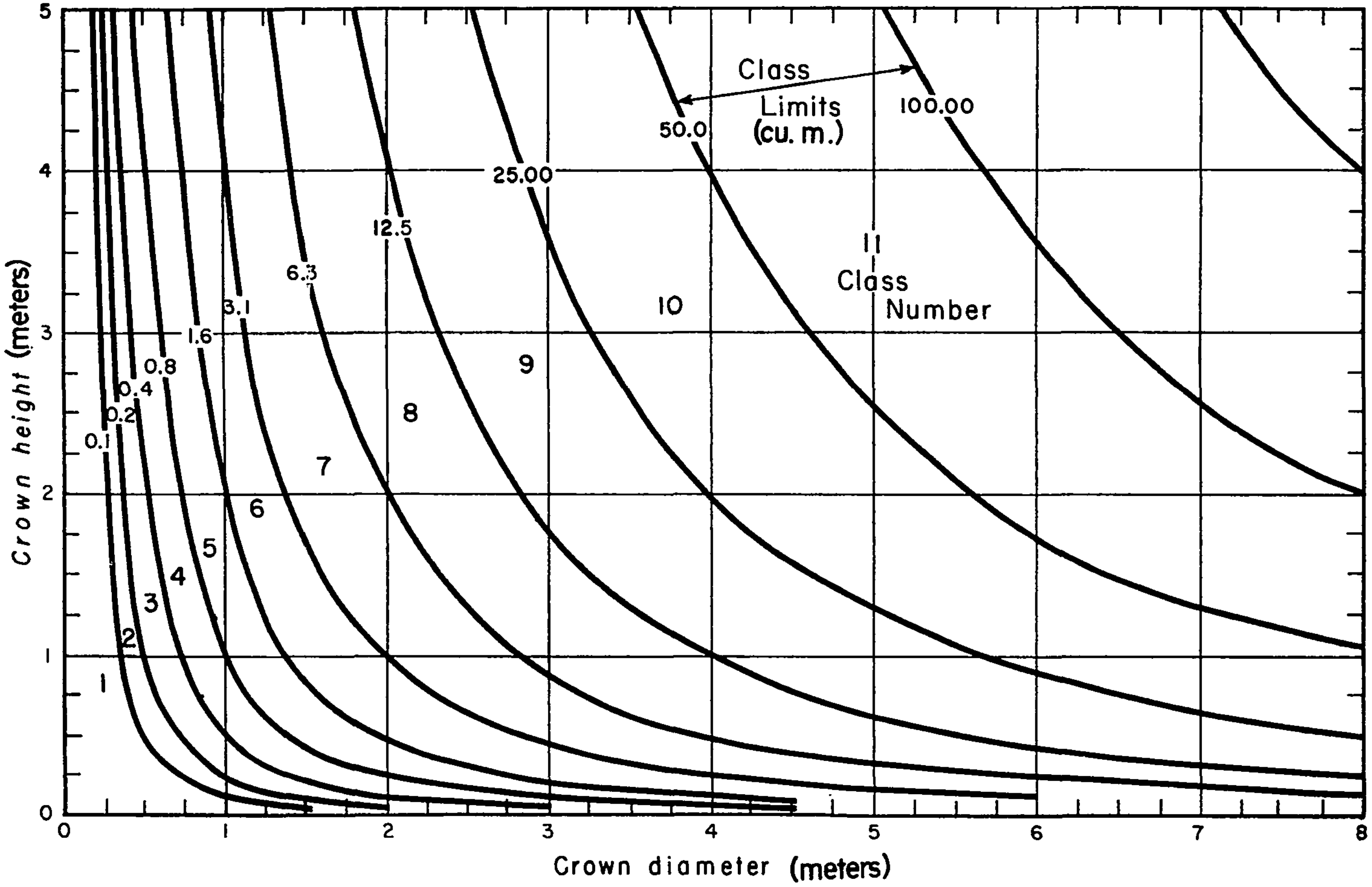


Figure 18. -- Limits of crown volume classes related to crown height and diameter

Source— Bentley and others, Sampling Low Shrub Vegetation, 1970 working with a single species of Arctostapholos; hence, it was less difficult than the recognition of the forms and dimensions of the several species of Mendocino Chaparral. In this study each plant -- in a specified sample site -- was measured and recorded.

Figure 18 is used to determine crown volumes. The height of the crown, expressed in meters, is along the Y coordinate and crown diameter expressed in meters is along the X coordinate. Class limits are drawn starting at 0.1 cubic meter and doubling with each class until 200 cubic meters are reached. Once the measurements of a particular shrub had been obtained it then had to be assigned a class value. This was achieved simply by finding the intersection of the abscissa and the ordinate and noting the index number which signifies the class limits.

Once the crown volume class index number was obtained it was necessary to refer to Table 3 to determine the assigned class value for each shrub. This value represented the plant's volume as though it occupied a cylinder. Since most of the area is occupied by the shrub it is assigned full value. Values for each shrub were totaled yielding the total volume of all shrubs occupying a sample site.

TABLE 3

CROWN VOLUME LIMITS AND MIDPOINT VALUES

FOR EACH 12 VOLUME CLASSES *

Crown Volume Class	Upper Class Limit (cubic meters)	Assigned Class Value (cubic meters)
1	0.10	0.02
2	.20	.15
3	.40	.30
4	.80	.60
5	1.56	1.18
6	3.12	2.34
7	6.25	4.68
8	12.50	9.37
9	25.00	18.75
10	50.00	37.50
11	100.00	75.00
12	200.00	150.00

* Adapted from Bentley and others, A Technique for Sampling Low Shrub Vegetation by Crown Volume Classes, 1970, p. 5.

CHAPTER IV

HYPOTHESIS TESTING

Implementation of a management plan for the Mendocino Chaparral is the objective of this research. If, upon the basis of analysis employed in this design, it becomes obvious that the variants of time and surface configuration do indeed affect fuel volumes it is imperative that the impact of these factors be considered. Those factors which have direct relationship to fuel volume are requisite in the formulation of a management plan and the application of that plan which will be discussed in Chapter V.

ANALYSIS OF FACTORS AFFECTING FUEL VOLUME

A statistical model, the general factorial model was chosen for this research because it can be employed to analyze both quantitative and qualitative variables. The factors which have been selected for analysis become interaction terms with the final result being a prediction of their contribution to fuel volume. Four different time levels described as quantitative, and three levels of environmental factors evaluated as qualitative variables were tested for their main effects and interaction.

A 90 percent confidence limit was selected for testing the research hypothesis and the supportive hypotheses. A (t) test was performed for 39 degrees of freedom and a critical (t) value of 1.68 was obtained. Testing of the contribution of the predicted values of β was executed with subsequent acceptance or rejection of the hypotheses. If the (t) score of a factor was equal to or greater than 1.68 then the research hypothesis is accepted. However, if the (t) score is less than 1.68 the null hypothesis that the factor has negligible effect must be accepted with subsequent rejection of that research hypothesis.

HYPOTHESIS

This factorial design was formulated primarily to test the main research hypothesis that the evolution of Mendocino Chaparral brushlands is dependent upon select environmental factors acting within a time dependent system such that fuel volume will significantly vary thus resulting in variance in wildfire potential.

If the interaction of these environmental factors through a span of time can be assessed, then management procedures can be formulated. Before the validity of this postulate can be ascertained it is necessary to evaluate supportive hypotheses.

THE EFFECT OF ALTITUDE UPON THE VOLUME OF FUEL PRODUCED

The supportive hypothesis that the volume of fuel produced in the Mendocino Chaparral is affected by altitude was tested. It is reasonable to assume that because of the effect of altitude upon such factors as thermal and moisture conditions fuel volumes will be affected. Subjective estimates after briefly considering the research area probably would be to attach considerable significance to this parameter.

It was found that altitude yielded a (t) score of -1.33 which is below the 1.68 acceptance level. Therefore, $H_{02} = 0$ was accepted and H_{12} and H_{22} were rejected(See page 65).

Consideration of Table 4 suggests that altitude does have some effect because of the differences in fuel volumes that occur at four different combinations of levels. Note that after thirteen years (1959) since the last wildfire burn the low altitude class situated on a south exposure produces greater fuel volume than any of the remaining combinations. (The descriptive terms high and low will in this discussion refer to one or the other of the two levels of each factor.) In fact if both levels of altitude for a south exposure are compared it is seen that low altitude fuel volume is practically 50 percent higher than that of high altitude. Fuel volumes for low altitude south slopes are greater than high altitude south slopes until burn level 40 (1932) is reached. Reference to Figure 21 indicates that high altitude south slope vegetation reaches the same volume as low altitude just slightly after 35 years since burn. Low altitude south slope vegetation is

TABLE 4

PREDICTED FUEL VOLUMES OF SPECIFIED BURN YEARS

SEGREGATED UPON THE BASIS OF A SINGLE VARIANT

	Total Volume		<762.5	>762.5	<762.5	>762.5	< 40%	>40%	< 40%	>40%
Years Since Burn	S	N	S	S	N	N	S	S	N	N
13	87.51	76.91	51.63	35.88	41.38	35.53	47.82	39.69	44.19	32.72
15	110.35	83.64	66.55	43.80	42.30	41.34	56.14	54.21	44.22	39.22
17	124.28	92.92	75.74	48.54	47.79	45.13	57.94	66.34	44.63	48.29
24	168.50	140.20	99.36	69.14	70.15	69.87	65.64	102.86	58.37	81.65
28	195.87	170.06	112.08	83.79	84.22	85.84	79.25	116.62	73.07	96.99
32	233.75	207.38	125.11	108.61	89.52	117.86	97.42	136.33	95.00	112.38
40	284.41	250.46	131.46	152.95	106.47	143.99	130.24	154.17	119.15	131.31
48	312.80	260.42	138.10	174.70	117.76	142.66	156.86	155.94	132.28	128.14
55	306.73	215.80	143.37	163.36	119.90	95.90	165.08	141.65	115.18	100.62

characterized by extensive areas with very steep slopes. Bentley (1965, p. 10) suggests that steepness of slope is as important as the soil type in the determination of the feasibility of type-conversion of chaparral brushlands because of the difficulty of operating machinery on steep slopes.

Logically, slope would seem to be an important environmental factor influencing the volume of fuel if for no other reason than the expected occurrence of shallow, rocky soils in areas of steep slope. Gentle slopes presumably could result in greater soil depths because of reduced sheet erosion and perhaps less gullying.

Testing of the supportive hypothesis that slope does affect the volume of fuel produced yielded at (t) score of 1.85. Therefore, H_{13} was accepted since the critical (t) value is 1.68 and it can be concluded that slope does affect fuel volume. H_{03} and H_{23} were rejected.

In consideration of the effect of slope it again is illuminating to consider Table 4. Where slope is less than 40 percent on a south exposure at the 13 year burn level, fuel volume is higher than for any other combination of slope and exposure for that year. Sites with low slope and north exposure display nearly the same volume as low slope-south exposure. Sometime during the 15th or 16th year since burn, high slope fuel volume becomes significantly greater than low slope fuels on southern exposures. Fuel volumes rapidly increase from the 17th year until the 24th year since burn after which there is slowing shown to gradually increase to the edge of the experimental region at 55 years (1917) since burn. Note that high altitude south slope vegetation volume maximizes at 48 years (1924) since burn and declines appreciably after that point is reached.

Again in referring to Table 4 the north exposure low altitude fuel volume is higher than high altitude volumes of the same exposure. When the fuel volumes are graphed (Figure 22) it is obvious that after 15 years (1957) since burn until 28 years (1944) both altitudinal classes are almost identical. However, at about 26 years since burn high altitude volumes become greater than that of low altitude and maximize at approximately 40 years (1932) since burn. After that time the volumes become less than low altitude volumes after 51 years (1921) and continue to decrease until 55 years (1917).

Apparently the influence of altitude is not important enough to generate an acceptable (t) score; however, it does appear that an altitudinal effect can be observed in tabular and graphic form. If altitude did not affect the volume of fuel, trend lines on the graphs (Figure 21 and 22) would be nearly identical. This, in fact, is exactly what happens for north slope volumes for the interval since burn of approximately 15 through 28 years. At all other points in time there is at least some volume difference linked to altitude.

THE EFFECT OF SLOPE UPON THE VOLUME OF FUEL PRODUCED

Mendocino Chaparral is found to occur in mountainous terrain characterized by extensive areas with very steep slopes. Bentley (1965, p. 10) suggests that steepness of slope is as important as the soil type in the determination of the feasibility of type-conversion of chaparral brushlands because of the difficulty of operating machinery on steep slopes.

Logically, slope would seem to be an important environmental factor influencing the volume of fuel if for no other reason than the expected occurrence of shallow, rocky soils in areas of steep slope. Gentle slopes presumably could result in greater soil depths because of reduced sheet erosion and perhaps less gullying.

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The trend lines for south facing exposures display some interesting features. The importance of the decreased rate of volume produced between 24 years and 28 years is indeed significant. Another interesting fact is the very uniform rate of increased fuel volume from the 24th year until the 48th year on gentle south facing slopes. It also should be noted that the volume of fuel is still increasing all the way to the extremity of the response region on gentle southerly facing exposures (The explanation of these trends will be speculated upon in the concluding chapter).

THE EFFECT OF DIRECTIONAL ORIENTATION UPON THE VOLUME OF FUEL

Directional orientation also may influence the volume of fuel that is produced and presumably in much the same manner that altitude would be expected to influence moisture and temperature conditions. The third sub-hypothesis that exposure affects the volume of fuel produced was tested under the same conditions as the preceding hypotheses.

A (t) score of -0.82 was generated by directional orientation. This is well below the critical (t) value of 1.68 so H_{14} and H_{24} were rejected. Exposure therefore, can not be considered as having contributed significantly to the volume of fuel produced in the Mendocino Chaparral. It should be noted that exposure displays the weakest association of influence upon fuel volume of any of the selected environmental factors.

South slope vegetation volumes at all levels of burn years are greater than those of north slopes (Table 4). Comparison of each of the trend lines (Figure 20) for the two levels of slope shows near uniformity until the 40th year since burn. At that time north slope volume is increasing at a retarded rate and south slope volumes display greater increase. After 48 years since burn, both north and south volume production is decreasing. At that point in time north slope volume decreases very rapidly and the greatest spread between the two trends is found to occur. It is quite possible that if a more lengthy history of burn were available and trends continue such as they are at 55 years that exposure might display greater significance than was generated by the model.

Consideration of the sub-hypotheses above resulted in the acceptance of only slope as being statistically important. However, altitude yielded a test statistic which was very close to the acceptance region. Exposure was the only environmental parameter which did not display an effect of at least considerable significance.

THE EFFECT OF TIME UPON EXPECTED FUEL VOLUME

Predicted fuel volumes for all levels of burn and various

FIGURE 19

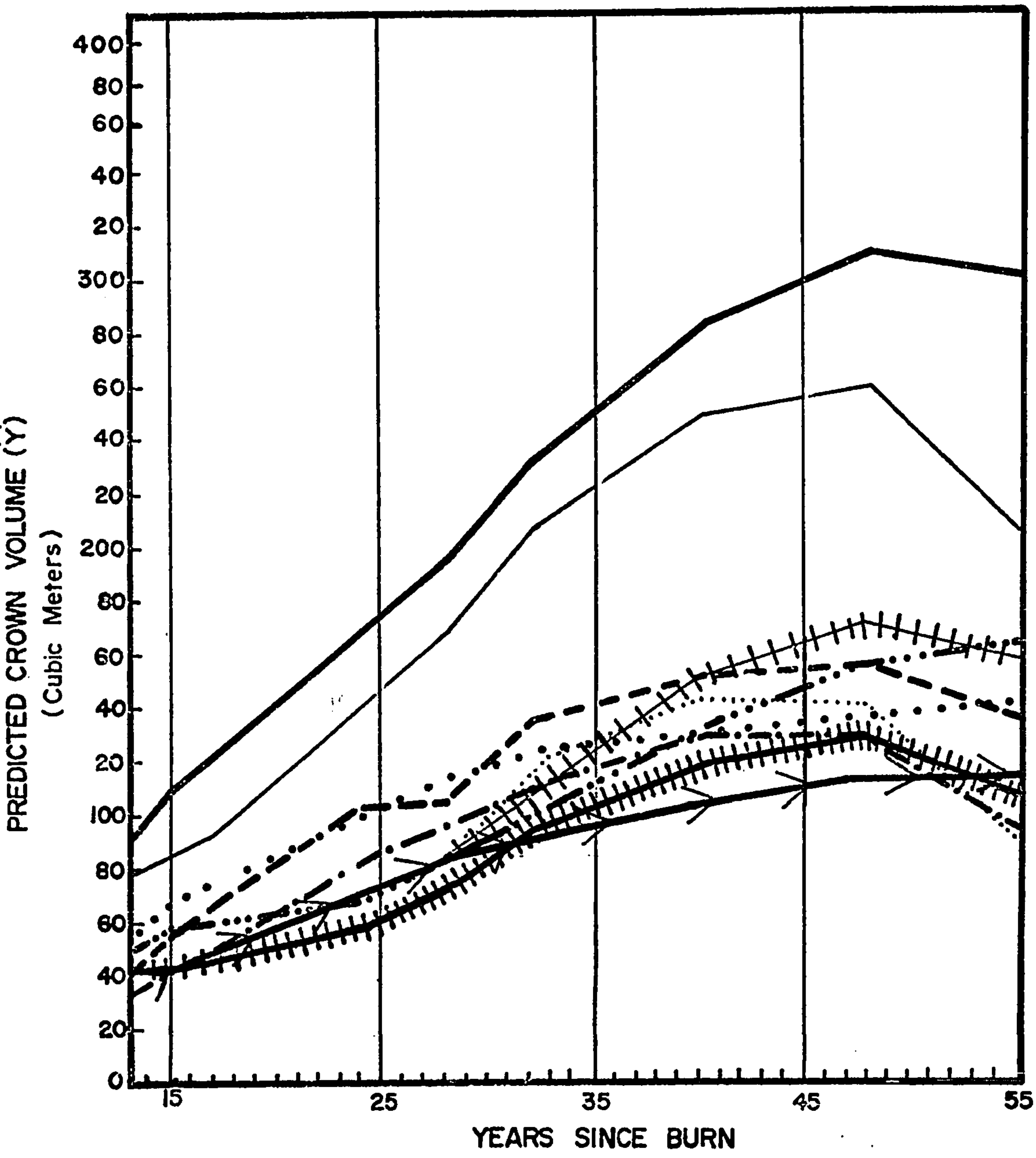


Figure 19. -- Predicted fuel volume for all combinations of altitude, slope and directional orientation

FIGURE 20

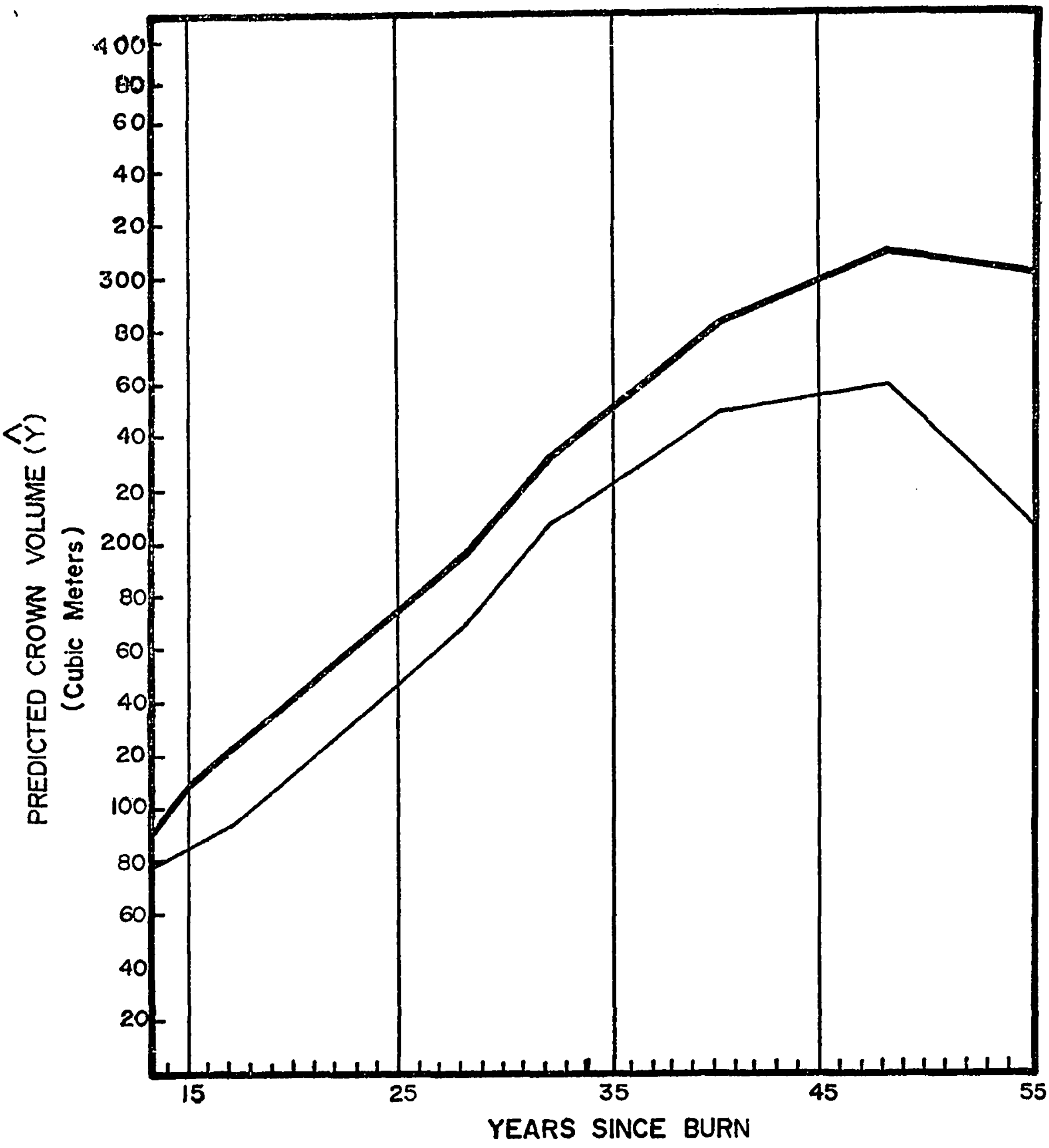


Figure 20. -- Predicted fuel volume for slopes oriented north or south

FIGURE 21

SOUTHERN ORIENTATION

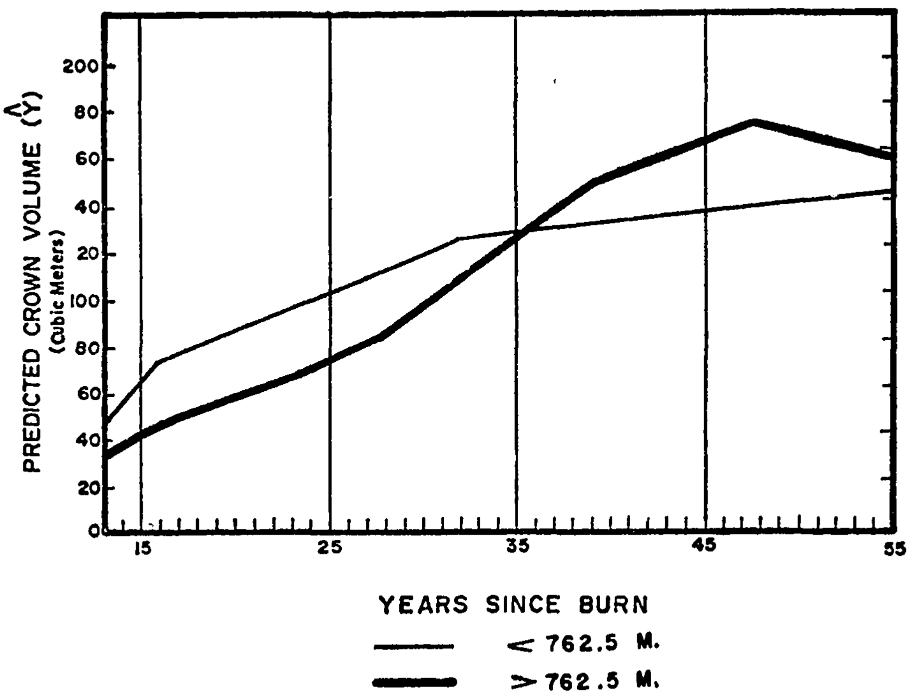


Figure 21. --Predicted fuel volume for south facing slopes greater than 762.5 m. and less than 762.5 m.

FIGURE 22

NORTHERN ORIENTATION

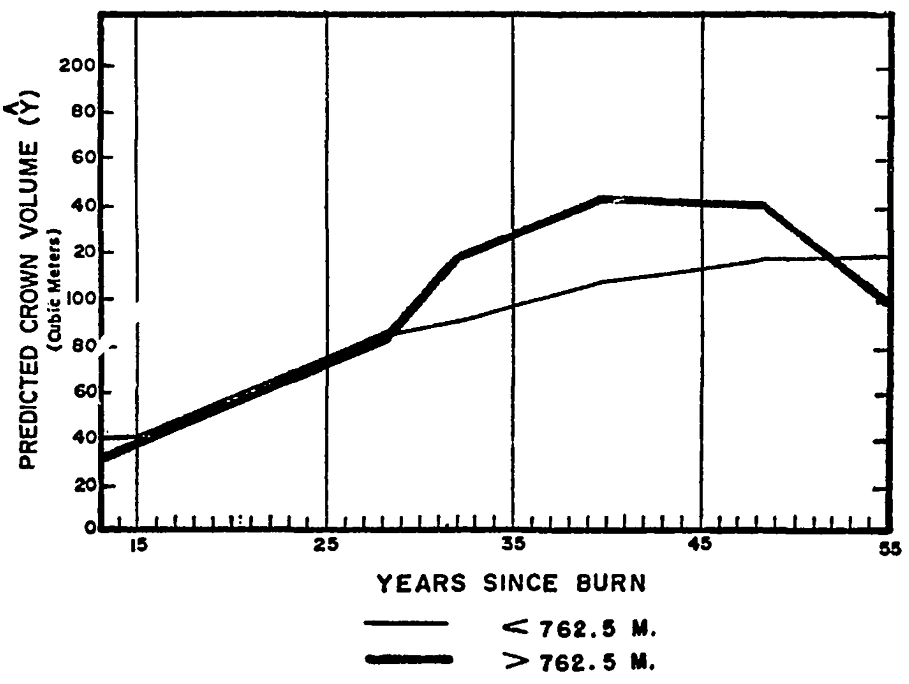


Figure 22. --Predicted fuel volume for north facing slopes greater than 762.5 m. and less than 762.5 m.

FIGURE 23

PERCENT S. SLOPE

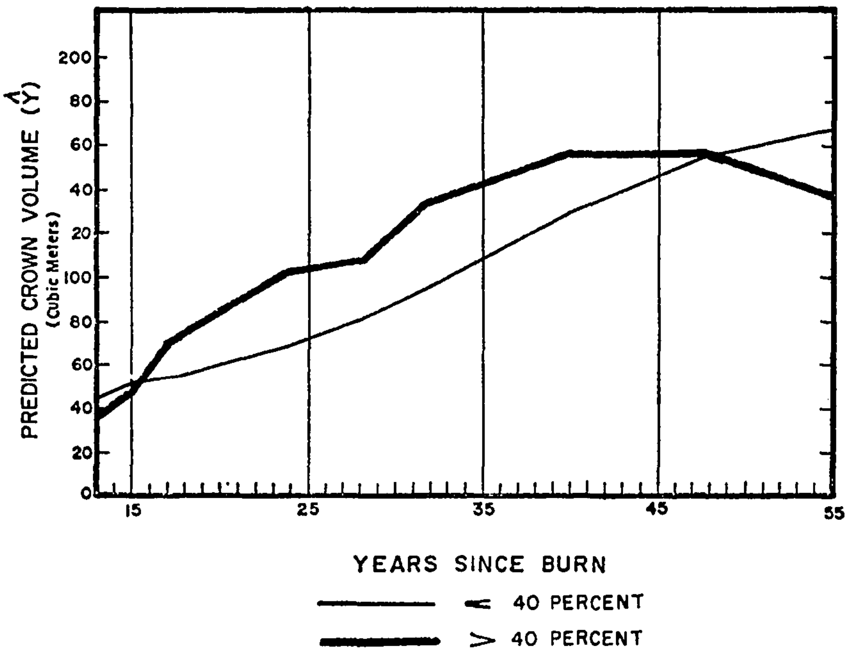


Figure 23. -- Predicted fuel volume for south facing slopes with less than 40 percent slope and greater than 40 percent slope

FIGURE 24

PERCENT N. SLOPE

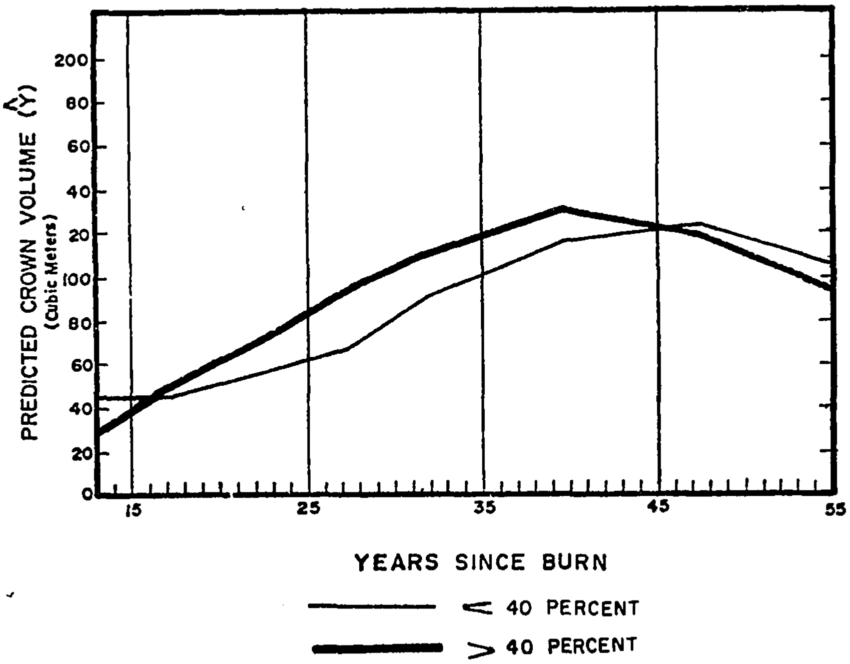


Figure 24. -- Predicted fuel volume for north facing slopes with less than 40 percent slope and greater than 40 percent slope

FIGURE 25

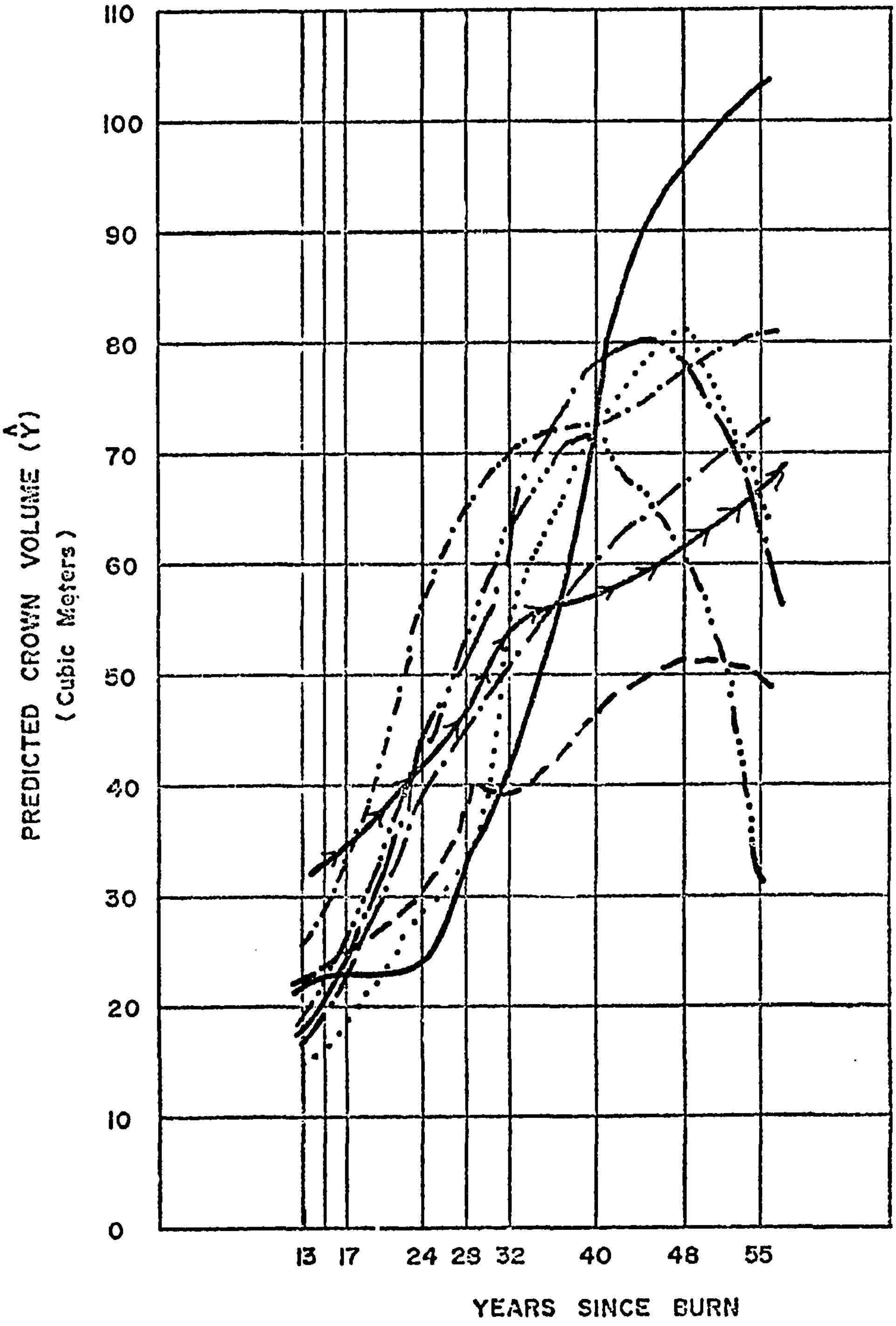


Figure 25. -- Predicted fuel volume for specific years and all combinations of levels of factors

I-I-I	><	S	-I-I-I	<<	S
I-I I	><	N	-I-I I	<<	N
I I-I	>>	S	-I I-I	< >	S
I I I	>>	N	-I I I	< >	N

FIGURE 26

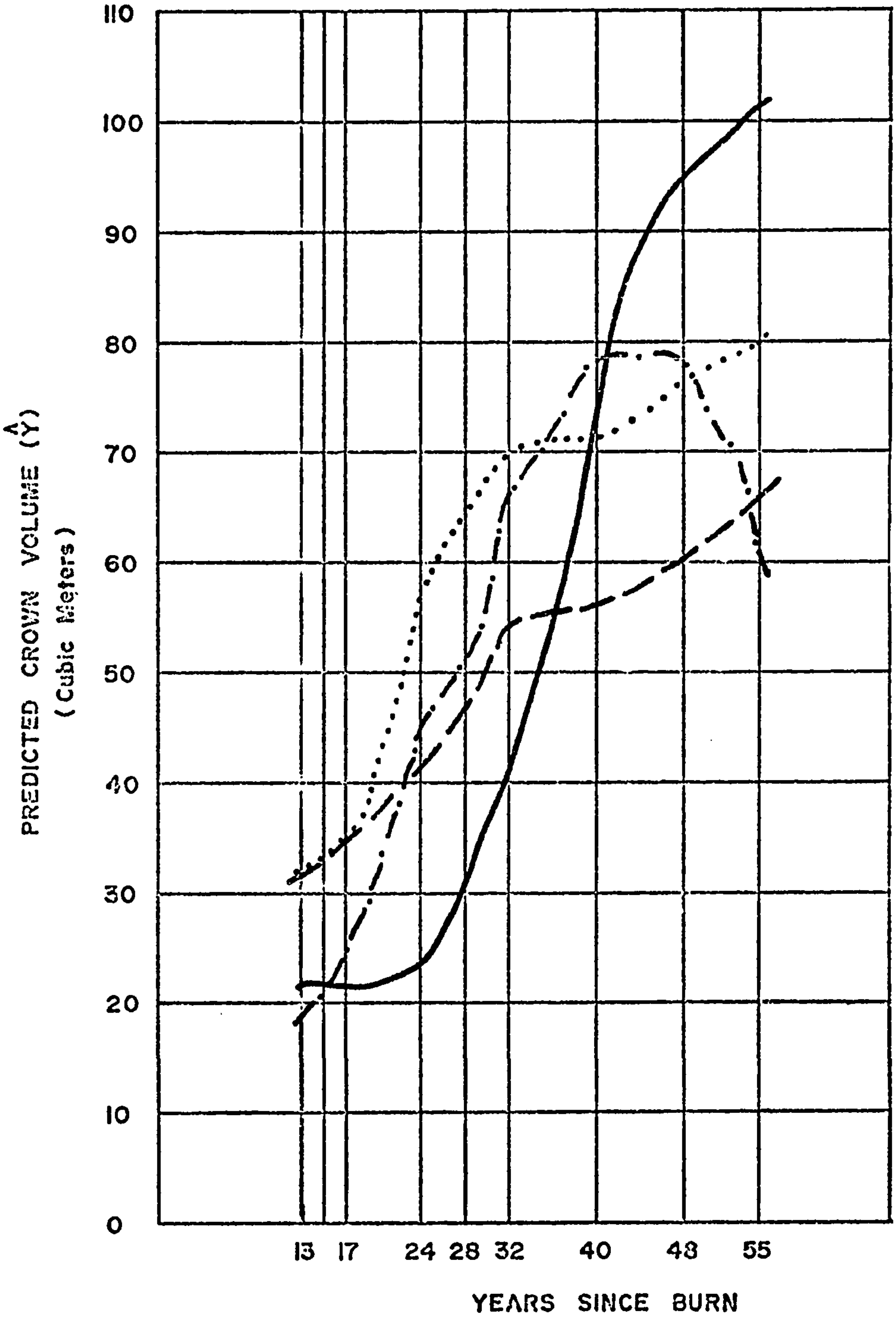


Figure 26. -- Predicted fuel volume for specific years and combinations of factors occurring at sites with south orientation

————	I-I-I	>< S	— — —	-I-I-I	<< S
—·—·—	I I-I	>> S	…………	-I I-I	< > S

FIGURE 27

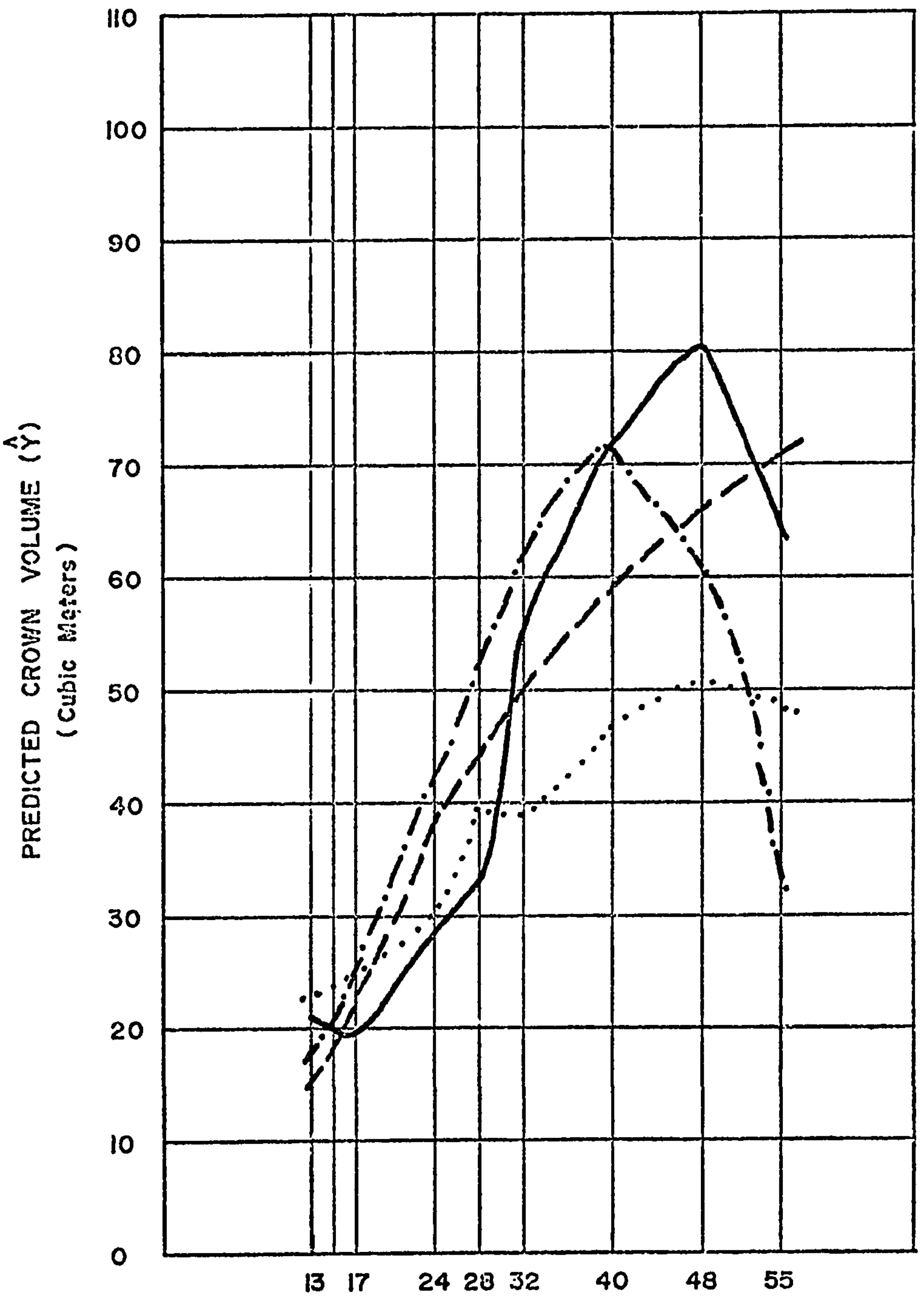


Figure 27. --Predicted fuel volume for specific years and combinations of factors occurring at sites with north orientation

———— I-I I >< N ——— -I I I <> N

—·—·— I I I >> N ·········· -I-I I << N

FIGURE 28

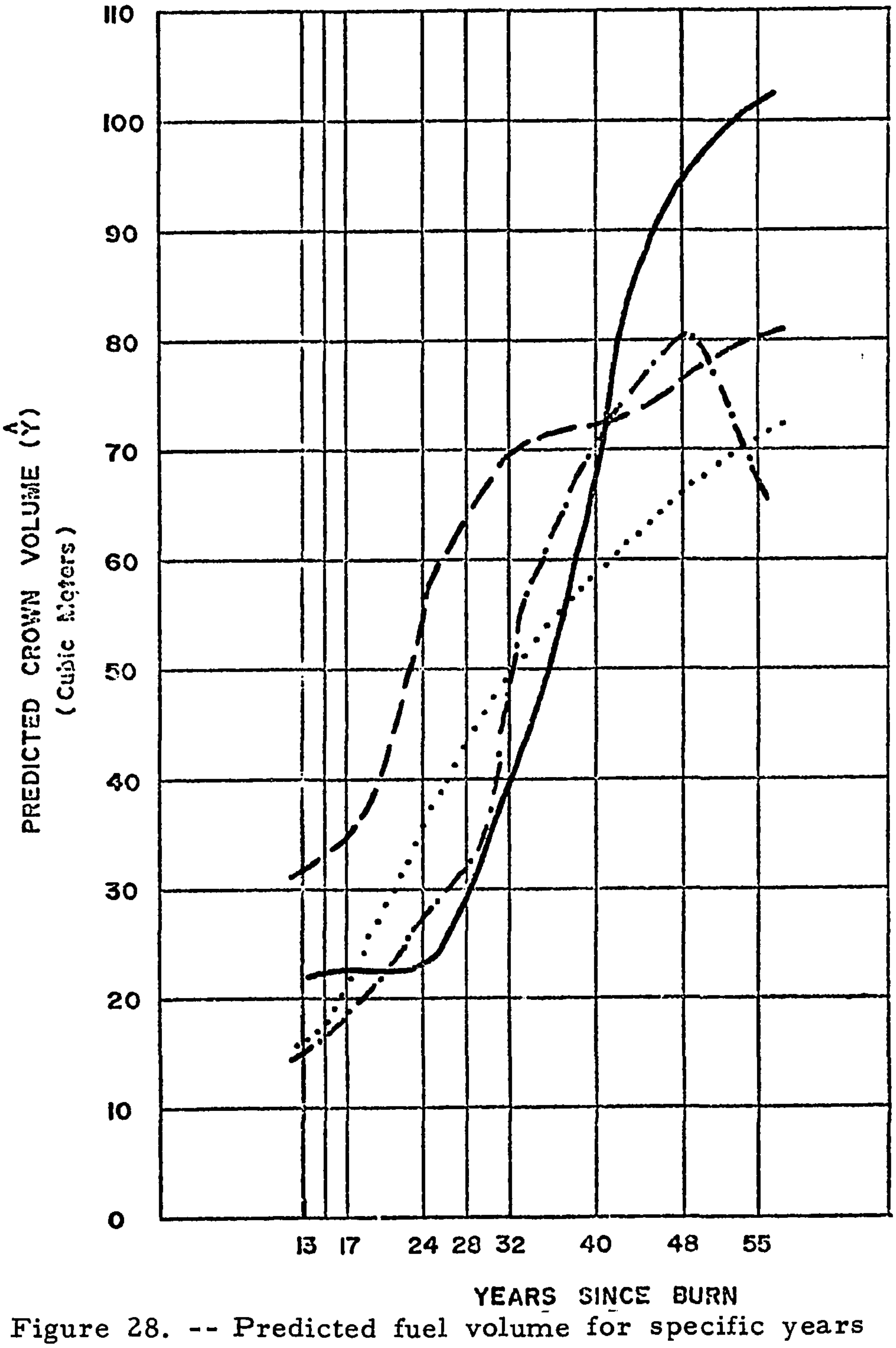


Figure 28. -- Predicted fuel volume for specific years and combinations of factors occurring both on north and south orientation

————	I-I-I	><	S
— — —	-I I-I	<>	S
——·—	I-I I	><	N
....	-I I I	<>	N

FIGURE 29

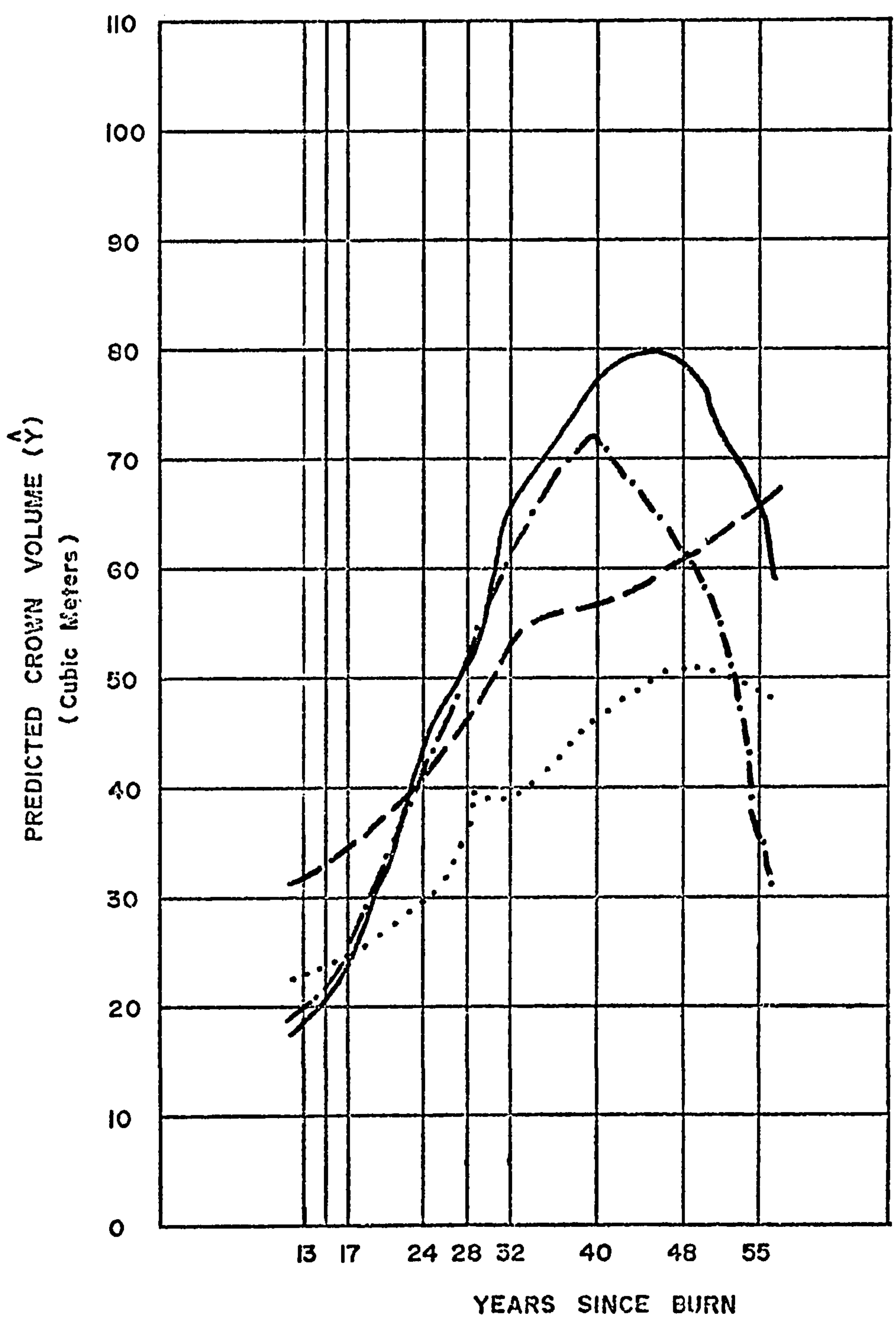


Figure 29. -- Predicted fuel volume for specific years and combinations of factors occurring both on north and south orientation

————	I I-I	>> S	— — —	-I-I-I	<< S
—·—·—	I I I	>> N	··········	-I-I I	<< N

combinations of factors were recorded in Table 5. The code for each combination of factors is recorded in the first column while the next three columns in the table are the factors corresponding to that code. Several representative burn years were selected for inclusion in this table. It should be noted that observed field data is available for 13, 24, 40 and 55 years since burn, although the values entered here are fuel volumes ascertained by the predictor equation. The additional levels of 15, 17, 28, 32 and 48 years since burn were arbitrarily selected and values were computed by the predictor equation. The time span for burn levels was chosen to yield a reading for periods of up to eight years between observations. Actually these nine burn levels yield values which can be plotted on a series of graphs, and an approximation of fuel may be made for any level of burn year and combinations of factors from 13 to 55 years (1959-1917) since burn.

The supportive hypothesis that Mendocino Chaparral increases in volume with increased age can be tested in two ways. First, the standard (t) test was performed and, second, the trend of each level of burn and factor combination was evaluated. Results of these two techniques are very revealing. The (t) test indicates the validity of the supportive hypothesis; and the evaluation of each level and combination of factor indicates the location of critical times for a specific treatment to control fuel volume.

Testing of the importance of increasing age in the determina-

TABLE 5

PREDICTED FUEL VOLUMES OF SPECIFIED BURN YEARS ACCORDING

TO CODED VARIANTS-TIME, ALTITUDE, SLOPE AND DIRECTIONAL ORIENTATION

Code	Altitude (meters)	Slope	Directional Orientation	Years Since Burn 13	15	17	24	28	32	40	48	55
-1 -1 -1	< 762.5	< 40%	S	25.54	33.14	35.33	41.80	46.68	55.05	57.71	60.94	62.75
-1 -1 1	< 762.5	< 40%	N	21.35	24.33	24.97	30.68	39.91	39.30	48.18	51.39	48.80
-1 1 -1	< 762.5	> 40%	S	26.09	33.41	40.41	57.56	65.40	70.06	73.75	77.16	80.62
-1 1 1	< 762.5	> 40%	N	20.03	17.97	22.82	39.47	44.31	50.22	58.29	66.37	71.10
1 -1 -1	> 762.5	< 40%	S	22.28	23.00	22.61	23.84	32.57	42.37	72.53	95.92	102.33
1 -1 1	> 762.5	< 40%	N	22.84	20.09	19.66	27.69	33.16	55.70	70.97	80.89	66.38
1 1 -1	> 762.5	> 40%	S	13.60	20.80	25.93	45.30	51.22	66.27	80.42	78.78	61.03
1 1 1	> 762.5	> 40%	N	12.69	21.25	25.47	42.18	52.68	62.16	73.02	61.77	29.52

tion of fuel volumes yielded a (t) score of 4.52 which exceeds the critical (t) of 1.68 by a considerable margin. The supportive hypothesis H_{11} was accepted, and it is concluded that the time since the last wildfire burn is critical to the volume of fuel produced. As simplistic as this sub-hypothesis may seem it lends credence to the analysis of predicted volumes year by year. Acceptance of this hypothesis implies that, in a broad sense, time is an extremely important variable. However, in particular instances as evidenced in Table 6, there may be cases in which the volume of fuel resulting from a particular combination of factors may be less than what would be expected for that level of burn year.

Further analysis of Table 5 is a worthwhile endeavor, for the practical application of observations garnered from this table surely will be of considerable value. For example, perusal of the first combination of factors (-1 -1 -1) indicates that volume tends to increase at every level of burn year from 13 to 55. When graphed (Figure 26) it is obvious that while the trend is for increased volume at all levels, the rate of volume increase is not uniform. Comparison of this with another combination of factors (1 -1 1) is revealing. At high altitudes on gentle north slopes the volume of fuel actually decreases from the point of beginning at 13 years since burn until 18 years since burn (Figure 27). In this instance, from 28 until 40 years since burn there is a rapid acceleration in the volume of fuel produced. During the period 40 until 48 years volume is still increasing, but the net gain is markedly less than that of the preceding 12 years. Finally, during the last time span the volume of fuel existing at 55 years has declined to a volume comparable to that present at approximately 37 years since burn.

Examination of one more combination of levels for illustrative purposes will present even another contrast. High altitude, gentle southern exposures (1 -1 -1) produce very little increase in fuel volume from burn year 13 through 24 (Figure 26). During the eight year span from 24 to 32 years since burn the fuel volume nearly doubles. The same observation may be made for the next eight year period (32-40 years since burn) where fuel volume again is nearly twice that of the preceding 8 year period. At 55 years since burn the volume of fuel produced is still increasing. In fact, the greatest volume of fuel for any level of burn year and combination of factors is found at high altitude on a gentle southern exposure.

The utility of the analysis of trends from this kind of data will be of considerable value in the recommendation of a management plan which is consistent with observed environmental factors in a specific location. In the last combination of factors considered it was noted that the volume of fuel produced was different for various time segments. For instance, in the case of high altitude gently sloping southern exposures (1 -1 -1) there is no reason to consider manipulation of fuel at least during the years 13 through 24 since burn. During those years the volume of fuel remained at practically the same level which leads one to conclude that manipulation should occur either before 13 years since burn or after 24 years since burn. Simply for illustrative purposes, suppose it is found that reduction of fuel volume should be instituted whenever a volume of 50 cubic meters is reached. Appraisal of Figure 28 suggests that treatment should occur after approximately 35 years since the last burn. Obviously, this procedure could be performed for all levels and combinations of factors which would assess optimal levels for implementation of a management plan.

THE RESEARCH HYPOTHESIS

The research hypothesis is the culminating link requisite to the formulation of viable resources management planning for the chaparral brushlands. It has been proposed that the evolution of chaparral brushlands is dependent upon select environmental factors acting within a time dependent system such that fuel volume will significantly vary, thus resulting in variance in wildfire potential.

Prescribed burning is suggested as the primary means of treatment to reduce fuel volume because of the efficacy of such an approach as applied to a variety of environmental and temporal parameters. Alternative means for destruction and rejuvenation of Mendocino Chaparral exist; however, they do not have the broad-scale potential application characteristic of prescribed burning. In no way is this to imply that in each situation burning will be the only means of controlling fuel volume. Undoubtedly, there is no single treatment for which this statement may be safely made. Admittedly, there probably are micro-situations in which prescribed burning would be a mistake, perhaps a drastic one. Nonetheless, prescribed burning is a powerful land management tool when applied after thorough assessment of the resource potential of the Mendocino Chaparral.

Analysis instituted in this research has resulted in the formulation of a logical assessment of those parameters which affect the volume of fuel produced at different levels and combination of factors. The testing of supportive hypotheses has yielded a direct relationship between the degree of slope and time since burn as primary determinants of the expected volume of fuel. Despite the rejection of the supportive hypothesis that altitude affects the volume of fuel produced, there is an indication that it at least makes some contribution. Directional orientation was the only factor in which a very weak association was detected.

Consideration of the supportive hypotheses has resulted in the substantiation of the basic premise of this research which indicates that the research hypothesis should be accepted.

CHAPTER V

CONCLUSION

The modular assessment design discussed in the preceding chapters has been developed to enable land managers to approach management decisions more objectively. The inputs include time since wildfire burn and variants of configuration; the model yields an output which is predictive of the volume of fuel (vegetation). Resource management can be readily enhanced through the application of this research.

A major objective of this research endeavor has been to develop a model which involves simplicity of application. The actual statistical design and the predictor equation are sophisticated techniques which would ordinarily be beyond the comprehension of a person with only a rudimentary knowledge of statistics. Fortunately, however, the model has been perfected in this research and now requires only application followed by the implementation of a management plan.

The procedures for application of the model require an input which can be garnered vicariously without engaging in extensive field data collection. A land management plan for the Mendocino Chaparral can be formulated by a planning technician utilizing a non-technical knowledge of the variants of configuration. The variants can be determined through the analysis of data obtained from existing topographic maps. The Mendocino Chaparral has been mapped in both the 15 minute and 7.5 minute topographic series. The 7.5 minute series (1:24,000) maps perhaps will be most useful in that brushlands probably should be segregated upon a unit-sub-unit basis. For example, in the case of a sub-unit encompassing three or four square miles the larger scale map would be desirable.

The application of this research to areas of chaparral in other parts of California is problematical. Procedures for assessing the variants of configuration would be the same for any geographic area possessing adequate map coverage. However, due to differences in environmental mixes the volume of fuel in another locale which accumulates through time could be quite different from that of the Mendocino Chaparral. Perhaps the procedures of field sampling employed in this research (See Chapter III) should be executed in other locations in California chaparral where the model could be applied. The results of analysis of these areas could be compared -- as a means of assessing the validity of application of this research model -- to the results obtained in the Mendocino Chaparral. If there is enough similarity in modular output it would then be safe to conclude that the techniques developed in this research might be applied to chaparral brushlands elsewhere in California. Even if this research is not applicable to other chaparral areas it at least can be utilized in the management of approximately 70,000 hectares of chaparral brushlands situated east of the summits of the Coast Range in the Mendocino National Forest!

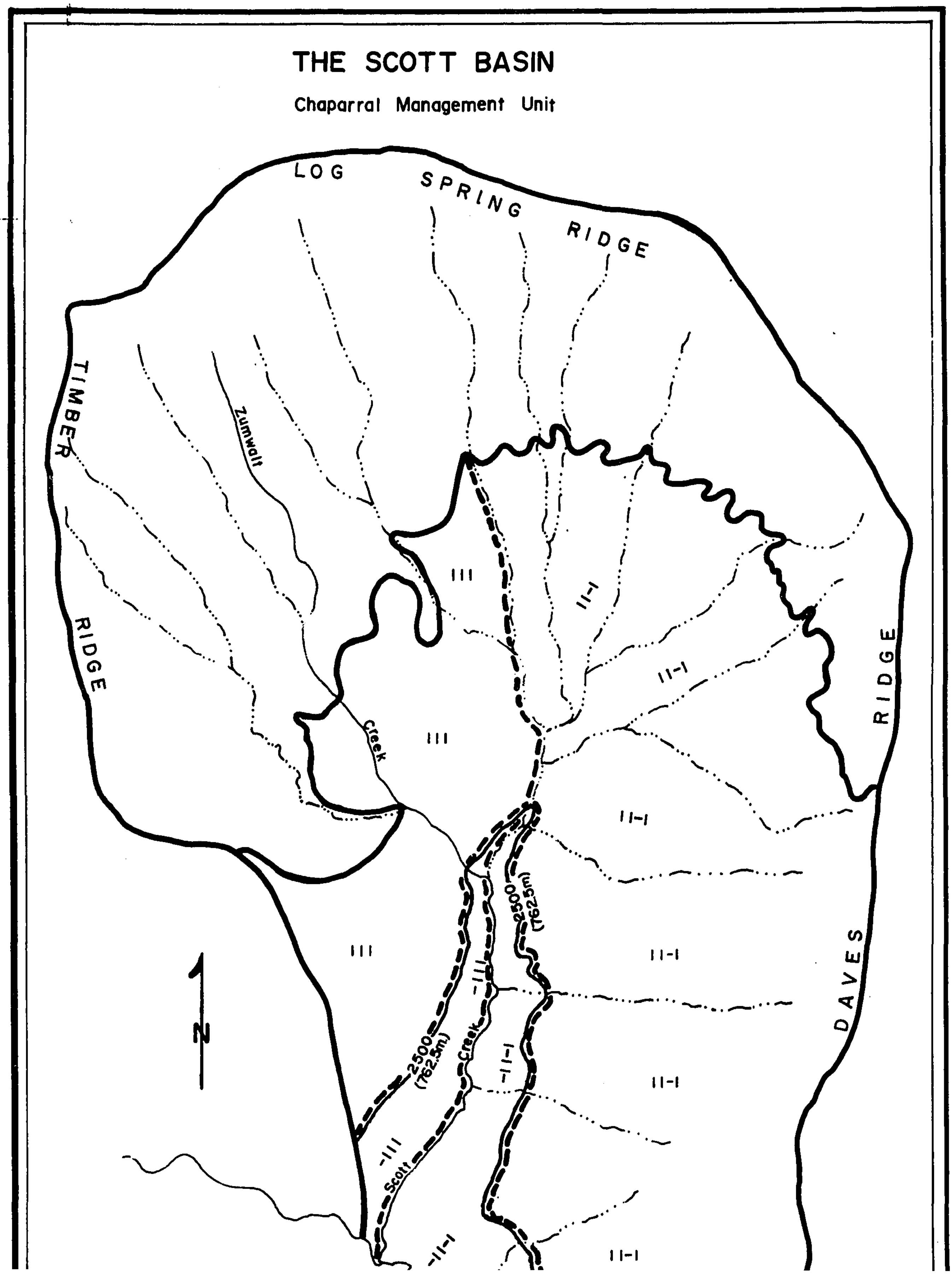
APPLICATION OF THE MODEL

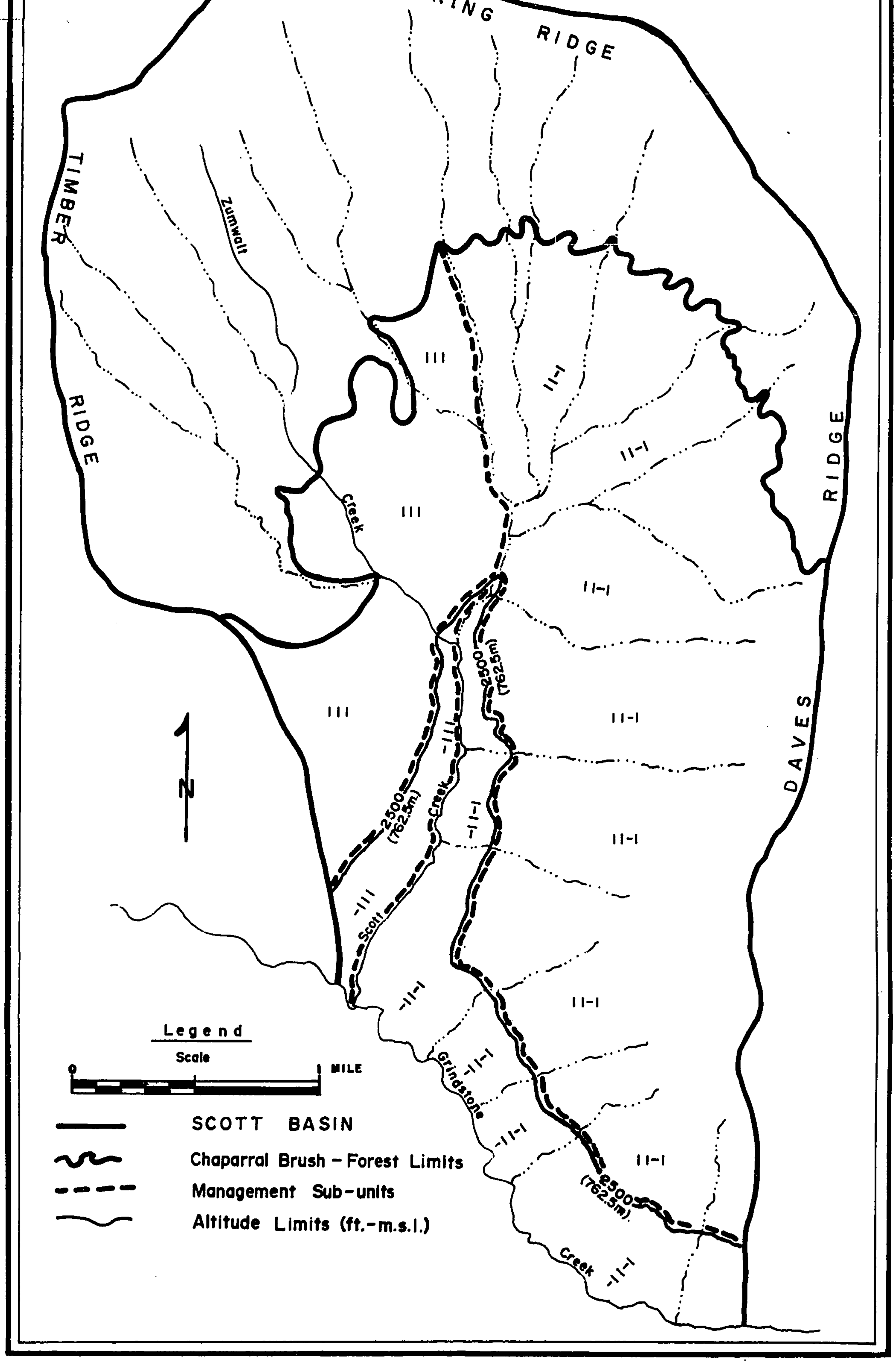
The Scott Basin, located in the northern Mendocino Chaparral, was selected as a test area for application of the model (Figure 30). It is drained by Scott Creek, a tributary of Grindstone Creek. This basin was chosen for several reasons. First, it seems that a small drainage basin might well be a manageable unit. It has some recognizable natural limits which aid in the definition of a management unit. Second, the range in altitudes is from approximately 520 m. to approximately 1,450 m. This particular basin possesses almost the full altitudinal range of Mendocino Chaparral. Third, the basin possesses a variety of directional orientation with the exception of north slopes. Most of the basin, however, is dominantly oriented in a westward and southward direction. Finally, because of its basically westerly-southerly directional orientation the dominant chaparral species is Adenostoma fasciculatum (chamise) -- a particularly hazardous wildland fuel. A second species, Ceanothus cuneatus (wedgeleaf ceanothus) is found to increase in abundance at altitudes in excess of approximately 762.5 m. These two plant species -- which are those most commonly found in the Mendocino Chaparral -- are dominant in the Scott Basin.

The first step in the procedure of developing a management plan was to designate a unit upon an appropriate map (Figure 30). It seemed advisable to select an area possessing some physical cohesiveness such as a stream basin or a main ridge in which the confinement of a prescribed burn could be accomplished. Many ridges in the Mendocino Chaparral are several miles long, a characteristic which is conducive to their delineation as management units. The designation of management units based upon physical factors is a logical choice since management plans would "fit" the landscape. Any other system of unit designation could be very arbitrary and ignore "natural boundaries". The variables utilized in this research are physical factors, hence they too coincide with the concept of physically designated management units.

The chosen area was subdivided into altitudinal classes with 762.5 m. contour line being the approximate boundary. Next, directional orientation was considered. It is rather obvious that in working with a management unit encompassing several square miles that a multitude of directional orientations probably exist. Perhaps this can be considered as occurring at two different scales -- macro-directional orientation and micro-directional orientation. Macro-

FIGURE 30


THE SCOTT BASIN
Chaparral Management Unit
LOG SPRING RIDGE
TIMBER RIDGE
DAVES RIDGE
Zumwalt
Creek
Scott Creek
III
II-I
2500 (762.5m)
N



RING RIDGE
TIMBER RIDGE
DAVES RIDGE
Zumwalt
Creek
Scott Creek
Grindstone Creek
III
II-I
2500 (762.5m)
N
Legend
Scale
0
1 MILE
SCOTT BASIN
Chaparral Brush - Forest Limits
Management Sub-units
Altitude Limits (ft.-m.s.l.)

directional orientation may be readily assessed by perusal of the topographic map after which they may be delineated on the management units base map (Figure 30). Micro-directional orientation can be ignored for the purposes of developing an overall management plan.

The last of the spatial variants to be considered was slope. In practice this was the most difficult to analyze from topographic maps and include in the design. It has been ascertained that steepness of slope is indeed an important factor in the determination of fuel volume. C.K. Wentworth (1930, pp. 184-194) has devised a method for determining average slope (Appendix 4). A problem arises in that the Wentworth system is of a questionable reliability in areas encompassing fewer than four square miles. If units smaller than four square miles are to be designated for management some alternative slope analysis technique should be instituted. For example, average slope may be determined by measuring the total length of contour lines which is multiplied by the contour interval; and the product of which is divided by the total area (Monkhouse and Wilkinson, 1969, p. 101). This technique is very laborious but might be readily applied to small areas.

It would also be desirable to know how many years it has been since the area burned. Scott Basin was last burned in 1922 (Figure 16) as a portion of the 14,950 hectares Grindstone Fire (The

Mendocino National Forest, Administrative Files). The chaparral brush has had fifty years in which to attain its present fuel volume which may be ascertained through a perusal of Table 5.

The next step in the development of a management plan for the Scott Basin was to divide the basin into subunits dependent upon the variants of configuration. The code for the variants was placed directly upon the base map. Altitude and directional orientation was determined from the topographic map. Average slope was determined by the Wentworth method and the appropriate code was applied (Figure 30). Average slope exceeds 40 percent so in all cases slope will be coded as (1).

An aid in the interpretation of codes is to list them in tabular form. If a particular known volume level is desired for a given set of variants of configuration then that predicted volume may be derived from Figures 26 and 27. A method for achieving that analysis was accomplished by designing a table listing the possible volumes (Table 6). For example, it may be desirable to maintain fuel volumes of less than 30 cubic meters at sites with altitude less than 762.5 m., greater than 40 percent slope and southerly orientation (-1 1 -1). If that is the case then by referring to Figure 26 it can be determined that prescribed burning should occur at something slightly less than 13 years. Or if it is desired to let 60 cubic meters of fuel accumulate then that would occur within 25 years since burn.

TABLE 6

SCOTT BASIN MANAGEMENT UNITS-ALTERNATIVE FUEL VOLUMES

	Cubic Meters			
Code	30	40	50	60
-1 1 -1	13 years	20 years	22 years	25 years
-1 1 1	21 years	25 years	32 years	40 years
1 1 -1	19 years	23 years	27 years	31 years
1 1 1	19 years	23 years	27 years	31 years

All of the combinations of factors which occur in the Scott Basin may be evaluated by this procedure.

If the desired fuel level is unknown, then Figures 26 and 27 may aid in a determination of that level. Each of the curves for a combination of factors may be considered. For example, sites with altitude less than 762.5 m., greater than 40 percent slope and southerly orientation (-1 1 -1) increase fuel production at a rather uniform rate until about 32 years since burn. Between 32 years since burn and 42 years since burn the actual increase of fuel is only two cubic meters. In the preceeding ten years (22-32 years since burn) fuel volume increased by 20 cubic meters. A logical time for treatment of chaparral brush might be at approximately 30 years since burn. Apparently the vegetation is vigorously growing until 32 years since burn, then it tends to enter a period of radically reduced growth. It is during this period of reduced growth and probably decadence that wildfire hazard would be at its peak.

The other subunits in Scott Basin were considered in the same manner. Areas classed as (-1 1 1) display no particular volume plateau except that there is a slight change at 24 years since burn. Fuel volume at that point is 40 cubic meters, and this may represent an opportune time to prescribe burn this subunit. Class 1 1 -1 displays undulations in volume increase at 24 through 28 years since burn and again at 32 years. At 24 years approximately 43 cubic meters of fuel is found to exist. Class 1 1 1 displays no discernible volume plateau, so if 40 cubic meters volume is desired then treatment of the brush should occur after about 22 years since burn. However, it should be noted that after 40 years since burn fuel volume decreases to 30 cubic meters at 55 years since burn. It would appear that of the several subunits in Scott Basin this one is the least critical as far as management is concerned because fuel volume will be decreasing from 40 to 55 years.

As a result of the analysis of fuel volume curves and tables, recommendations for the management of Scott Basin can be made. Subunits classified as having an altitude of less than 762.5 m., greater than 40 percent slope and of southerly orientation (-1 1 -1) should be prescribed after a time span not to exceed 30 years since burn. Subunits classified as being less than 762.5 m., greater than 40 percent slope and of a northerly orientation (-1 1 1) should be prescribed burned after 24 years. Subunits with an altitude greater than 762.5 m., greater than 40 percent and southerly orientation (1 1 -1) should be prescribed burned at 24 years since burn or when approximately 43 cubic meters of fuel is found to exist. The last management subunit to be considered is for a combination of factors including altitude greater than 762.5 m., greater than 40 percent slope and northerly orientation (1 1 1). It is recommended that subunits in this category may be treated at any time after 23 years since burn (40 cubic meters volume) and 40 years since burn. However, if treatment can not be effected within 40 years then it is not necessary to expressly treat this subunit before 55 years since the last treatment.

BENEFITS FROM MANAGEMENT

The benefits from management of the Mendocino Chaparral are many -- both long term and short term. It is indeed clear that the benefits of marginal management are few and that the propensity for deterioration is in fact heightened.

Perhaps one of the most significant management attributes would be the reinclusion of occasional fire in chaparral brushlands. At the onset this would have to occur as the result of the implementation of a prescribed burning program. However, after the chaparral brush has witnessed some regrowth it should no longer be excluded from possible wildfire burning. If the chaparral in a management unit is not subjected to a wildfire burn over a period of years it may then be necessary to once again prescribe burn. The actual length of time that should be allowed before a second prescribed burn takes place can be determined from the research design. The length of time will be dependent upon the particular combinations of spatial variants which are operant in that management unit.

Even if no other benefits are derived upon implementation of management, the possibility of eliminating potential mass conflagration is worthy of achievement. The deleterious effect of extremely hot wildfires; the reduction in down-slope movement of surface materials, and the maintenance of high moisture content in chaparral species for a greater part of the growing season have been considered earlier in this research. Additional benefits from management will accrue in the general areas of: (1) water resources; (2) a more viable wildlife resource, especially deer; and (3) recreation.

The proper management of chaparral brushlands will result in enhanced water quality and quantity. In a densely entangled chaparral brushfield there is a continuous vegetative canopy due to the interlocking of crowns and branches of chaparral species. During the rainy season there may be very little throughfall (the quantity of rain actually falling to the ground) as a result, stemflow (the rain which actually reaches the ground as flow down the shrub stem) may be increased. Hamilton and Rowe (1949, p. 6) found that the amount of interception loss is directly related to the amount of rain received during a particular storm. If rain is heavy there is minimal loss by evaporation since under a very dense chaparral cover the majority of the moisture is intercepted and becomes stemflow. However, if storms produce only small amounts of precipitation over short periods of time there is an opportunity for a high rate of evaporation.

A logical conclusion is that a desirable chaparral vegetation cover would be one in which there is opportunity for both throughfall and stemflow. A dense chaparral cover would tend to concentrate moisture at the bases of plants as well as create conditions conducive to loss of moisture by evaporation. A water resources management goal worthy of achievement would be to distribute available moisture over a larger surface area.

Another beneficiary would be wildlife populations -- especially deer and associated predators. There presently is no concerted management effort to maintain wildlife populations at a maximal level. The history of the dynamics of deer herds in the Mendocino Chaparral is interesting. Deer hunters who slaughtered the animals primarily for their hides and secondarily for jerky -- dried meat -- decimated the deer herds before the turn of the 20th Century (Woolfolk, 1959, p. 170). Shortly after that wildlands came under the jurisdiction of governmental agencies, and the California State Legislature enacted game laws (Longhurst and others, 1952, p. 15). Deer herds situated in chaparral brushlands greatly increased since they were utilized less fully. This trend continued until after World War II when game hunting became very popular. Deer herds have since decreased as hunting pressure has increased.

One of the primary reasons for a decreasing deer population in the Mendocino Chaparral has been the policy of fire exclusion. Occasional rejuvenation of chaparral brush is necessary to increase the nutrient level of vegetation. Fire, of course, is an effective means of rejuvenation over large areas. Biswell and others (1952, pp. 460-462) found that the kind of chaparral habitat affected the reproductivity of California blacktail deer. Deer were studied in three different habitat situations in chaparral brushland: (1) in a heavy unburned brush cover; (2) in an area of wildfire burn; and (3) in open brush consisting of small burned patches within a dense brushfield. Their study revealed that for every 100 adult does in heavy brush 60 to 85 fawns were produced; on the wildfire burn 100 to 110 fawns were produced per 100 adult does; and in open brush a ratio of 115 to 140 fawns per 100 adult does. The overall quality of the animals was higher in open brush. Deer from open brush weighed more, and due to better physical conditions displayed lower mortality rates

(Biswell and others, 1952, p. 462).

The Mendocino Chaparral is an area in which deer herd improvement would occur as a result of prescribed burning. Most of the old decadent brush is unpalatable. New growth that does occur in old brush is found at heights too far above ground-level to be readily obtained by deer (Figure 31). Where brush is not yet so tall as to be beyond reach it is heavily browsed by deer (Figure 32). In effect, there is a vast amount of vegetation, yet deer are either starving or at least in something less than a healthy condition because browse is unavailable to them.

A final consideration is that the Mendocino Chaparral could provide a wildland environment for outdoor enthusiasts. There presently is some recreational activity in the Mendocino Chaparral, but it is largely restricted to hunting and fishing.

The Mendocino Chaparral is as much a wilderness as many alpine wilderness areas in California. Visitors should be encouraged to utilize this area, especially since it is more readily accessible during winter months than are high mountain wilderness areas. During the hot summer months few people would tolerate the chaparral for very long. Therefore, it is doubtful that there would be any appreciable increase in man-caused wildfires.

This research endeavor has resulted in the obvious conclusion that the Mendocino Chaparral can be managed differently to

Figure 31. -- New growth chaparral brush too high to be browsed by deer

Figure 32. -- <u>Ceanothus cuneatus</u> which has been hedged as a result of heavy browsing by deer

enhance its resource potential. Perhaps a logical approach to the proper management of chaparral brushlands would be to charge the U.S. Forest Service or similar public agency with the responsibility of implementing a comprehensive resource management plan for the Mendocino Chaparral. That plan should contain management procedures which recognize the viability of chaparral brushlands and the desirability of managing those lands so as to: (1) reduce potential mass conflagrations and to mitigate the deleterious effect of extremely hot wildfires; (2) yield additional water resources; (3) intensify production of wildlife, especially deer; (4) create a landscape that provides the opportunity for people to appreciate the scenic and recreational quality of chaparral wildlands; (5) reduce the downslope movement of surface materials; and (6) maintain a high moisture content in chaparral species for a greater part of the growing season.

APPENDIXES

APPENDIX 1

SYMBOLS FOR TABLE (Soils)

Permeability	rap. = rapid; per. = moderately rapid permeability; mod. per. = moderate permeability; sl. per. = slow permeability; v. sl. per. = very slow permeability	
Reaction	calc. = calcareous (pH 7.5 or greater)	sl. acid = slightly acid (pH 6.1-6.5)
	basic = basic reaction (pH 7.4-7.8)	mod. acid = moderately acid (pH 5.6-6.0)
	neut. = neutral (pH 6.6-7.3)	st. acid = strongly acid (pH 5.1-5.5)
		v. st. acid = very strongly acid (pH 4.5-5.0)
Parent Material	bas. rks. = basic igneous rocks (basalt)	
	meta sed. and sed. rks. = metamorphosed sedimentary and sedimentary rocks	
	sch. sed. rks. = schistose sedimentary rocks	
	serp. rks. = serpentine rocks	
Drainage	R = good to excessive	P = poor
	G = good	VP = very poor
	I = Imperfect	
Erosion	0 = none or very little	3 = severe sheet erosion
	1 = slight sheet erosion	4 = gullied
	2 = moderate sheet erosion	

Fertility	VG = very good	P = poor
	G = good	VP = very poor
	F = fair	
Vegetation cover	C = chaparral	M = mixed conifers
	G = grass	

Storie Index

Soils that rate 10-19 are of very limited use for cultivated crops due to adverse relief, texture, shallowness, etc.

Soils that rate less than 10 include steep, rocky upland areas and miscellaneous waste lands

Grazing Ratings

	Carry Capacity (acres/cow/yr.)
VH = very high	10 ac.
H = high	10-20 ac.
M = medium	20-40 ac.
L = low	40-60 ac.
VL = very low	60 ac.

APPENDIX 2

90% CONFIDENCE LIMIT: on y

Site Classes	Year	90% LCL	Prediction	90% UCL
8		44.4404	62.7511	81.0618
7		30.4881	48.7988	67.1095
6		62.3128	80.6235	98.9342
5		52.7909	71.1016	89.4123
4	1917	84.0153	102.326	120.637
3		48.0735	66.3842	84.6949
2		42.7238	61.0345	79.3452
1		11.2120	29.5227	47.8334
8		40.7693	57.7628	74.7563
7		31.1824	48.1759	65.1694
6		56.7223	73.7158	90.7093
5		41.2972	58.2907	75.1842
4	1932	55.5409	72.5344	89.5279
3		53.9749	70.9684	87.9619
2		63.4288	80.4223	97.4158
1		56.0247	73.0182	90.0117
8		25.4547	41.8031	58.1515
7		14.3288	30.6772	47.0256
6		41.2143	57.5627	73.9111
5		23.1170	39.4654	55.8138
4	1948	7.49281	23.8412	40.1896
3		11.3389	27.6873	44.0357
2		28.9543	45.3027	61.6511
1		25.8290	42.1774	58.5258
8		7.45491	25.5393	43.6237
7		3.26701	21.3514	39.4358
6		8.00371	26.0881	44.1725
5		1.94521	20.0296	38.1140
4	1959	4.19611	22.2805	40.3649
3		4.75321	22.8376	40.9220
2		-4.48249	13.6019	31.6863
1		-5.79589	12.2885	30.3729

APPENDIX 3

FIELD DATA SHEET

Year burned ________ Altitude ________

Sample Site No. ________ Slope % ________

Directional Orientation ________

Litter Depth:

1	1-2	2-3	3-4	4-5	5-6	6 cm.

Crown Volume Measurements *

Species	H	W	Species	H	W	

* H = height W = width

APPENDIX 4

Wentworth method of average slope determination

1. Select typical area to be assessed.

2. Lay out grid-template of not less than four square miles.

3. Count and tabulate all contour crossings and determine the average number per mile. Tangency contacts which are not true crossings should be counted as one crossing each.

4. Repeat the procedure with grid-template placed at an oblique angle covering substantially the same area.

5. Total all crossings and determine the average number of crossings per mile. Multiply that average by the contour interval.

6. Divide the product of average crossings per mile times the contour interval by constant 3361.

7. The quotient is a tangent, the degree of which may be ascertained from standard trigonometric tables.

The Scott Basin

Contour line crossings

N-S	108
E-W	173
NW-SE	132
NE-SW	96
	529 = total crossings

$$16 \overline{)\,529.00\,} = 33.06$$

16 = total miles

33.06 = crossings per mile
40 = contour interval
1322.40

$$3361 \overline{)\,1322.40\,} = 0.39$$

0.39 = 21° 42' = 43.24% average slope

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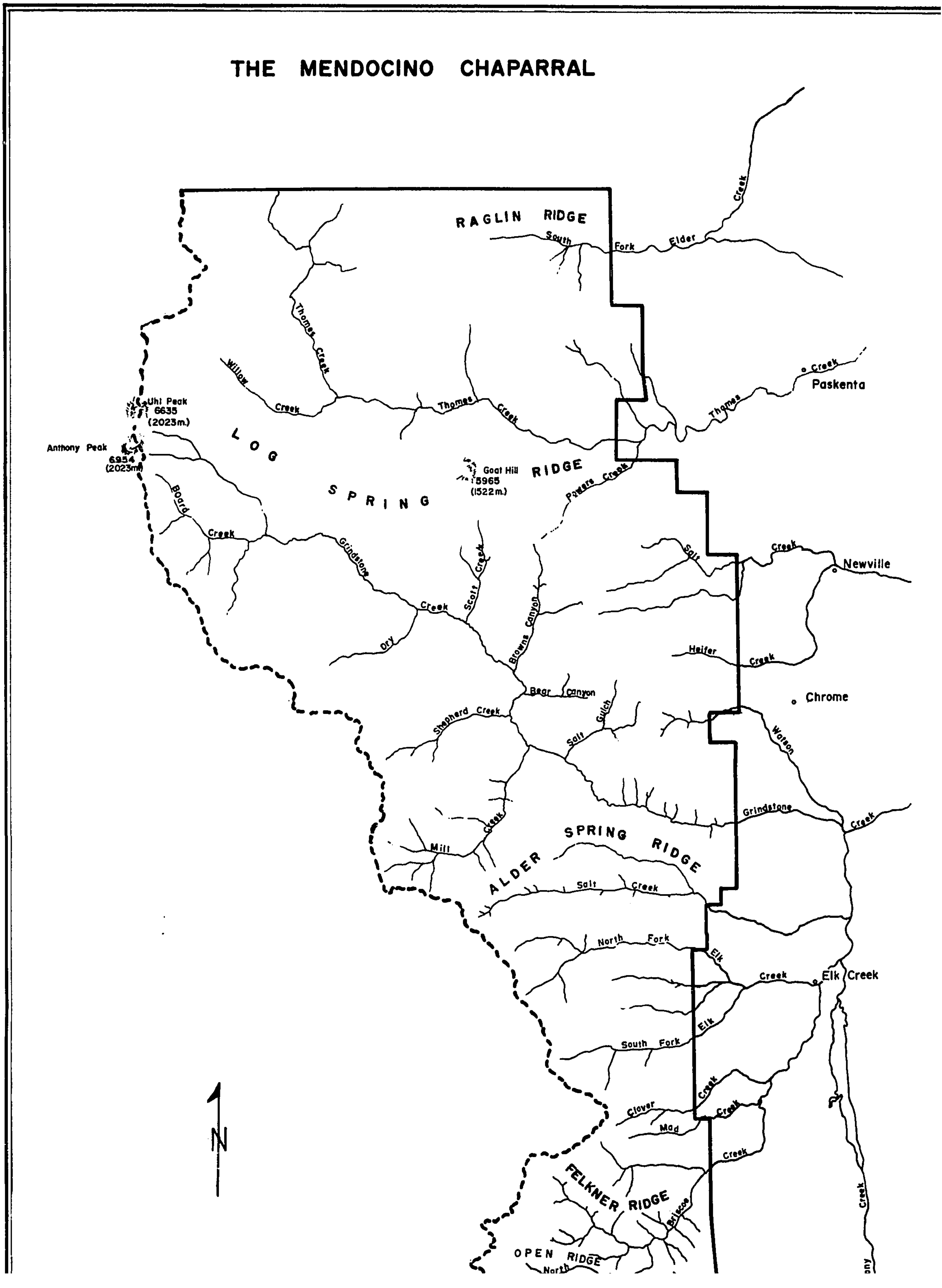
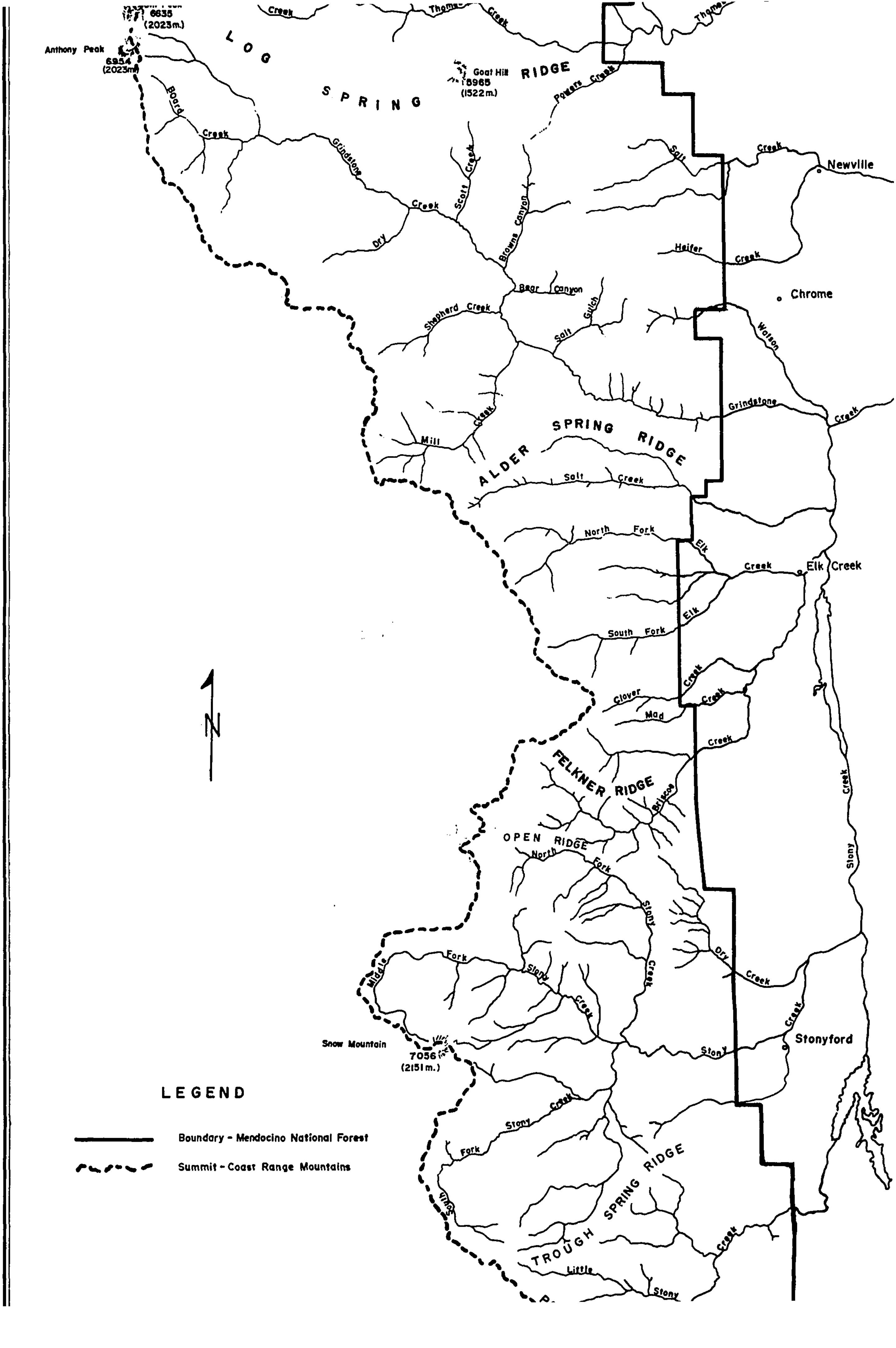
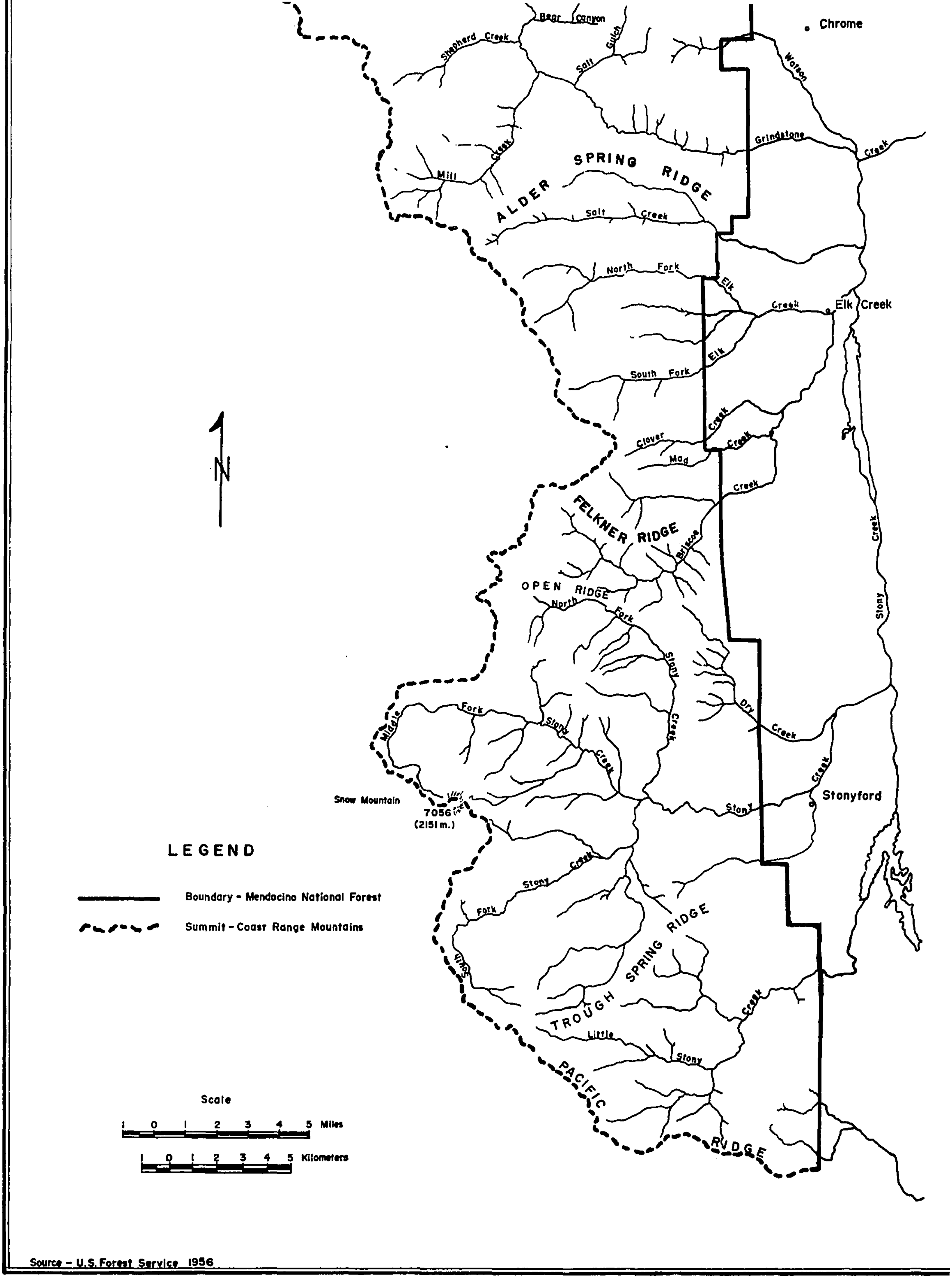
FIGURE 4


THE MENDOCINO CHAPARRAL
RAGLIN RIDGE
South Fork Elder Creek
Creek
Paskenta
Thomes Creek
Creek
Willow Creek
Thomes Creek
Uhl Peak 6635 (2023m.)
Anthony Peak 6954 (2023m)
LOG SPRING RIDGE
Goat Hill 5965 (1522m.)
Powers Creek
Board Creek
Grindstone Creek
Scott Creek
Salt Creek
Newville
Browns Canyon
Dry
Heifer Creek
Chrome
Bear Canyon
Shepherd Creek
Salt Gulch
Watson
Grindstone Creek
Mill Creek
ALDER SPRING RIDGE
Salt Creek
North Fork Elk Creek
Elk Creek
South Fork Elk
Creek
Clover
Mad
Creek
Creek
FELKNER RIDGE
Briscoe
OPEN RIDGE
North
N



6635
(2023m.)
Anthony Peak
6954
(2023m)
LOG SPRING RIDGE
Goat Hill
5965
(1522m.)
Board
Creek
Grindstone
Creek
Dry
Scott
Creek
Browns Canyon
Powers Creek
Thomes
Creek
Salt
Creek
Newville
Heifer
Creek
Bear Canyon
Chrome
Shepherd Creek
Salt Gulch
Watson
Grindstone
Creek
Mill
Creek
ALDER SPRING RIDGE
Salt Creek
North Fork
Elk
Creek
Elk Creek
South Fork
Elk
Creek
Clover
Mad
Creek
Creek
N
FELKNER RIDGE
Briscoe
OPEN RIDGE
North Fork
Stony
Creek
Dry
Creek
Stony
Creek
Middle
Fork
Stony
Creek
Snow Mountain
7056
(2151m.)
Stony
Stonyford
Creek
LEGEND
Boundary - Mendocino National Forest
Summit - Coast Range Mountains
Stony
Creek
Fork
South
TROUGH SPRING RIDGE
Creek
Little
Stony



Source - U.S. Forest Service 1956