MOUNTAIN FORESTS AS COMMON-PROPERTY RESOURCES: MANAGEMENT POLICIES AND THEIR OUTCOMES IN THE COLORADO ROCKIES AND THE SWISS ALPS

by

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Mountain forests as common-property resources: management policies and their outcomes in the Colorado Rockies and the Swiss Alps.

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This is a historical, comparative study of the development, implementation, and results of policies for managing the forests of the Colorado Rockies and the Swiss Alps, with emphasis on two study areas in each region. The Pikes Peak (Colorado) and Davos (Switzerland) areas have been adjacent to regional urban centers since the late 19th century. The Summit (Colorado) and Aletsch (Switzerland) areas have experienced a rapid change from a resource-based to a tourism-based economy since the 1950s. The study's theoretical basis is that of common-property resources. Three primary outputs of the forests are considered: wood, recreation, and protection. The latter includes both the protection of watersheds and the protection of infrastructure and settlements from natural hazards.

Forest management policies date back to the 13th century in Switzerland and the late 19th century in Colorado, but were generally unsuccessful in achieving their objectives. In the late 19th century, the early foresters in each region succeeded in placing the protection of mountain forests on regional, and then national, political agendas. In consequence, by the beginning of the 20th century, federal policies were in place to ensure the continued provision of the primary functions of the forests recognized at that time: protection and timber supply. During the 20th century, these policies have been expanded, with increasing emphasis on the provision of public goods.

However, most policies have been reactive, not proactive. Many of their long-term objectives have not been realized, especially because the structure of the forests is generally not adequately diverse, largely as a result of human *actions. Other major* conclusions and recommendations are as follows. The concept of sustained-yield forestry is not sufficient for the management of these forests. Management requires increased involvement from members of local communities. This must be based on public understanding of the interactions between ecological processes and human actions in these forests, and should not be based on short-term economic factors or nationally-set goals for producing forest outputs.

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1. INTRODUCTION

1.1 Objectives

This study is a historical, comparative analysis of the development, implementation, and outcomes of forest management policies in the Colorado Rockies and Swiss Alps. It has three main objectives, which are closely related to the major themes outlined in the following section. The first objective is to identify the conditions which led to the formulation of national policies, to trace the regional and local implementation of these policies, and to assess and explain the degree of success of policy implementation in the forests of the study areas. The second objective is to compare the development of policies within and between regions, and explain these policies in relation to socio-economic, institutional, and ecological changes. The third objective is to show that mountain forests are common-property resources, and identify the ways in which their common-property characteristics have changed over time.

1.2 Background

There is a large literature on forestry, and forest policy in particular, from both Switzerland and the United States. In both countries, there are important journals, such as the Journal of Forestry and the Schweizerische Zeijschrift fur Forstwesen; three large bibliographies show the extent of past work in the United States (Davis, 1977; Fahl, 1977; Ogden, 1976). However, there is a dearth of literature on the three primary themes of this dissertation.

The first theme is the development of forest policies and their interpretation and outcomes at the regional and local levels. In the United States, while there have been many studies of national forest policy and its development (e.g., Ise, 1920; Cameron, 1928; Gulick, 1951; Greeley, 1953; Dana, 1956; Worrell, 1970; Clawson, 1975; Dana and Fairfax, 1980; Alston, 1983; LeMaster, 1984; Wilkinson and Anderson, 1985; O'Toole, 1988), studies of regional, local, or issue-specific policies have been quite rare, and principally the subject of dissertations, some of which have subsequently been published as books (e.g., Voss, 1931; Gilligan, 1953; Schiff, 1962; Cates, 1963; McCarthy, 1977; Nash, 1982; Alexander, 1987), In Switzerland, while national-level studies exist (e.g., Bloetzer, 1978; Schoeffel, 1978; Steinlin et al., 1975), most of the literature has been published as papers in the Schweizerische Zeitschrift fur Forstwesen or by the Eidgenossische Anstalt fur das forstliche Versuchsweserf. There have also been a few local and regional studies (e.g., Fankhauser, 1893; Gnagi, 1965; Grossman and Krebs, 1965; Giinter, 1980; Kempf and Scherrer, 1982; Wuilloud, 1981).

Second, in spite of similarities in the development of policies in response to comparable changing conditions in these two temperate

mountain regions, there has been limited discussion of the parallels and lessons which can be learned from a comparison such as presented here. The need for such comparisons has been indicated through programs such as UNESCO's Man and the Biosphere (MAB) Program, which was the impetus to this study. The Swiss portion of the study draws much of its material from the Swiss MAB program, which is part of MAB Project 6 (impact of human activities on mountain and tundra ecosystems). With respect to temperate mountain ecosystems, the objectives of MAB-6 are "to give a better knowledge of the mountain ecosystems in the temperate zone in relation to human use, so that present ecosystems can be conserved and new ecosystems devised to replace old systems which are no longer socially relevant and economically viable. . . . this research should make it possible to give management prescriptions to achieve desired aims in the management of [these] ecosystems" (UNESCO, 1973). The study also falls within MAB Project 2 (temperate forest ecosystems) and is presented as a contribution to both of these MAB Projects.

The comparison is validated not only by the relevance of similar trends in the two study regions, but also on historical and institutional grounds. Both Switzerland and the United States are federal nations, where jurisdiction over the majority of the mountain forests moved from the local or state level to the national level in the late nineteenth century; a comparability emphasized by Fernow (1913), Cameron (1928), Greeley (1953), and others. Furthermore, forestry, as practised in both countries, has its origins in nineteenth-century Germany, a densely-populated country with a clear social hierarchy and plentiful (i.e., cheap) labour, where forestry was based on scarcity of wood supply and stability of demand for wood (Dana and Fairfax, 1980). These characteristics have not typified the Swiss or the Colorado situation for decades, yet the principle guiding German forestry, derived from the principles of scarcity and stability, persists: certainty in management (i.e., sustained yield; non-declining even flow).

As Alston (1983) has discussed with respect to the United States, these origins have led to continuing tensions in forest management. These tensions have grown as the forests have, in comparative terms, become less important for the production of tangible, measurable outputs (e.g., timber and forage), and more important for less tangible outputs (e.g., recreation, protection from natural hazards, and species and ecosystem diversity). Particularly in the United States, most previous studies of policy development have primarily considered the obvious output of the forests: wood. In contrast, this study will emphasize other outputs of key importance in both regions. However, it must be realized that wood production results from nearly all aspects of the active forest management which is necessary for the production ill of all outputs; consideration of wood production is therefore essential in any discussion of forest policy.

Finally, there are few studies discussing the fact that the common-property characteristics of a resource may be defined at various scales and with respect to different outputs. A primary aim of the study is to expand the application of the theory of common-property resources, presented in section 1.4,through a historical analysis of the changing importance of the outputs of these forests, and discussion of the applicability of the study's findings to common-property resources in general. The long historical perspective is crucial because the trees which comprise these forests, unlike the components of some other common-property resources such as stocks of fish and game, typically have life-spans measured in decades, if not centuries. Thus, one might expect that policies implemented around the turn of the century would have significantly influenced the structure of today's forests.

The study is based on a wide range of sources, including published and unpublished literature, documents from government and non-government organizations, and interviews with individuals at all levels within and outside the forest services. Wherever possible, quantitative data are used. However, in many cases these are not available or comparable over either space or time. Such shortage of data limits statistical analysis, but illustrates the realities involved in policy development. The types of data sources used for the two regions differ somewhat, as a result of the time available for data collection. In general terms, while primary sources were used wherever possible for both regions, the Swiss portions of the study rely to a greater extent on secondary sources.

1.3 Choice of study regions and areas

The study considers parts of two temperate mountain regions: the European Alps and the North American Rockies. The specific study regions are the Swiss Alps and the Colorado Rockies. These study regions were not chosen as typical of the regions as a whole; such a statement could not be supported in view of the great human and physical geographical diversity of both regions. The same applies to the study areas within each study region.

The Swiss study areas are two of the four Swiss MAB-6 "test areas", chosen by the Swiss MAB Committee, based on information collected from scientists engaged in environmental research in Switzerland. Questionnaires were sent to 350 scientists who expressed an interest in research with the scope of the MAB program, to ascertain the extent of both basic scientific research and interdisciplinary studies on the relationships between human and natural systems in the Swiss Alps. Eighty questionnaires were returned, providing the basis for identifying potential test areas for research to fulfil the aims of the MAB-6 program. Initially, twelve potential areas were identified; these were subsequently reduced to four (Aletsch, Davos, Grindelwald, Pays d'Enhaut), using the following criteria (SMK, 1976): 1) level of extant or completed research relevant to the themes of

MAB-6: a high level would provide a stronger basis for interdisciplinary research;
2) spatial distribution: representation from the east and west and French- and German-speaking parts of Switzerland, and from the outer and inner Alps;
3) accessibility to research institutions: to permit participation
by scientists from as wide a range of institutions as possible;
4) increasing impacts and conflicts resulting from current land-use and management practices.

Both of the areas considered in this study are in the German-speaking part of Switzerland, one in the eastern inner Alps (Davos), and one in the Rhone valley of the western inner Alps (Aletsch). Grindelwald, in the western outer Alps, was not considered because information on forest policy, structure, and outputs is only available for the 60 percent of the forest area in public ownership. Pays d'Enhaut was not considered primarily because it is in the Pre-alps, with very different conditions with respect to climate, topography, and the economic bases of the local communities. While the study areas are not necessarily representative of the Swiss Alps as a whole, they provide good examples of both socio-economic trends and forestry policies and practices found throughout the region.

The Colorado study areas were chosen after wide-ranging discussions with individuals concerned with forestry and forest policy in Colorado. These areas provide a wide range of outputs typical of the Colorado Front Range (Pikes Peak study area) and the central Rockies (Summit study area). Again, it cannot be said that these areas are characteristic of the Colorado Rockies in terms of the mixture of outputs, forest policies and practices, on socio-economic trends. In particular, livestock grazing is not a major emphasis, in contrast to the western Colorado Rockies, where grazing has been crucial in the evolution of policies relating to the management of the National Forests (e.g., McCarthy, 1977). As with the Swiss study areas, a major consideration was the availability of information; there is a significantly larger base of data for these two areas than for most others in Colorado.

Another reason for choosing these two areas is a general comparability with the Swiss areas, as discussed in detail in Chapter two. The Pikes Peak area, like the Davos area, has been adjacent to a regional urban center since before the turn of the century. In contrast, the Summit area, like the Aletsch area, was primarily rural until the middle of this century. Since that time, the basis of local economies has rapidly changed from the direct exploitation of natural resources to tourism.

1.4 Common-property resources, private goods, and public goods: definitions and a classification of forest outputs

The concept of common-property resources, on which this study is based, overlaps many other concepts, including those of common-

pool and free- (or open-) access resources, commons, and public goods. In order to clarify the meanings of, and relationships between, these concepts, and to provide a basis for the analysis of temperate mountain forests as common-property resources providing a wide variety of outputs, this section begins with a discussion of these terms.

Beginning at the core of these concepts, a resource is "an attribute of the environment appraised by man to be of value over time within constraints imposed by his social, political, economic, and institutional framework" (O'Riordan, 1971: 4). This definition provides the basis for the whole of this study, which considers the changing values of forests to people in Switzerland and Colorado. As discussed in Chapter two, the social and economic framework of these two regions has changed substantially over the past century; Chapters three and four consider the development of the political and institutional framework.

The next concept which must be defined is property: "a bundle of rights in the use and transfer of natural resources" (Ciriacy-Wantrup and Bishop, 1975: 714). Different people and institutions (e.g., governments) use, and have used, mountain forests in different ways over time: for instance, as a source of timber, forage, and germplasm; for recreation; and for protection from natural hazards and of watersheds. Changes in the regulation of use and the transfer of ownership in forests are considered in Chapters three and four. One of the possible combinations of a resource and property is a common-property (or common-pool) resource: a resource which is "used, if not necessarily owned, in common by all of the members of a community. Neither exclusion nor discrimination is permitted with respect to its access" (Krutilla and Fisher, 1985: 20).

As discussed by Ciriacy-Wantrup and Bishop (1975) and Howe (1979), this economic definition of a common-property resource is not the same as in other disciplines, such as law. Legal terminology differentiates between two concepts: res *communes* and *res nullus.* In the former, "a well-defined set of users has a well-defined (not, necessarily equal) right to use the resource, while all potential users not belonging to that set are excluded" (Howe, 1979: 242). The latter refers to an unowned resource: i.e., one to which no property rights are defined, Such resources may also be described as open- or free-access. One of the objectives of this study is to assess how mountain forests have changed between the res *nullius* and *res communes* conditions, with changing sets of users, as the demands on these resources have altered. This assessment, based on the analysis of the development and implementation of policies presented in Chapters three to five, is presented in Chapter six.

The definitions presented so far are taken from the work of economists. The economic concept of common-property natural resources has undergone considerable development over the past three decades. From the earliest literature in this field, common-

property resources have typically been discussed in terms of a problem, summarized by the phrase "everybody's property is nobody's property" (Ciriacy-Wantrup and Bishop, 1975). The earliest resource to be considered in these terms was the fishery without controls on catch levels, depletion would occur (e.g., Gordon, 1954; Scott, 1955; Clark, 1973; Wilson, 1977). This "problem" has been modelled by various economists (e.g., Olson, 1971; Haveman, 1973; Muhsam, 1973) and is treated in algebraic terms in many economic textbooks (e.g., Freeman et al., 1973; Boadway, 1979; Howe, 1979).

Outside economics, common-property resources have typically also been treated as a "problem", first brought to general attention by a biologist (Hardin, 1968) as the remorseless, inevitable "Tragedy of the Commons". Nevertheless, Baden and Hardin (1977) reflect that Aristotle identified this tragedy, and Hardin (1968) cites two lectures delivered in 1832 by the obscure W. F. Lloyd as the source of his exposition. The commons initially considered by Hardin (1968) was land available to all members of a community for grazing their livestock. Each herder would naturally try to keep as many animals as possible on the commons. This is not a problem while populations of both men and animals are below the land's carrying capacity. However, even when this limit is reached, each herder will still add animals to his herd, acting for his own good without regard for that of the other members of the community. In economic terms, his positive utility from this action is nearly 1, while his negative utility is only a fraction of 1. In the long term, this leads to the destruction of the pasture through the addition of each herder's component partial utilities (in the form of animals). The key variable is thus population; the tragedy begins when this is so large that consequent use of the resource exceeds the supply, and climaxes when, in the absence of regulation, the resource is exhausted.

The theme of this "tragedy" has been repeated in countless papers, books, and dissertations in many disciplines, considering numerous resources. For example, a search of Dissertation Abstracts International in August 1987 found 136 dissertations which considered the idea of the commons. Two recent publications (BOSTID, 1986; McCay and Acheson, 1987) show the scope and direction of recent research, which has mainly considered common-property resources in developing nations. Hardin (1977b: 112) attributed the success of his idea to the favorable climate of opinion resulting from the rapid growth of the environmental movement, and also to his clearly-stated definition of the tragedy; in addition, publication in a widely-read journal doubtless helped. He also ascribes the previous lack of acceptance (or awareness) of the tragedy to the perceived threat to "cherished beliefs and practices" and mentions that the abandonment of traditional practices requires political change; a point which will be considered with respect to the development of policies for mountain forests. However, since the mid-1970s, increasing numbers of authors have discussed the fact that the fate of common-property resources is not always tragic (e.g.,

Ciriacy-Wantrup and Bishop, 1975; Bullock and Baden, 1977; Ostrom, 1987), and others (e.g., Cox, 1985) have argued that this also applied to the English common pasture which Hardin (1968, 1977a) used to expose the tragedy. For this reason, "commons" should not be used as a synonym for "common-property resource"; the latter term will be used throughout this study.

Analyses of common-property resources by economists and other scientists have generally concentrated on one, or a very small set of outputs from these resources. One example is provided by the classical case of the fishery, where one species is the subject of study. However, each fish species occupies a specific niche in the ecosystem - or many ecosystems if it migrates or lives in a littoral community - so that population changes will necessarily affect other species in the food and decomposition chains. Loss of a species, or even a local population, results in the irreversible loss of genetic information. Similarly, on Hardin's common pasture, increases in the populations of animals past the carrying capacity would not merely result in decreased pasture quality and quantity, leading eventually to weak and dying animals and people. The composition of vegetation would have changed and soil erosion increased, and perhaps the herders would turn to raiding their neighbors' herds or limiting population growth. Furthermore, while the concept of carrying capacity, like that of the tragedy of the commons, is simple and intuitively understood, carrying capacities are not fixed. They can be changed by changes in any part of the framework which defines a resource; economic, institutional, social, or technological. Thus, the tragedy of the commons is not inevitable.

The examples of the fishery and the commons show that no resource should be regarded in isolation, and also that changes in the use of a resource affect its various outputs in different ways. This point will be further discussed with reference to mountain forests; however, in order to conclude this definitional section, it is necessary to present a classification of the possible range of outputs which a natural resource may provide. Such a range of outputs may be referred to as joint products (Cornes and Sandier, 1986). Furthermore, a single output may fall in more than one category, depending on the user; this is discussed below with reference to forest outputs and summarized in Table 1.1. The classification of outputs presented below derives principally from economic theory. A range of outputs is described, from private (market) to pure public goods. Different outputs within this range are defined by two factors: the ability to provide values for them in realor simulated markets, and the size of the community which can benefit from their use. However, in reality, the values of forest outputs to different communities should be placed along a continuum, rather than in the discrete categories shown in Table 1.1.

The outputs considered by classical microeconomics are private goods, whose value is determined in terms of their price in the competitive market-place, at the equilibrium between supply and

TABLE 1.1 CLASSIFICATION OF FOREST OUTPUTS

OUTPUT	TYPE OF GOOD		
	PRIVATE (MARKET)	IMPURE PUBLIC	PURE PUBLIC
ECOSYSTEM DIVERSITY			Option/ existence
FISH	As input to economy (sold)	Recreational use (Club good if permits sold)	
FORAGE	Grazing permits sold on open market	Community use (Local public good)	
GAME	As input to economy (sold)	Recreational use (Club good if permits sold)	
GENETIC DIVERSITY			Option/ existence
HAZARD PROTECTION		Individuals' life. property, safety	Public land, facilities
LANDSCAPE		Limited access viewpoints	Public access viewpoints
RECREATION	Developed: ski areas, private campgrounds etc.	Undeveloped: trails, campsites, picnic areas	
WATER QUALITY	Industrial, municipal, domestic use	Recreational use	Perception
WATER QUANTITY	Industrial, irrigation, municipal use	Recreational use (type of craft)	Perception
WILDERNESS		Perceived environment for recreation	Existence value
WOOD	Sold on market: stumpage fees, market products	Community use (Local public good)	Long-term security of supply

demand. Many forest outputs fall within this category, notably timber and other tree products, such as leaves for forage and Christmas trees. Forage from shrubs, forbs, and grasses can be valued in terms of the value added to grazing herds. Similarly, the water used for irrigation can be valued in terms of the value added through increased crop yields. Game animals and fish may also be valued in terms of their contribution to the economy as a source of food. Finally, the use of developed recreational facilities, such as ski areas or private campgrounds, takes place within the market economy.

However, many of the joint products of forests cannot be valued in the market-place; i.e., they are non-market goods. Some of the outputs mentioned above display non-market characteristics, and their value in real markets may be changed by various types of market intervention (e.g., taxes, subsidies). At the other end of the spectrum from market goods are pure public goods, first defined by Samuelson (1954): each individual's consumption of a public good, once made available, has no effect on any other individual's consumption. A number of forest outputs fall into this category. One instance is protection from floods or avalanches, which provides an example of the fact that the avoidance of a public bad (e.g., destruction of property by an avalanche) is a public good. Another public good is the existence value of a particular forest landscape, clean, free-flowing stream, or wilderness area - the mere knowledge that it exists. In this case, as with the value of preserving a landscape or the gene pool of a forest ecosystem, consumers do not have to be present in either space or time to derive benefits. The preservation of a resource for unknown long-term benefits provides option values (Krutilla and Fisher, 1985).

Between market goods and pure public goods are a wide range of other goods, whose characteristics have recently been summarized by Cornes and Sandier (1986). These may be described as impure public goods. The characteristics of such outputs are that their benefits are partially rival and/or partially excludable. In other words, the consumption of the output by one individual affects its consumption by someone else and/or certain individuals or groups can be excluded from the benefits of the output. The use of forests for recreation and as wilderness provides an example of an impure public good. Up to a certain level of use, the benefits of use are equal for all consumers. However, past this level, one or more individuals perceive that congestion is occurring; i.e., the social carrying capacity (Heberlein, 1977) has been reached. Thus, one person's use affects another's use (rival benefits). To avoid congestion, fees or permits can be used to limit use (excludable benefits). Exclusion may be through a number of means, including direct (e.g., price of permits) and random (e.g., a lottery) methods. Most forest outputs, in some sense, are impure public goods, including water quantity, which may limit the use of a river to certain types of craft; landscapes which can be viewed only from viewpoints with limited access; and hazard protection

which benefits individuals' lives, safety, and property rather than public facilities.

An output whose benefits are excludable but partially nonrival is known as a club good; one example is the sale of permits at a price set to exclude a significant proportion of potential users. Exclusion can also be a function of the scale at which benefits occur, in which case the output is a local public good. One example is the use of the forest for timber by members of a specific community; in contrast to use by the highest bidder in a market situation (private good). In the latter case, the economic value of this output is determined in the market; in the former, it is very difficult to put such a value on the output, since all public goods represent examples of market failure. At the smallest spatial scale, the availability of a public good may be reflected in private values. One example would be a privately-owned hunting and fishing lodge on an unpolluted stream, adjacent to a wilderness area, and protected by public hazard protection programs. The value of this property would clearly reflect the local, joint availability of these public goods.

In the United States, though not in Switzerland, attempts to find economic values for impure public goods have spawned a considerable literature over the past two decades, spurred by various factors. The ability of computers to process ever-larger volumes of data in ever-shorter time periods has led to the development of increasingly complex approaches to these comparisons, all needing numerical data (e.g., Iverson and Alston, 1986). As discussed in Chapter four, such developments have been encouraged by legal and administrative requirements that federal agencies should consider and compare all benefits of alternative uses of natural resources before decisions are made. Briefly, the many attempts at valuation try to find values of the willingness of potential, or actual, users of impure (and even pure) public goods to pay to use them (e.g., Peterson and Randall, 1984). The two main types of approach are indirect methods, which estimate benefits from the observed behavior and characteristics of users; and direct methods, which estimate benefits from surveys of users' perceived willingness to pay (Bockstael and McConnell, 1980).

While a comprehensive longitudinal study of all forest outputs in the two study regions, and policies and actions relating to them, might be possible, this study focuses on three. Each of these was chosen because it falls primarily within one of the classes described above, and was identified in policy and practice as important in both regions during the period considered in this study. Wood was chosen as an example of a market good; recreation as an impure public good; and protection (from natural hazards and of watersheds.) as a pure public good. Other output's could have been chosen, but were rejected for various reasons such as lack of long-term data in one or both regions (e.g., diversity [both areas], fish and game [Alps]) or inapplicability (e.g., wilderness in the Alps).

1.5 Outline of study

Following this introductory chapter. Chapter two provides brief descriptions of the study regions and areas, in two parts. The first defines the regions and areas in physical and ecological terms, i.e., topography, climate, soils, and major tree species. The second describes the development of the population, economy, and transportation pattern and presents the current pattern of forest ownership for each study area. At the end of the chapter, the study regions and areas are compared. The purpose of the comparison is to show the existence of sufficient physical, ecological, and historical socio-economic similarities to permit the subsequent analysis, and to identify differences which must be considered in this analysis.

The three subsequent chapters consider policy development and implementation, each concluding with a discussion of the differences and parallels between study regions or areas. These chapters are presented in a way that develops an increasing focus from the national to the local level. In each chapter, policy development and implementation are considered in relation to ecological processes and socio-economic and political/ institutional changes. Chapter three considers the period up to and including the definition of effective federal policies for the protection of the forests of the study regions. The focus of this chapter is on policy development at the national and regional level. Chapter four considers legislation and policies for the management of the forests of the two study regions during the 20th century. For each region, the organization of the forest management agencies is presented, followed by a discussion of the development of legislation and policies at three levels: national; regional (Cantons in Switzerland); and local (i.e., management plans for study areas).

Chapter five brings the focus of the study to the local level (i.e., study areas). A three-part analysis is presented for each study area. The first is a description of the extent of human influences on the forests prior to the passage of effective federal legislation. The second is an assessment of how the implementation of this legislation and other policies affected the outputs and structure of the forests, using quantitative data where possible. The final part is an analysis of whether the outputs provided by, and forest structure resulting from, the implementation of forest management policies were those intended. The final chapter pulls the findings of the previous chapters together within the framework of common-property resources, considering especially the changing outputs of the forests and their importance to different communities of users. The chapter concludes with a discussion of the implications of these findings for the management of temperate mountain forests.

2. STUDY REGIONS AND AREAS

2.1 Swiss Alps

Switzerland can be topographically divided into three parts, as shown in Figure 2.1. The main centers of settlement are in the Mittelland, which has 59% of the country's population. There are also many large urban centers in adjacent countries which are within a day's drive of the Swiss Alps. These include about three-quarters of Switzerland's area, and have 25% of the population and 62% of the total forest area (Combe and Frei, 1986). As discussed in Chapter three, the area of mountain forests has been significantly diminished by human activities. One of the greatest changes is that timberline was lowered by 200-300 m (Langenegger, 1984); some high valleys were completely deforested.

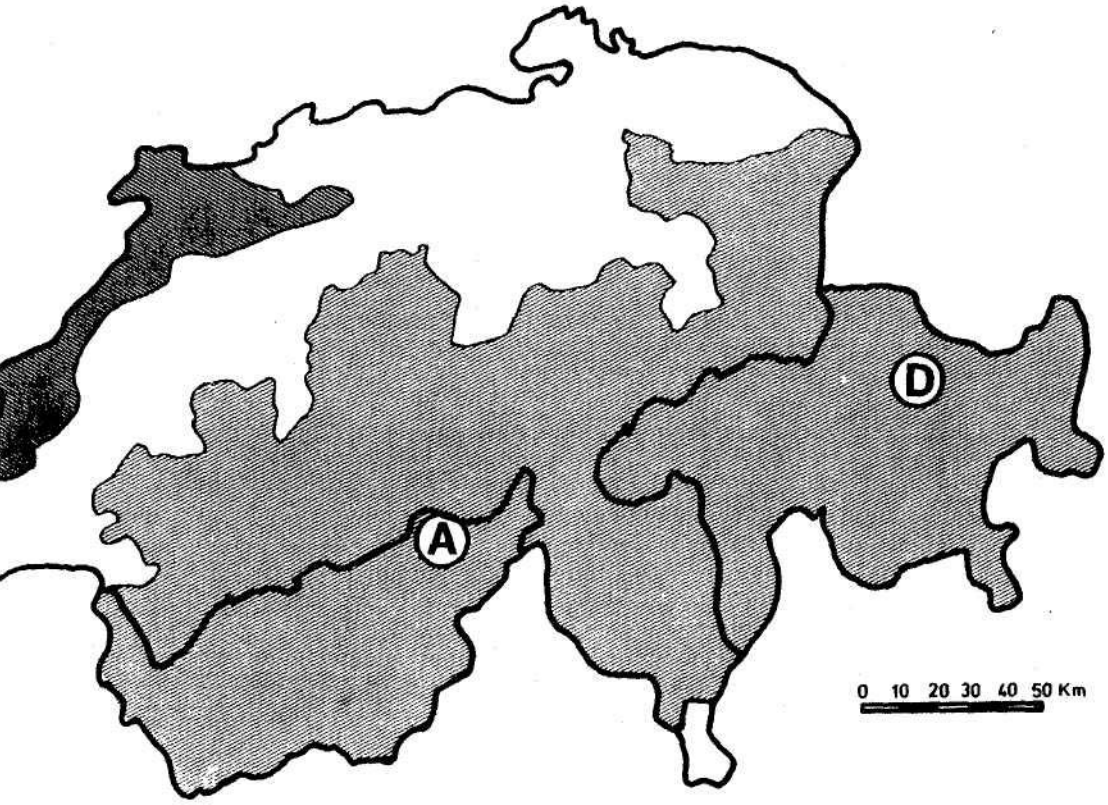
Of the 735,311 ha of forest in the Alps, 72% is owned by Communes, 4% by other public bodies, and 24% by private individuals and organizations (BFL/BFS, 1985). It is important to distinguish between the civil Communes (Burqergemeinden) and the political communes (Burgergemeinden), which have identical names. and boundaries. The members of the former are families who have centuries-old rights to the forests, and may not even live in the area. The political commune includes all Swiss citizens who live in the area, and is responsible for local taxation, regulation, and the maintenance of community facilities, including hiking trails. In general, taxes or other income collected by the political commune are not invested in forest management, since the political commune's members derive no direct benefit from the forests unless they are members of the civil Commune.

2.1.1 Ecology and distribution of forest species.

The ecology and distribution of Switzerland's forest tree species have recently been summarized by Leibundgut (1984), which is the source used below except where others are cited. Only four major tree species occur in the study areas. Spruce *(Picea abies)* is the commonest, as throughout the Swiss Alps; the others are larch *(Larix decidua)*, arve (cf. cembran or Arolla pine: *Pinus cembra)* and pine *(Pinus montana)* . Larch is the only deciduous species,

but it has needles, rather than leaves. Other deciduous tree species occur at low elevations and as bushes in avalanche paths. The dominance of spruce in the Swiss Alps is natural, but has probably been maintained by the lack of seed sources for other species, resulting from the high levels of logging which persisted until the end of the last century, as discussed in Chapters three and five, and its competitiveness.

Some comparisons between the major tree species are shown in Table 2.1. The species vary greatly in their requirements for light and water. Particularly important is the difference between



2.1: Switzerland; topographical divisions and study areas

hading = Jura, Unshaded = Mittelland, Light shading = Alps.
etsch study area, D = Davos study area. Also shown are the
ries of Canton Valais and Canton Graubünden.

TABLE 2.1

SWISS ALPINE FOREST TREES

	Larch	Pine	Spruce	Arve
Light requirement	Medium	Very high	High	Medium
Drought susceptibility	High	Medium	Low	High
Potential growth rate	Low	High	Medium	High
Preferred soil type	Iron Podsol	Brown Earth, Iron Podsol	None	Podsolic Brown Earth, Iron Podsol
Upper limit	2400 m	2300 m	2400 m	2200 m

Source: Leibundgut (1984)

spruce and larch, the two commonest species. Larch cannot easily become established in spruce stands because of its high light requirement. However, it can survive the drier soil conditions which exist outside existing forest stands, and tends to prefer slightly less acidic soils than spruce; these are also often found on drier sites. The upper limit shown is for upright trees, and varies significantly with aspect and climatic conditions. However, larch and arve tend to be the timberline trees, often growing together. The latter's distribution was most affected by the anthropogenic lowering of timberline; it does not become established in spruce stands because of its slow growth rate.

The growth of spruce trees is strongly dependent on the amount of light that reaches them. Maximum height can be reached in 60-80 years on low-quality unshaded sites; but in dense stands, trees may only be 2-3 m high after 100 years. However, when released, such trees can begin to grow rapidly. In most stands where spruce occurs, it is dominant; commonly monospecific. Of the four major species, spruce is generally the most susceptible to climatic, biological, and physical hazards. Pure spruce stands are inherently unstable (Mayer, 1976). The susceptibility to climatic hazards is particularly great because of its shallow-rooted habit; both wind and heavy snowfalls can bring down dense stands of thin trees or individual large trees. Drought can lead to cracking, which can penetrate to the heartwood. Roots and trunks are easily damaged, permitting secondary fungal infection and insect infestation.

The commonest fungal infection is red ring rot (*Trametes radiciperda)*, affecting both trunk and roots; *Armlllaria mellea* is particularly common in pole-sized stands. The most serious insect pest is the bark beetle *Ips typographus,* which attacks trees weakened by drought. Infestations begin in mature trees and spread to smaller trees while conditions remain suitable. Finally, spruce needles are is susceptible to various fungi (e.g., *Herpotrichia juniperi, Phacidium infestans)*, especially during periods of long snow cover. These particularly affect young trees and are one of the primary limitations to the establishment of trees above the current timberline and in plantations.

Larch is the most successful of the four major species in becoming established at timberline (Schonenberger, 1975). It develops a deep root system, which permits high rates of transpiration in the summer and relatively fast growth. Its plasticity also allows it to become established in avalanche paths; though it can be broken by heavy snowfalls or avalanches. However, larch is the most frequently browsed species, particularly in winter, by game animals and birds. Insect pests are rarely fatal, though infestations of the larch leaf roller *(Zelraphera diniana)* can lead to severe defoliation for a season or two. The only significant fungal infection is a canker (*Lachnellula willkommii),* which is typically a secondary infection after frost damage.

Like larch trees, pine trees can become established in avalanche paths, where they assume a bushy form. Pine can grow on very poo: sites, but much more slowly than spruce. Monospecific stands are not uncommon, though it also occurs with spruce. The main hazard; which affect it are fungi, which mainly attack trees in plantations and avalanche paths during winter (*Phacidium infestans, Herpotrichia juniperi, H. coulteri)*, and also needles,

Arve survives best on west- and north-facing slopes, its long roots permitting it to grow on moist, nutrient-poor soils with a thick raw humus layer. Of the four major species, it grows the slowest, but also the longest: 1000-year old trees have been found. One of the limits to its spread are that its seeds are large, and are eaten by the spruce jay *(Nucifraga caryocatactes),* The main physical hazard which affects it is avalanches. Biological hazards are of little importance except in plantations, where young trees are often damaged or killed by the fungus *Crumenula abietina* and the moth *Ocnerostoma copiosella.*

2.2 Aletsch study area

2.2.1 Physical setting

The study area is on the north side of the deeply-cut glacial valley of the Rhone in the Canton of Valais (Wallis), and falls within the boundaries of 12 communes, many of which reach from the valley floor to the alpine zone (Figure 2.2). The main valley settlements are located where the valley floor is locally widened. The south to southeast slopes of the area are generally quite steep - the average slope angle between Morel (760 m) and Riederalp (1900m) is 50% - and are dissected by deep stream valleys. The majority of the permanent settlements in the area are on "sun-slopes", at flatter sites with altitudes from 1170 to 1360 m. Above 1900 m is the flatter alp zone and the tourist settlements of Riederalp and Bettmeralp. Above this rises a steep and often rocky ridge, culminating in the summits of the Riederhorn (2230 m) and the Eggishorn (2926 m). Northwest of this ridge is the steep slope covered by the Aletschwald and, below this, the Aletsch glacier.

The soils of the area have developed on morainal deposits. These were created by the Rhone glacier from the underlying silicate rocks during the last ice age, which ended about 10,000 years ago (Krause, 1982). The upper limit of glaciation is 2670 m (Baumgartner, 1977), i.e., all of the area was glaciated. On unforested slopes at the lowest altitudes of the area (up to a maximum altitude of 1600 m) are phaeozems, typical of dry inner-alpine valleys. Under forests up to this limit are brown earths. Above these, generally up to 1900 m, are dystric cambisols or rendzinas (depending on parent material), occurring under all vegetation types. These soils occur as high as 2200 m on low-angle slopes. At higher altitudes, soils are podsolized, with dystric cambisols recognized up to 2000 m and podsols above; podzolisation is greatest under coniferous forest and on north- rather than south-facing slopes.

2.2.2 Climate

The climate of the area is typical of its position in an inner-alpine valley, protected by two major mountain ranges - the Bernese and Valais Alps. This continental climate is characterized by warm, dry summer months and extreme yearly and diurnal temperature fluctuations. There are few meteorological stations in the Valais, so that most of the data presented below are interpolations or estimates, based on Bouet (1978), Mattig et al. (1980), and Primault and Catzeflis (1966).

Precipitation

Annual precipitation is directly related to altitude. The averages for the slope settlements are probably 800-1000 mm. The frequency of summer rain and thunderstorms is low compared to

Figure 2.2: Aletsch study area

other parts of the Swiss Alps, since the high mountain ranges act to impede the penetration of warm moist air. The precipitation maximum is in November, when the south-moving polar front, associated with strong west winds, crosses the area. A second maximum occurs in March and April, and minima occur in July and September. The proportion of snow and length of snowcover increase with altitude, respectively from 25% and 85 days at 1000 m to 39% and 130 days at 1500 m, and 52% and 200 days at 2000 m.

Thermal regime

Levels of insolation on the south slopes are high, resulting in strong warming during the day, particularly in summer but also in spring and fall. Nocturnal re-radiation is also high, leading to large diurnal temperature changes, associated with a high frost frequency in the spring. Estimated mean monthly temperatures at the slope settlements (1250 m) vary from 13.8°C in July to -3.9°C in December, with a yearly average of 3.7°C. Average monthly values for relative humidity vary little at stations along the Rhone valley, with around 65% in summer and 80% in winter. However, daily fluctuations in summer are large, from 90% in the early morning to 40-50% in the afternoon.

The area is characterized by a mountain-valley wind system. During good weather conditions (high or stable pressure), wind directions change twice daily as a result of the large altitude and temperature differences, with mountain winds at night and the stronger valley winds during the day. Less frequent are two large-scale wind systems: the west wind, generally associated with rain; and the easterly fohn (Lombarde), which usually occurs above 1000 m. The percentage of calm periods is inversely related to altitude. Ground-level inversions are relatively rare, so that the annual frequency of valley fog, up to 100 m, averages 5-10 days. On the south side, up to 1500 m, there is occasional slope fog, associated with inversions. Annual averages are 15 days with lasting fog, 60 days with quick dissipation.

2.2.3 History: demography, economy, and transportation

The history of the Aletsch area is summarized by Mattig and Zeiter (1984); the discussion in this section is based on this source unless others are cited. Until the middle of this century, the economy of the area was based on primary activities. The land use pattern was typical of such areas, including three zones (Messerli et al., 1980). The lowest of these was the Heimquter: the valley floor, with permanent settlements, such as Morel, Lax, and Fiesch, surrounded by fields and winter pastures. Above this was the subalpine Maiensass, with irrigated pastures and fields and periodically-inhabited settlements. The highest level was the Alp, with summer pastures and buildings used only during the summer grazing season; for instance, Bettmeralp and Riederalp. These complementary zones were used in the typical pattern of transhumance, with farming in the lower two zones, and domestic

animals moving from the valley to the Alp for the summer. While the economy primarily depended on primary activities, the limited resource base of the area was reflected in relatively small changes in the population (Figure 2.3).

Limited summer tourism began in the 1850s, when guest houses were built for visiting naturalists and mountaineers at Riederalp and at the foot of the Eggishorn. In the 1860s, small hotels were built in the valley settlements of Morel and Fiesch, which was a relay station on the post road along the Rhone valley. These facilities were expanded from the 1880s to the beginning of the First World War, in response to increasing demand, mainly from foreign guests. However, access to the area remained limited until 1915, when the Furka-Oberalp railway was opened. In spite of this improved access, the economic importance of tourism did not increase greatly in the inter-war period since, as in much of Switzerland, demand remained at low and fluctuating levels. Access was further improved by the construction of the highway along the Rhone valley, completed in 1955.

As late as 1950, the primary sector accounted for over half of the employment in the area as a whole (Figure 2.4) and in the upper settlements. However, the secondary and tertiary sectors accounted for over half of the employment in the valley settlements. From 1950 onwards, the basis of the area's economy changed rapidly from primary activities to tourism. The impetus to this change was the construction of cable-cars to the alpine terrace: to Riederalp in 1950 and Bettmeralp in 1951, with capacities of eight and four people respectively. In 1954, another 4-person cable-car system was built to Riederalp, and the! Bettmeralp system was upgraded to 10 people in 1957. During the 1950s, accommodation at the two new resorts increased 130%, from 622 to 1440 beds, while accommodation in the valley settlements only increased by only 20%, to 657. The reason for this rapid change was the development of the skiing industry; the first lifts at Riederalp were built in 1951, the first at Bettmeralp in 1954. However, summer remained the principal tourist season.

During the 1960s, both the demand for tourism and the facilities related to it continued to grow rapidly. By 1970, there were 3904 beds at the alpine resorts: an increase of 170% over 1960. The capacity of the cable-cars was upgraded from 22 to 73 passengers. There was a great increase in the capacity of the ski lifts (Figure 2.5) and, in 1971, the number of winter guests first exceeded the number of summer guests. In the valley, although accommodation in the valley had increased to 2337 in 1970, a decadal increase of 255%, summer remained the primary season. Significant demographic and economic changes occurred during the 1960s: the population grew by 5% after two decades of decline and, while the proportion of employment in the primary sector halved, that in the service sector almost doubled.

Tourism's dominance in the economy has continued to grow although, since the mid-1970s, rates of increase in the number of

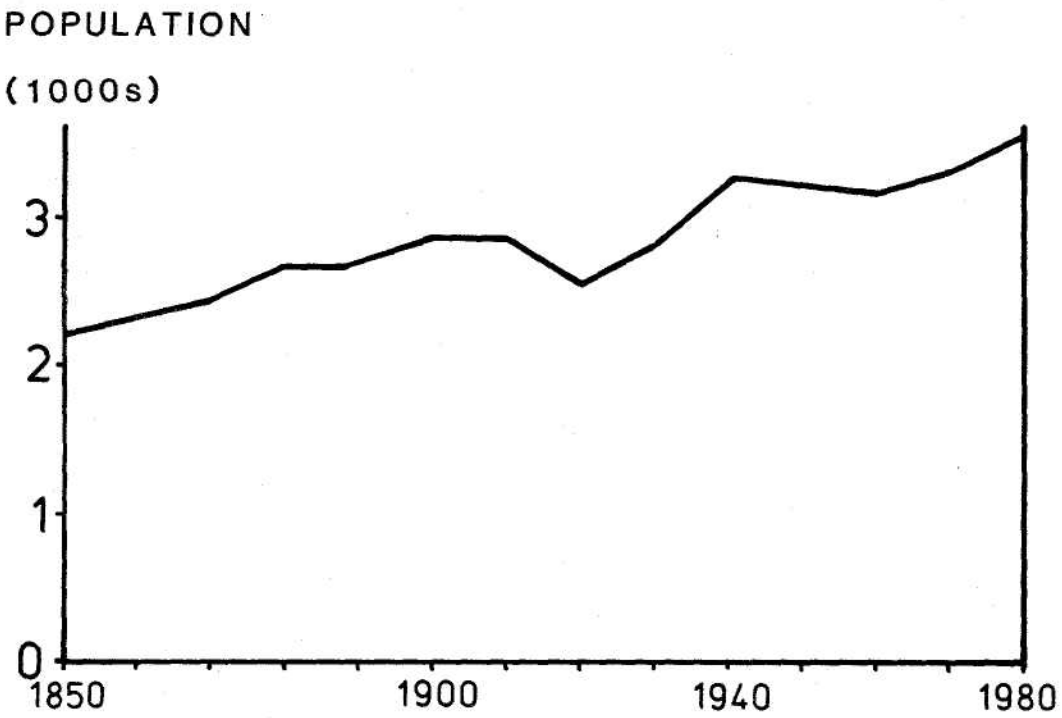


Figure 2.3: Aletsch study area: population 1850 - 1980

Sources: Census documents

winter visitors have slowed and numbers of summer visitors have remained almost static. In the 1970s, the accommodation capacity of the area doubled, though with greater increases in the valley settlements than the resorts. However, access to the two resorts was greatly improved: by 1975, the transport capacity of gondolas and cable-cars had increased to 220 passengers at one time. The growing importance of winter tourism is shown by increases of winter passengers of 79% from 1970 to 1975, and 56% from 1975 to 1980; numbers of summer passengers increased by only 38% and 24% respectively. The capacity and number of ski lifts continued to expand during the 1970s. By 1980, the service sector dominated employment though, with continued construction, the secondary sector was still strong, providing 33% of employment. The primary sector accounted for only 13% of employment; although it must be realized that many people work in both agriculture and tourism.

The area's economy is now clearly based on tourism. The Alp, with its ski lifts, hotels, and chalets, is now the dominant zone, in contrast to the integrated land-use system that persisted until the middle of this century. In particular, the meadows and pastures of the Maiensass are no longer ploughed or grazed, and the emphasis of the remaining farmers of valley settlements has changed from mixed farming to market-oriented cattle-breeding (Messerli et al., 1980). As discussed in Chapter five, the local people hardly use the forests any more; and they are little used for recreation in either summer or winter, since the terrain is steep, there are few skiing trails, and hiking trails are often badly maintained. Most hiking takes place above timberline or in the valley; no absolute data on use levels are available. The valley settlements have grown substantially in area, but without great population growth; most of the new construction has provided second homes and condomiminiums for short-term visitors,

2.2.4 Forest ownership patterns

The ownership of the forests is mainly public: 72% of the forested area of 2452 ha belongs to 11 civil Communes (Burqerqemeinden), with holdings from 44 to 372 ha. The ownership situation is complicated by the fact that seven of the Communes own parcels of forest within the legal boundaries of another Commune. Of the forests in private ownership, 19% of the area is owned by individuals, and 2% belongs to a private corporation. About a quarter of the private forest consists of coppices. For 7% of the forest area, ownership could not be determined (Bellwald and Graf, 1985). The proportion of private ownership is higher than for Valais as a whole: 8% (BFL/BFS, 1985).

2.3 Davos study area

2.3.1 Physical setting

The study area (Figure 2.6) comprises the Landwasser, Dischma, Fliiela, and Sertig valleys (Taler) in the Biindner Alps of the Canton of Graubunden (Grisons). The Landwaasertal is oriented NE-SW, with a flat valley bottom (average elevation of 1600 m) on which the principal tourist settlement of Davos (-Dorf and -Platz) and smaller settlements are located. At the east end of this main valley is the Wolfgang Pass (1631 m). The three side valleys, oriented NW-SE, enter on the SE side of the Landwaasertal, and contain small farming settlements. The sides of both the main and side valleys are steep, becoming flatter at c. 2000 m at the edge of the Alp. zone. Of the forested area, only 20% has slope angles below 40%; 42% has angles from 41-60%, and 38% over 60%, i.e., potential avalanche starting zone (Teufen, 1985). Above this is the rocky alpine zone, culminating in summits from 2500 to 3146 m.

The geology of the area is very complex, so that there is a great variety of soil parent materials. These have been further mixed by glacial action; some small remnant glaciers remain at the upper ends of the side valleys, but the main period of glaciation ended about 10,000 years ago. With the exception of some soils which have developed on deposits derived from serpentine or limestone, soils are acidic. Most soils are <50 cm in depth, permeable, and have a high rock content. The soils of the valley bottom are mainly brown earths. Valley-side soils are principally podsols, in various stages of development. On dry, warm slopes, Podsolization is less, and the organic content of the soil is greater; i.e., humic, rather than iron, podsols develop. In the alp zone are cambisols, with regosols above, in the alpine zone (Krause, 1986).

2.2.2 Climate

The area lies at the divide between the damp northern and dry central Alps, and has a temperate central alpine or continental climate with generally clear skies, low relative humidity and little wind (Moser, 1985). Climatic data have been collected at Davos-Platz (1561 m), Schatzalp (1872 m), and the Weissfluhjoch (2540 m) throughout this century (Grunder, 1984). However, most published data has been concerned with snow cover and avalanches (Walder, 1983).

Precipitation

Average annual precipitation is 1037 mm at Davos-Platz, and 1224 mm at the Weissfluhjoch. There is a clear summer maximum: July and August are the wettest months. From October to April, at least 85% of precipitation in Davos is snow; snow cover lasts, on average, 160 days from mid-November to late April (Jorger, 1984).

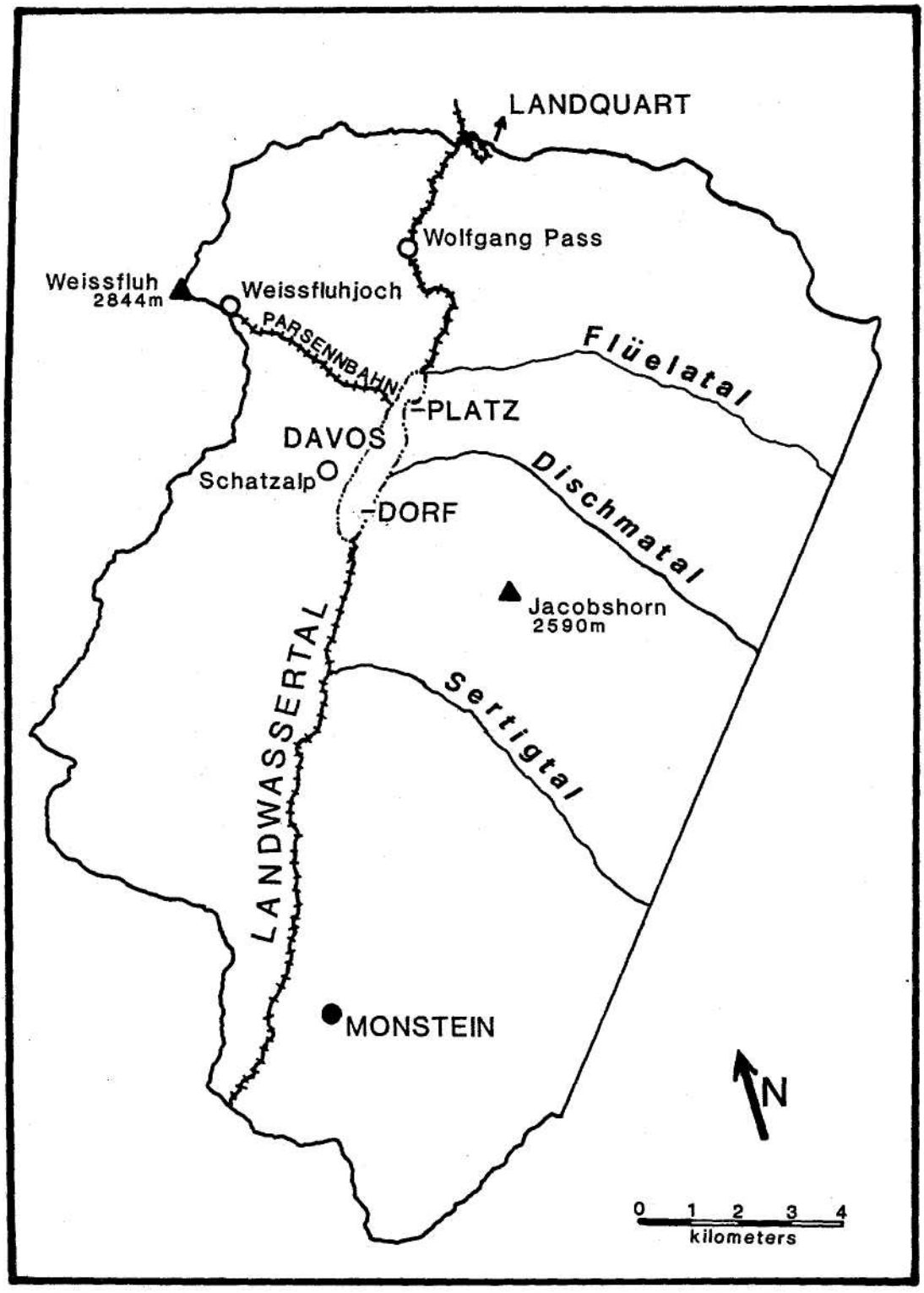


Figure 2.6: Davos study area

Thermal regime

The coldest month is January, with an mean temperature of -7°C at Davos-Platz (average minimum -21°C). In July, the hottest month, the mean temperature is 12°C (average maximum 24°C>. At the Weissfluhjoch, respective mean temperatures are -9 and 5°C. Frost can occur in Davos-Platz in any month of the year (192 frost-days); fluctuations across the freezing-point occur on 132 days, thus encouraging physical weathering. Inversions are common, particularly in winter, as shown by the small difference in January mean temperatures from 1561 to 2540 m, and the fact that the mean monthly temperatures at Schatzalp are higher than in Davos-Platz from November to February (Moser, 1985). In summer, a strong mountain-valley wind system develops under the typical clear weather conditions, so that inversions are less frequent; the mean annual temperature at Schatzalp (2.4°C) is lower than in Davos-Platz (2.8°C). Mountain-valley winds also occur in the Dischmatal and between the side and main valleys.

2.3.3 History: demography, economy, transportation

The documented history of the Davos area (Pfister, 1978) goes back to the late twelfth century, when the area was settled by people migrating from the German-speaking part of Valais. The area was cleared and divided into 14 farming settlements (Einzelhofe), each with its own fields, pastures, and forest. This initial division of land remained in existence until the mid-nineteenth century. From the mid-seventeenth century, the forests were allotted among the members of each Einzelhof, and further divided through inheritance. However, fields and pastures remained in the hands of private cooperatives (Alp- and Weidqenossenschaften) (Gunter 1980; Keller and Kneubiihl, 1982).

From the fourteenth century, mining also contributed to the economy of Davos and the development of trade routes over the passes into the valley. The first mining boom, mainly for iron, occurred from the mid- to late sixteenth century, with 39 mines in operation (Pfister, 1978). Although the boom ended by the beginning of the seventeenth century, Davos was quite a wealthy community in the eighteenth century, its economy based on both agriculture and trade. However, by the beginning of the nineteenth century, the agricultural sector was declining, and much of the traffic on which the community depended had been diverted elsewhere; access was only possible on horseback or foot (Bernard, 1878). However, the early nineteenth century was also marked by a resurgence of mining for lead and zinc. A zinc smelter was completed in 1816; the boom lasted until 1848 (J6rger, 1984).

Tourists began to come to the area from the early nineteenth century, but not in any number until 1859, when a carriage road was completed to Landquart, in the Rhine valley. Most of the first visitors came to improve their health; Davos became known early as

a health resort for people with rheumatism and tuberculosis (Bernard, 1978). The first hotels and sanatoria were built in the 1860s, and there was a construction boom in the 1870s in spite of the European economic depression. People did not only come for their health, however; facilities for various winter sports were developed from 1869 onwards. Also, many guests decided to stay: by 1887, 40% of the population were foreigners (Keller and Kneubuhl, 1982). The 1870s and 1880s were a period of great population growth: from 2002 in 1870 to 3891 in 1888 (Figure 2.7).

In 1890, a railway was completed from Landquart to Davos. This led to further development of the tourist industry; between 1886 and 1900, the number of beds more than doubled, from 1000 to 2100 (Bernard, 1978). The industry was based not only on cures, but also a wide variety of summer and winter sports. The population continued to grow rapidly: to 8,089 in 1900 and 9,905 in 1910, when 48% were foreigners. The development of the tourist industry had significant effects on agriculture. From 1850 to 1900, the number of farming enterprises decreased from 310 to 200. This was related not only to the opportunities for employment in tourism and the need for building land, which increased land prices, but also to the requirement of the sanatorias' patients for large volumes of milk. This resulted in a change of agricultural emphasis from cattle-breeding and arable farming to more intensive dairying (Keller and Kneubuhl, 1982). Thus, while the primary sector dominated employment until the 1880s, by 1900 employment in agriculture was only slightly more important than that in the service sector. The sectoral distribution of employment from 1888 is shown in Figure 2.8.

The tourist industry continued to grow rapidly until the beginning of the First World War; by 1915, 4,100 beds were available (Bernard, 1978). However, after three decades of increases, the number of visitors decreased after the high point of 1.1 million in 1913; this level was not reached again until 1923. During the inter-war years, tourism remained dominant in the economy although the number of visitors fluctuated greatly. Winter sports became increasingly important, especially after the Parsenn railway was opened in 1931 and the first ski-lift in 1934. Yet the inter-war years were characterized by slow growth, and even decreases in population, particularly in the late 1930s, when the unstable international situation and the onset on the Second World War led to a severe decline in the demand for tourism. This was also reflected in the proportion of employment in the different sectors: between 1930 and 1941, the service sector dropped from 52% to 43%, while the primary sector rose from 11% to 16%. The 1941 proportions were almost identical to those in 1920.

Soon after the Second World War began, Davos experienced a rising demand for accommodation for refugees, the wounded, and even tourists. In 1947, there were two million visitors and, for the first time since 1926, 70% of the available accommodation capacity was used. In the late 1940s and 1950s, demand again declined, to a low of 1.4 million in 1957, due to restrictions on the travel of

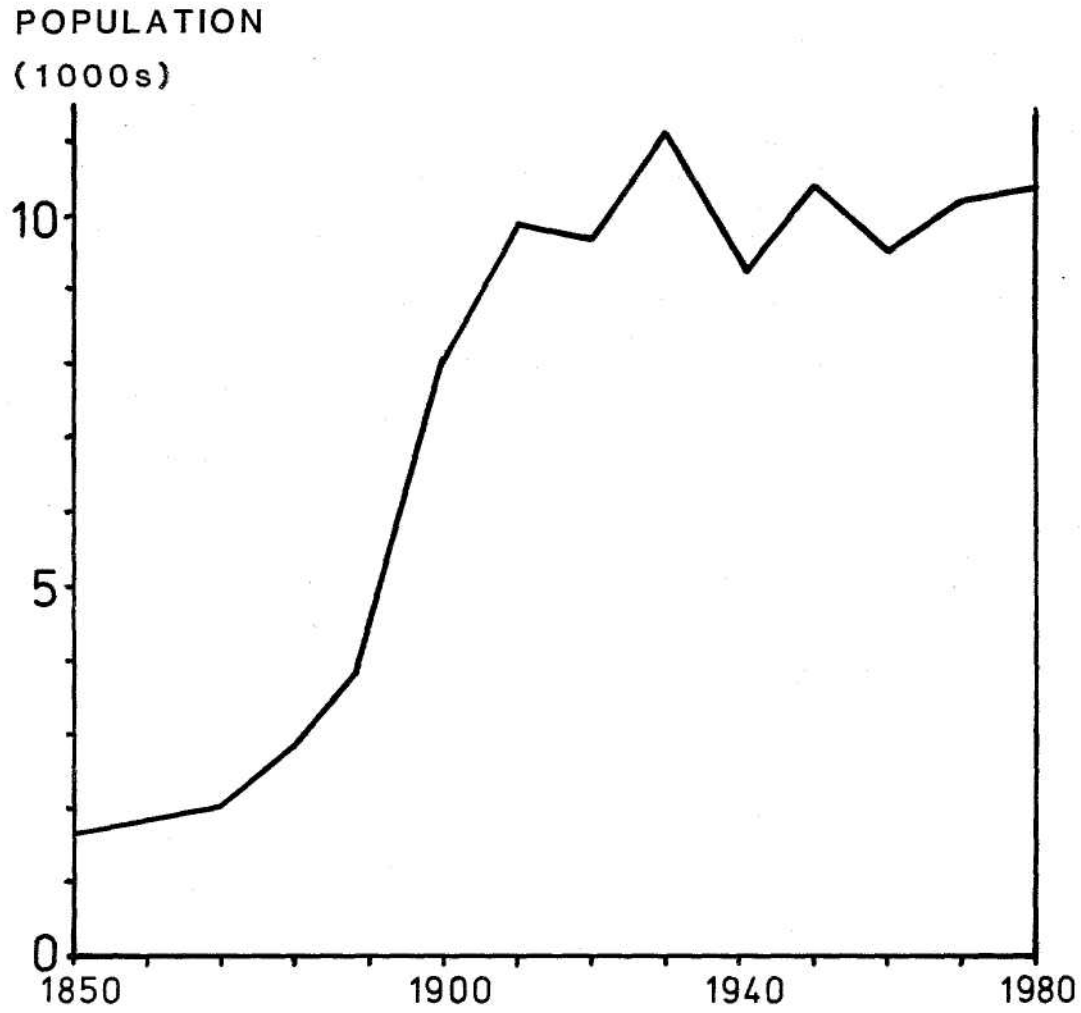


Figure 2.7: Davos study area: population 1850 - 1980

Sources: Census documents

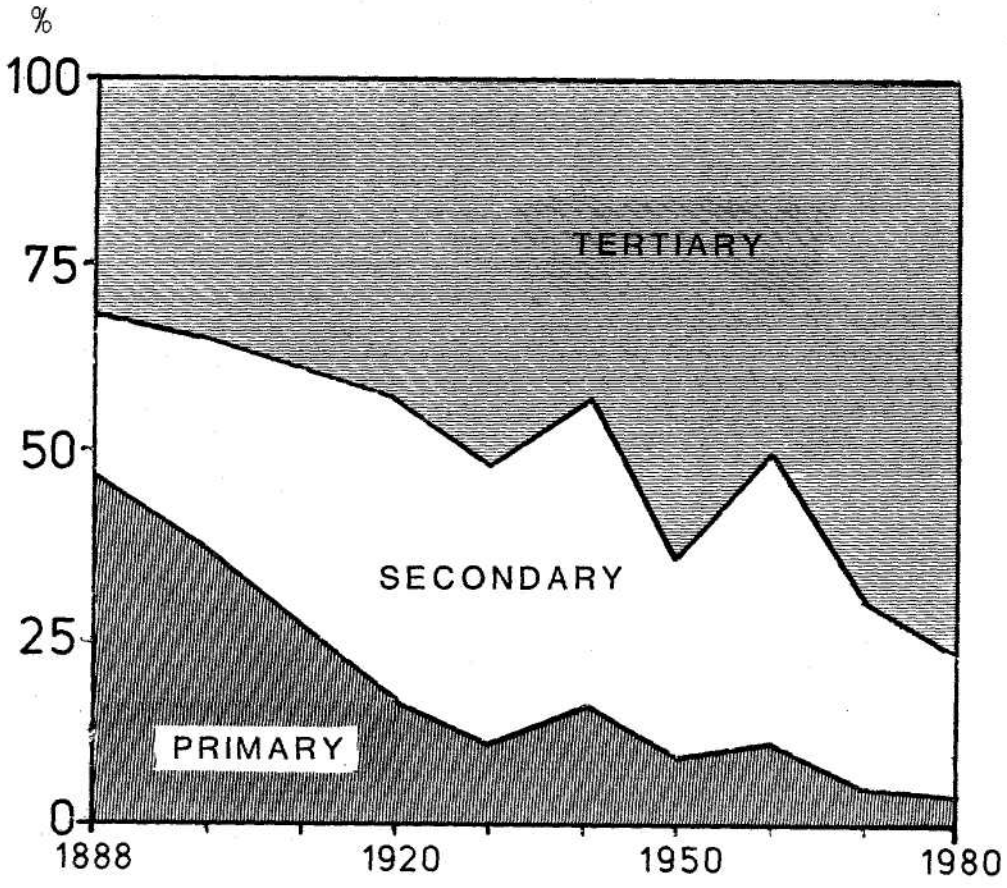


Figure 2.8: Davos study area: employment structure 1888 - 1980

Sources: Census documents

potential foreign guests and the introduction of chemotherapy as a cure for tuberculosis. During this period, the sanatoria were converted to "sport-hotels", and a period of expansion of both downhill skiing facilities (Figure 2.9) and accommodation began, lasting into the mid-1970s. Nevertheless, the downturn in the economy in the 1950s led to an overall decrease in the population. From 1957, numbers of visitors increased until 1973 (2.5 million). Since the 1950s, winter has been the primary season, with between 63% and 72% of the total number of visitors.

Changes in population and employment since 1960 reflect the changing demand for tourism in what is now an important international commercial and conference center, as well as the largest tourist resort in the Swiss Alps, with 2.4 to 2.6 million visitors a year in the 1980s. While the population grew by 7% between 1960 and 1970, growth in the 1970s almost stopped after the demand for tourism declined after its peak in 1973. In general, the service sector has continued to expand its dominance of the economy. However, employment in the secondary sector during the construction boom of the late 1950s and early 1960s rose more rapidly than that in the service sector, to 39% in 1960; the proportion decreased to 25% by 1970. The expansion of a service economy has continued to strongly affect the agricultural sector. Until 1960, this sector accounted for about 8% of employment; by 1980, the proportion had declined to 4%. There is continued pressure for the development of the remaining agricultural land, which is still principally used by dairying operations, which have rapidly decreased in number since the mid-1950s. Host farmers also work in the tourist industry, which is often the primary source of income.

2.3.4 Forest ownership patterns

Over three-quarters (77%) of the 4485 ha of forests is owned by private individuals. Each owner usually has two or three parcels, with an average size of 3 ha each. Another 7% of the forests are owned by private corporations, including 35 cooperatives (Alp-, Atzunqs-, and Waldqenossenschaften). Only 16% of the forest area, mainly at the south end of the main valley, is publicly-owned. The proportion of public forest has increased during this century, as small areas of private forest were expropriated by the Commune, mainly to provide protection against avalanches. The preponderance of private ownership is atypical for Graubunden, in which 92% of the total forest area is publicly-owned (Gunter, 1980; Teufen, 1985). As discussed in Chapter four, both public and private forests have been under unified management since 1984.

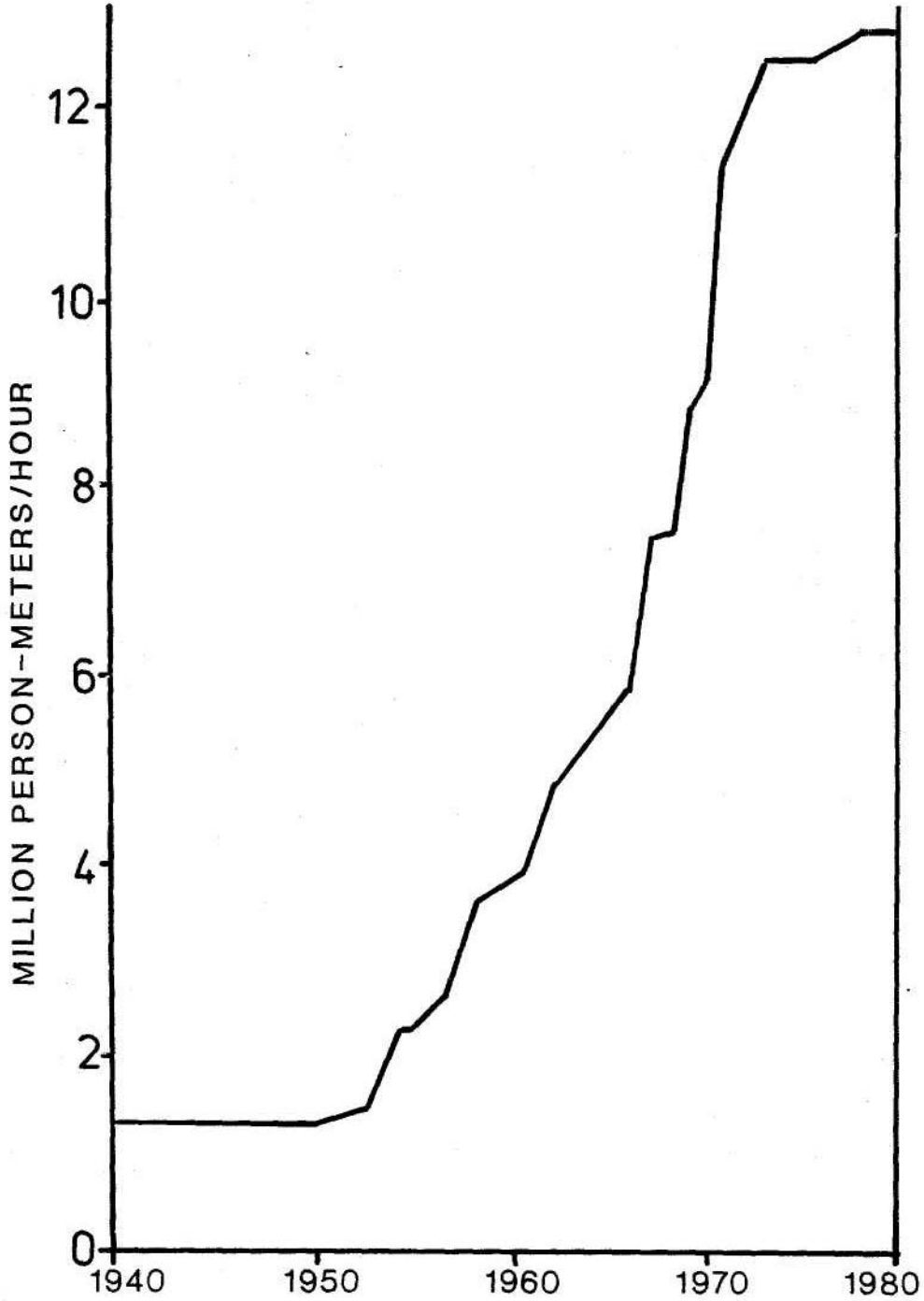


Figure 2.9: Davos study area: ski lift capacity 1940 - 1980

Source: Keller and Kneubühl (1982): Page 89

2.4 Colorado Rockies

Colorado can be topographically divided into three parts, as shown in Figure 2.10. The main centers of settlement are on the west edge of the plains, along the east edge of the Front Range of the Rocky Mountains. About 80% of the state's population live in this narrow corridor. The Rockies include about 35% of the state's area and most of the forested land (Erickson and Smith, 1985). Of the 8,694,800 ha of forested land, 48% is part of the National Forest System; 24% is administered by other federal or state agencies; and 28% is in private ownership (Benson and Green, 1987: 3). This study primarily considers the forested land which is under federal jurisdiction within the National Forest System.

2.4.1 Ecology and distribution of forest species

Colorado's mountain forests, as described by Peet (1981: 9) "can best be described as disturbance phenomena. Owing to the agencies of fire, wind and insect attack, these forests are periodically destroyed in a patchwork manner. . . . Before European settlement. . ., fire was by far the most important form of disturbance. . . . it is inappropriate to ask whether a particular forest has burned; one should ask when it last burned and what the nature of the fire was."

The distribution of tree species in the study areas is therefore highly dependent on their fire histories; as discussed in the following chapters, the period since European settlement has been marked by eras of both high and low fire frequency resulting from human activities. Seven major tree species occur in the study areas. One of these is deciduous: aspen *(Populus tremuloides);* the rest are coniferous: lodgepole pine *(Pinus contorta),* ponderosa pine *(Pinus ponderosa)* , douglas fir *(Pseudotsuga menziesii),* engelmann spruce *(Picea engelmannii),* subalpine fir *(Abies lasiocarpa)* , and limber pine *(Pinus flexilis)* . The following description of the species concentrates on their interactions with fire and other disturbance factors.

2.4.1.1 Aspen

Aspen occurs both as a dominant species in seral and climax stands, and as a successional species after fire, being replaced by conifers. The speed of replacement is highly variable: from within one generation to 1,000 fire-free years (Johnston and Hendzel, 1985). Aspen is found from the plains to the upper subalpine, i.e., from 1,700 to 3,650 m (Daubenmire, 1943; Greene, 1971; Schneider, 1909; Sudworth, 1934). The lower limit is defined by the availability of water needed to satisfy the species' heavy evapotranspirational demands; the upper limit by wind and factors which shorten the growing season (Jones and DeByle, 1985a). The relative infrequency of fires and competition

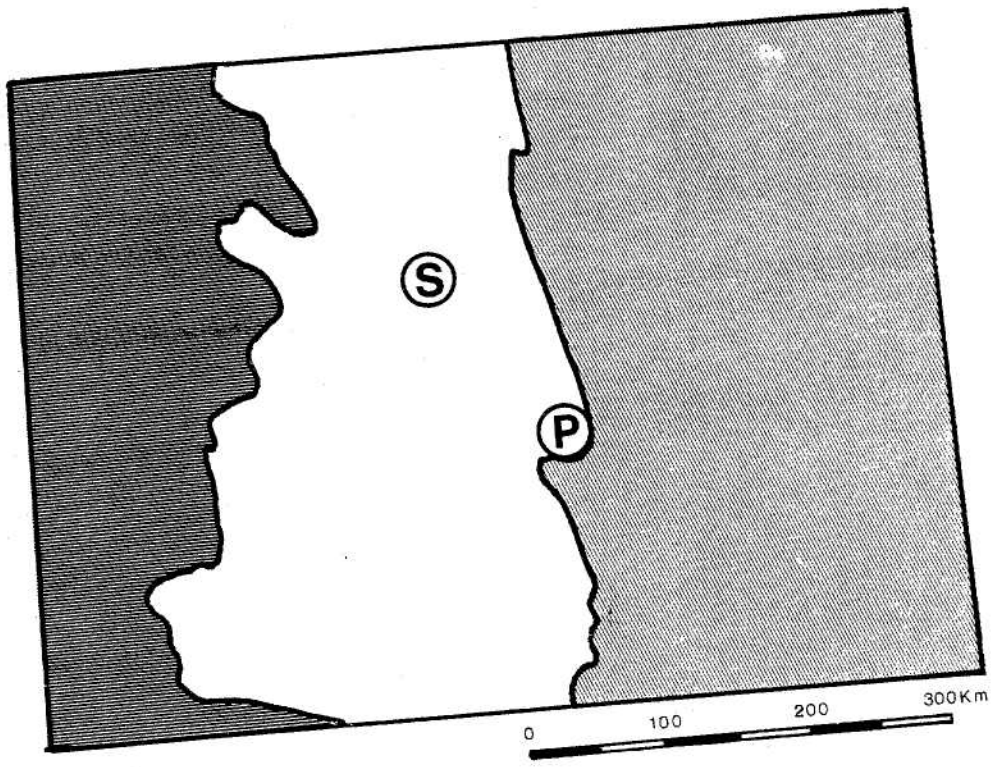


Figure 2.10: Colorado: topographic divisions and study areas

Dark shading = Colorado Plateau, Unshaded = Rockies, Light shading = Plains. P = Pikes Peak study area, S = Summit study area.

from conifers are additional factors at the upper limit (Jones et al., 1985a); the species' abundance in Colorado is directly related to the past frequency of fires.

Aspen differs from the coniferous species not only by being deciduous, but also because it rarely reproduces from seed (McDonough, 1985). Reproduction after fire or logging is primarily vegetative, resulting in the characteristic clonal habit (Barnes, 1966). Each clone covers 2-3 acres or more and is composed of stems with a typical life expectancy of 50-70 years, and a maximum age of about 150 years (Johnston and Hendzel, 1985; Mitton and Grant, 1980). There is a marked difference between the fire resistance of the clone and individual stems. The latter are easily killed by fire and, if not killed, are usually infected by fungi through basal scars (Davidson et al., 1959). In contrast, a clone can live through many fires, perpetuated by suckering from roots; suckers can be produced as much as 1 m below the soil surface (Schier and Campbell, 1979). The species' clonal habit and its intolerance of shade lead to a predominance of even-aged single-storied stands, in which almost all the trees originated during a period of four years or less (Baker, 1925).

Aspen is attacked by many diseases, though few kill or seriously injure trees. A clone's susceptibility increases as stems mature and growth slows. Trunk cankers are the most serious form of disease. These are caused by fungi which attack even previously undamaged trees; the effects are even greater on trees damaged by logging or natural causes. Fungi also cause trunk, butt, and root rot where the tree has been damaged (Hinds, 1985). Aspen is attacked by many insects, particularly the defoliating western tent caterpillar, *Malacosoma californicum;* successive years of infestation can markedly decrease growth and kill trees over large areas. Trees can also be damaged and killed by various boring insects (mainly beetles), which also provide access for pathogens (Jones et al., 1985b).

Animals have various effects on aspen (DeByle, 1985). Browsing by wild and domesticated ungulates can limit sucker regeneration and prevent sapling growth. However, because of the large initial number of stems, dense even-aged stands can withstand considerable stem loss in the years following disturbance. Furthermore, selective browsing of competing species, such as subalpine fir, can favor aspen. Elk generally have greater effects than deer, particularly during winter, not only browsing, but also chewing the bark off large trees. Other animals also affect aspen by eating bark, leaves, and buds, providing access for pathogens.

2.4.1.2 Lodgepole pine

Lodgepole pine is the principal post-fire successional conifer in much of Colorado. It is highly intolerant of shade and, in the absence of fire, is usually succeeded by engelmann spruce or subalpine fir at higher elevations, and douglas fir at lower

elevations. Replacement can take from 50 to 200 years, depending on the site and the density of other species in the understory; the period is decreased when mountain pine beetles kill the older trees, as discussed below. Climax stands probably develop only where repeated fires have eliminated seed sources for other species; or because adverse site conditions, such as very infertile soil, will not permit other species to survive (Moir, 1969; Pfister and Daubenmire, 1975; Tackle, 1961).

Lodgepole pine is found from the plains to the upper subalpine, i.e., from 2,130 to 3,500 m (Knowles, 1980). It can grow on soils' developed on most substrates, but is sensitive to moisture availability, requiring more than douglas fir or ponderosa pine and less than engelmann spruce or subalpine fir (Lotan and Perry) 1983) . However, the principal factor determining its distribution is fire. While the trees have thin bark and thus are quite easily killed by fire, the species perpetuates itself by its serotinous cones, whose scales are bound by a resin that melts at 45°C (Clements, 1910). Serotiny is variable between trees, tending to decrease with increasing elevation and decreasing fire frequency (Perry and Lotan, 1979); serotiny does not occur in trees <30 years old (Lotan, 1975). The species' success on recently-burned sites also derives from the ability of young trees to produce seeds; prolific seed production; high seed viability; and high survival and rapid growth of seedlings (Powells, 1965).

Stands are commonly even-aged, consisting of densely-packed tree; with thin trunks ("doghair stands"). Such stands occur when fire seed, and climatic conditions combined to kill existing trees and produce many seedlings at one time. The rate of growth is inversely related to tree density, and stands can soon become stagnated (Cole, 1975). Two-aged and multi-storied stands also occur. One cause can be a severe forest fire, which leaves only enough cones to produce an open stand whose trees later provide seeds for an understory to develop. A second is an infestation of mountain pine beetles *(Dendroctonus ponderosae)*, which first kil the older larger-diameter trees. Susceptibility is greatest for trees >20 cm dbh and >80 years old, and is also inversely relate to altitude. As the population of beetles increases, smaller and younger trees less suitable for brood production are killed; the infestation ceases when all or most of the large-diameter trees have been killed (Cole and Amman, 1980). The open spaces may the be taken over by understory trees or new seedlings of either lodgepole pine or other species. However, there may be additional mortality from sun-scald, windthrow, or snow pressure (Wellner, 1978).

Lodgepole pine is also attacked by other insects and a number of diseases. The most significant of the latter is dwarf mistletoe (*Archeuthobium americanum)*, which reduces growth and seed production, and increases mortality. The rate of mortality is greater for younger trees, on poorer sites, and where the stand has been opened up by natural factors or logging (Hawksworth and Dooling, 1984). A significant effect of both dwarf mistletoe and

beetle infestation is to create large fuel supplies which, if ignited, can permit a new stand of lodgepole pine to establish itself from seed.

2.4.1.3 Ponderosa pine

Ponderosa pine occurs throughout the montane zone of Colorado, occurring as a dominant species from 1,700 to 2,800 m. It is commonly found with douglas fir, which constitutes a greater portion of stands with higher elevation and moisture; at the lower limit, stands become more open, grading into grassland (Feet, 1981). The density and sizes of trees in these forests vary significantly. In mixed stands with a well-developed understory of douglas fir, this species can eventually take over in the absence of disturbance (Alexander, 1986). Ponderosa pine preferentially grows on deep, moderately sandy or gravelly soils; other species become more frequent and tend to outcompete it in more mesic sites (Schubert, 1974).

Like lodgepole pine and aspen, ponderosa pine is commonly found on sites where fires are common. However, the latter survives in such sites by very different means. Seedlings and saplings can withstand high temperatures, whether from fire or radiation on exposed slopes and, if fires are not severe, can maintain themselves on sites with fire intervals as short as six years. Also, the shade-intolerant seedlings establish themselves well on the bare mineral soil available after fires. Mature trees are well adapted to survive fire, with thick bark; open, loosely-arranged foliage with a high moisture content; deep roots; and a tendency for lower limbs to self-prune, particularly when shaded, so that fires do not reach the crown. The success of these adaptations, however, can be limited as resin in the bark and litter accumulate (Crane, 1982). The degree of survival also declines on moister sites, primarily because understory trees carry fires upwards, increasing the frequency of crown fires. Understory trees may be douglas fir or ponderosa pine; on moist sites, the latter are more susceptible to fire because of slow growth and bark development, and the greater flammability of the dense foliage (Fischer and Bradley, 1987).

Mountain pine beetle *(Dendroctonus ponderosse)* is the most serious pest attacking ponderosa pine, usually killing trees during the first season of infestation. Groups of trees are killed, the numbers increasing as new generations of beetles develop. The stands which are most susceptible are pure, even-aged; 50 to 100 years old; >15 cm dbh; overcrowded and slow-growing; and with live crown ratios less than one-third (McCambridge and Trostle, 1972; McGregor and Cole, 1985). Less important beetles are the red turpentine beetle (*Dendroctonus valens)*, which attacks fresh logs and stumps and the base of trunks, weakening trees and making them more susceptible to damage by other beetles; and pine engraver beetles *dps* spp.), which commonly develop in logging slash (Stevens et al., 1980).

Ponderosa pine is also affected by a number of diseases, of which dwarf mistletoe *(Archeuthobium vaginatum)* is the most serious, reducing growth and seed production and viability, and increasing mortality. Rates of mortality are greater for young trees, and 01 poorer sites and those opened up by mountain pine beetles, windfall, or logging (Hawksworth, 1961). Other diseases which weaken or kill trees are red rot *(Dichomitus squalens),* which attacks trunks; armillaria root rot *kArmillaria mellea)* (Hepting 1971); and limb rust (*Peridermium filamentosum)* (Peterson and Shurtleff, 1965). The development of all of these diseases is encouraged by damage from insects and logging, and also by browsing by animals, such as mule deer and elk. Porcupines, squirrels and many rodents also damage trees. In general, young trees are affected more, but older trees can also suffer severe damage (Schubert, 1974).

2.4.1.4 Douglas fir

Douglas fir is principally found in the montane zone from approximately 1,800 to 2,730 m, either mixed with ponderosa pine or in pure stands on steeper, more mesic, north-facing slopes with deeper soils (Marr, 1961). Daubenmire (1943) suggests that douglas fir would constitute climax forest in most of the upper montane zone, but was eliminated from large areas by extensive fires that destroyed the seed source, allowing lodgepole pine and aspen to take over. However, where seed sources were available, douglas fir is important in the understory of fire-initiated lodgepole pine stands, being more shade-tolerant than this species; where light is adequate, it also occurs in lower-altitude spruce-fir stands (Peet, 1981).

Individual trees may live for 400 years, though growth slows considerably after 200 years (Fowells, 1965). The fire resistance of the species varies with age. Saplings are vulnerable to surface fires because they have thin bark with resin blisters; thin bud scales and twigs; and flammable foliage. Also, the low, dense branches enable surface fires to be carried into the crown of older trees. After about 40 years on moist (i.e., favorable) sites, a thick layer of insulating bark develops. While this protects trees from cool to moderately severe fires, dead branches, heavy lichen growth, and resin streaks on the lower trunk can offset this protection (Fischer and Bradley, 1987). After fire, the light seed can be carried at least 1 km into disturbed areas by the wind (Arno, 1976); good cone crops are produced about every three years (Roeser, 1942). However, successful seedling establishment is often low because of predation and drought (Krauch, 1936). Douglas fir is attacked by the douglas-fir beetle (*Dendroctonus pseudotsugae),* douglas-fir dwarf mistletoe *(Arceuthobium douglasii),* and also the spruce budworm *(Choristoneura occidentalis),* though it is less susceptible to the latter than engelmann spruce or subalpine fit in mixed stands (Brookes et al., 1985).

2.4.1.5 Engelmann spruce

Engelmann spruce is typically associated with subalpine fir, but may also occur in pure or nearly pure stands, particularly on drier sites (Peet, 1981). Trees in forests where the species is dominant or codominant are often 250 to 450 years old, and can reach 600 years. Average life spans are greater than those of fir, so that spruce is more often able to dominate the canopy (Oosting and Reed, 1952). It is found at altitudes from 2440 to 3,500 m, i.e., from the montane to the alpine, where it is the most common krummholz tree (Wardle, 1968). Its distribution is restricted by its soil moisture requirements; it grows best on moderately deep, well-drained soils with an accessible water table (Alexander and Shepperd, 1984).

Since seedlings require shade for successful establishment, they develop best under species such as douglas fir, lodgepole pine, or aspen which require more light (Bates, 1925). Subsequently, the young trees have a high rate of survival, growing slowly until released (LeBarron and Jemison, 1953). Cones are produced by trees from 16 to 25 years old (Fowells, 1965), with maximum production from trees 150 to 250 years old (Alexander and Shepperd, 1984). Good seed years occur every three to five years (Noble and Ronco, 1978). The species is highly susceptible to fire, with dead, dry, lower limbs; a low-growing canopy; thin bark; lichen growth on the branches; a shallow root system; and accumulations of needle litter around the base of the trunk. However, engelmann spruce can be one of the first constituents of fire-initiated stands dominated by lodgepole pine if trees survive within 90 m of the burn (Fischer and Bradley, 1987), later taking over the site after the demise of the seral species.

After fires, trees which are not killed are often attacked by wood-rotting fungi, which enter through fire scars and are the most common diseases affecting the species. Windthrow and windbreak often result (Hinds and Hawksworth, 1966); these are the most common cause of mortality in disturbed and cut areas (Alexander, 1974). The most serious insect pest affecting the species is the spruce beetle (*Dendroctonus rufipennis),* which mainly attacks older trees. Outbreaks mainly occur after windthrow, when downed trees provide adequate food for populations to develop and expand into the living trees (Schmid and Frye, 1977). Nearly 4 billion board feet of standing timber were killed in Colorado from 1939 to 1951 (Massey and Wygant, 1954). The only other insect which has potentially severe effects on growth and mortality is the defoliating western spruce budworm *(Choristoneura occidentalism,* which also attacks older trees. However, mortality tends to be concentrated among smaller, suppressed trees (Brookes et al., 1985).

2.4.1.6 Subalpine fir

Subalpine fir commonly occurs with angelraann spruce, and has a similar altitudinal range. However, it has less exacting soil requirements for both establishment and growth. Fir is most likely to form pure stands at high elevations (Alexander, 1980), Fir seedlings are more shade-tolerant than those of spruce, and thus are generally more common below early successional species (Alexander et al., 1984). However, after seral species die, spruce is more likely to dominate because of its greater growth rates in the open (Fischer and Bradley, 1987) and its longer life-span: firs generally live for 300 years at most (Oosting and Reed, 1952).

Subalpine fir is very susceptible to fire, having very thin bark with resin blisters; a low dense crown with flammable foliage and heavy lichen growth; a shallow root system; and moderate to high tree densities in mature stands. Even relatively cool ground fires can kill trees (Fischer and Bradley, 1987). While the species can occur in fire-initiated stands, it is more likely to invade gradually into such stands (e.g., lodgepole pine); seed sources are usually adequate to restock naturally-caused clearings (Shea, 1985). Subalpine firs can produce cones after they are 20 years old, though production occurs later in dense stands. Maximum seed production is from dominant trees 150 to 200 years old (US Forest Service, 1974); but good seed years are less frequent than for engelmann spruce (Noble and Ronco, 1978).

In disturbed areas, windfall is the most common cause of mortality (Alexander, 1974). This is generally linked to the species' shallow root system, but is exacerbated by the large number of diseases to which it is prone: these include fir broom rust *(Melampsorella caryophyllacearum)* and various fungi which cause root and butt rot (Hinds et al., 1960). Subalpine fir is also attacked by many insects (Furniss and Carolin, 1977). The most destructive are the western balsam bark beetle *(Dryocetes confusus),* which has similar habitat requirements to the spruce beetle; the fir engraver (*Scolytus ventralis);* and the western spruce budworm (*Choristoneura occidentalis).* The latter tends to affect fir more than spruce (Brookes et al., 1985).

2.4.1.7 Limber pine

Limber pine is found from the plains to the alpine, from approximately 1600 to 3570 m (Schuster, pers. comm., 1987). It occurs in stands dominated by all other conifers except ponderosa pine, and forms pure stands on ridges, hillsides, and other sites where harsh conditions exclude other tree species (Crane, 1982. On more mesic sites, it can be successional to spruce-fir forest, since it is shade-intolerant and can become established after fire if seeds are available (Peet, 1981). The large seeds are dispersed by birds, particularly Clark's nutcracker *(Nucifraga columbiana),* which may transport seeds 22 km from the seed

source, to cache sites on ridges and other windswept areas where snow does not accumulate (Lanner and Vander-Wall, 1980).

Young trees are easily killed by fire because of their thin bark. However, the bark of mature trees can be up to 5 cm thick, protecting them from most surface fires. In addition, tight clusters of needles around terminal buds protect the buds from scorching (Fischer and Clayton, 1983). At lower altitudes, the trees are often short, with low branches so that fires can cause considerable damage if adequate fuel (e.g., shrubs) is available. However, at higher altitudes where trees are usually upright, the bark protects them; krummholz trees rarely experience fire because of inadequate fuel (Douglass and Douglass, 1955). In general, the species escapes severe damage by fire because of the xeric nature of the sites it inhabits.

2.5 Pikes Peak study area

2.5.1 Physical setting

Pikes Peak is the eastern and southernmost unit of the Front Range of the Rocky Mountains. The study area (Figure 2.11) is defined to the west, south, and east by the boundaries of the Dillon Ranger District of the Pike National Forest, and to the north by the Ute Pass Highway along the Fountain Creek valley. Elevations within this area range from 4300 m, at the summit of Pikes Peak, to 1980 m on the east edge. Pikes Peak is near the midpoint of a 10-km long ridge, trending northwest-southeast. To the east and south of the main ridge are a number of subsidiary summits. The southeast side of the area is dissected by long, deeply-incised canyons with steep walls; the northeast side shows the effects of glacial erosion, with streams starting in cirques and gently-sloping lower courses. Along Fountain Creek, to the north of the area, are the settlements of Green Mountain Falls, Cascade, and Manitou Springs; the city of Colorado Springs is on the plains to the east (Figure 2.12).

During the Pleistocene, glaciers developed from 3890 to 2890 *m*, forming the cirques of the northeast side. These valleys, up to a distance of 8 km from the summit, contain glacial and fluvioglacial deposits on which soils have subsequently developed. However, the soils of most of the area have developed directly from gravel formed by the weathering of the granite bedrock, with little organic matter or horizon development. Soil depths are highly variable, and tend to increase as slope angle decreases. The soils are coarse and very porous, with a low water holding capacity; the texture on gentle slopes is a sandy loam, changing to gravelly sandy loam as the slope angle increases. The combined characteristics of these soils make them highly erodible, particularly when vegetation cover has been removed (Lynch, 1972).

2.5.2 Climate

The area has a continental climate, characterized by low humidity, and a wide annual and diurnal temperature range. Climatic data are available from a number of stations, from Colorado Springs to the summit of Pikes Peak, where the Army maintained a station from 1873 to 1888. The stations with the longest periods of record are Colorado Springs (1890 m), Ruxton Park (2758 m), and Lake Moraine (3130 m). The discussion below is based on current data from the Colorado Climate Center.

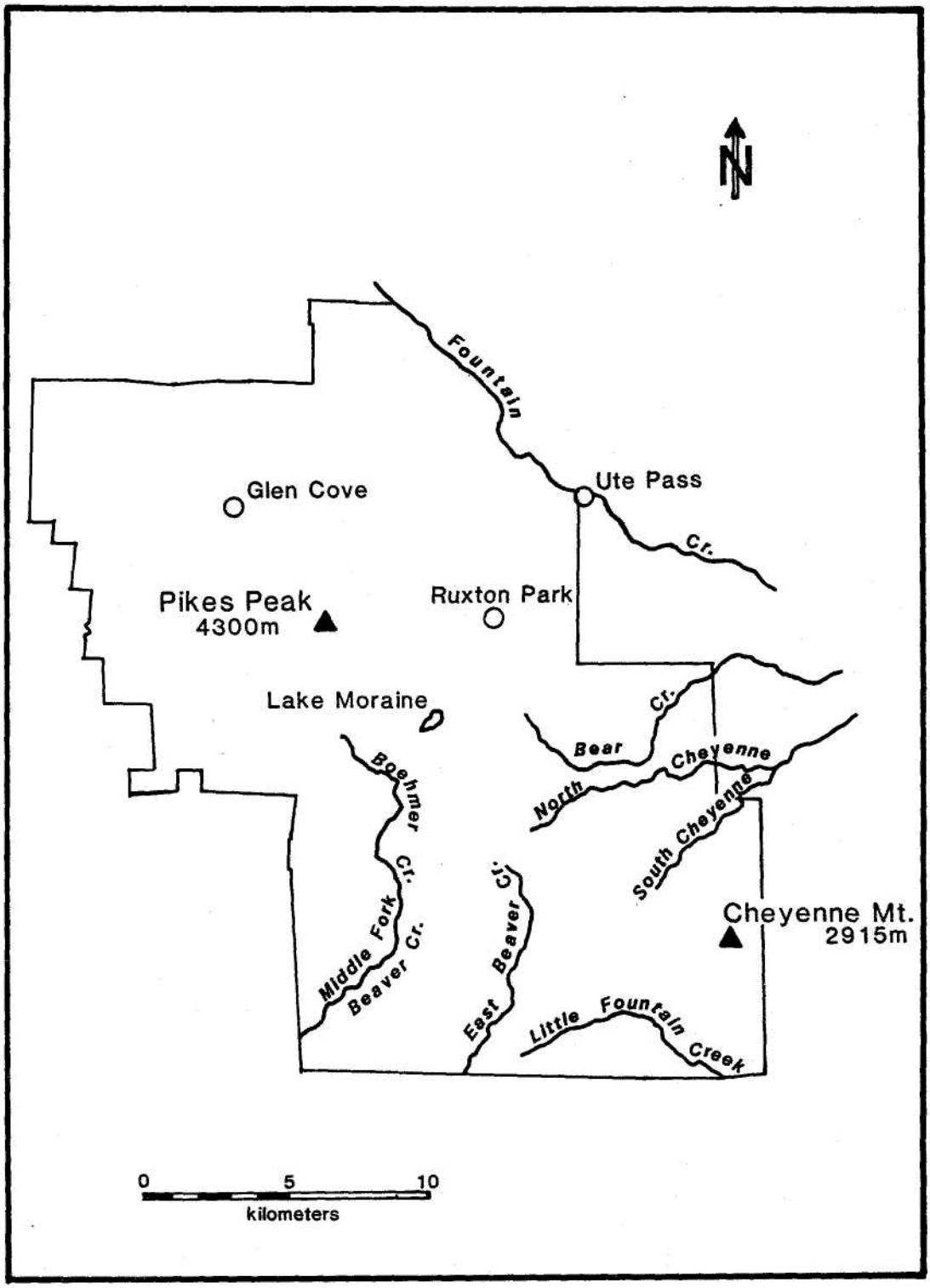


Figure 2.11: Pikes Peak study area: physical features

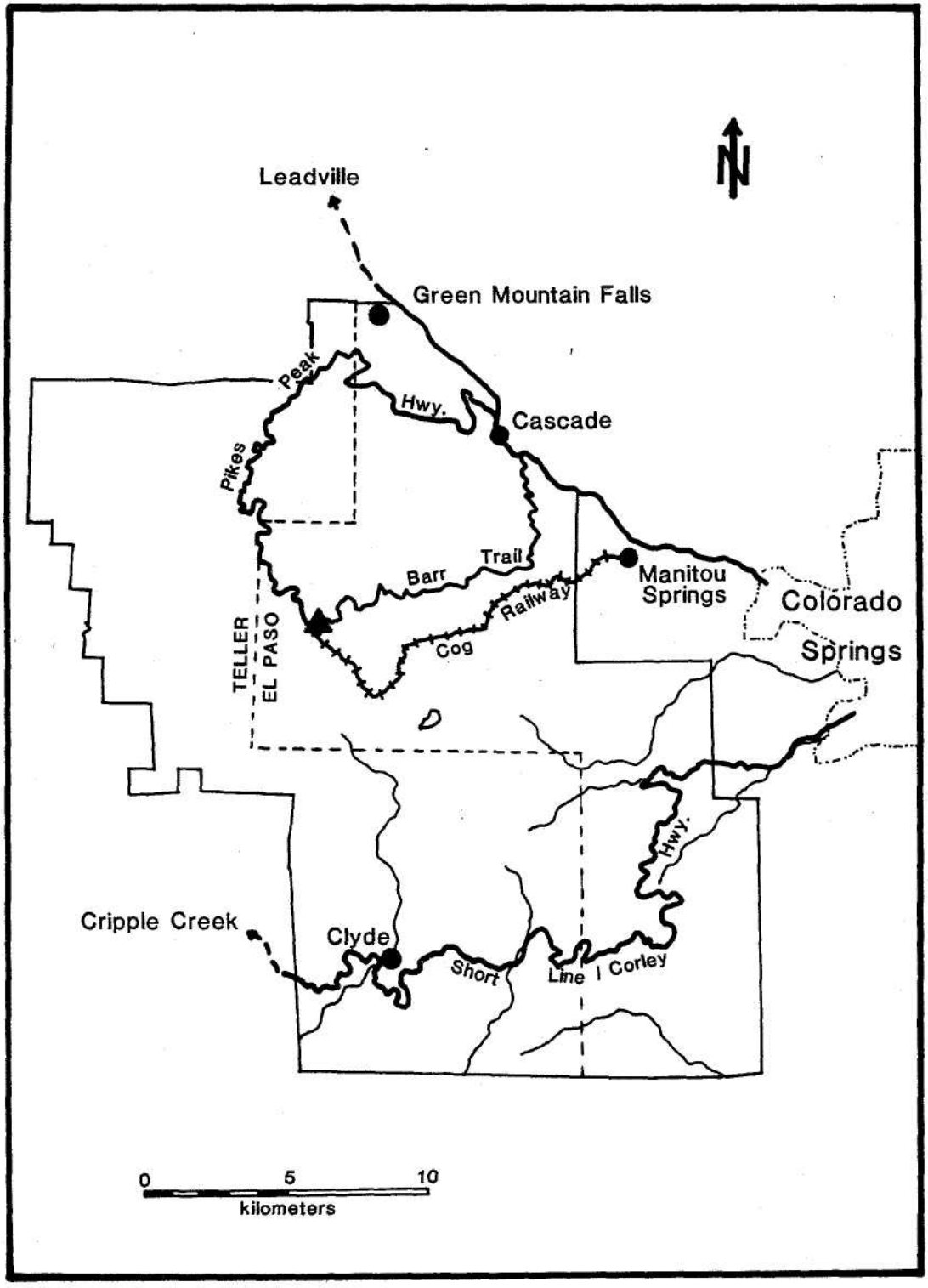


Figure 2.12: Pikes Peak study area: settlement and infrastru

Precipitation

Average annual precipitation increases with altitude, from 392 mm at Colorado Springs to 592 mm at Ruxton Park and 615 mm at Lake Moraine. Precipitation data from other stations at comparable altitudes show that the south side of the area receives more precipitation, since most comes from high-intensity storms originating in the Gulf of Mexico. These storms are most frequent in July and August; a third of the precipitation falls during these months. There is a secondary maximum in May; all major floods have occurred in these three months. The driest period is from November to February (especially December and January), in contrast to other parts of the Colorado Rockies, which receive much of their precipitation from winter Pacific Northwest storms. The winter is also characterized by chinooks: strong, warm, dry westerly winds, which can rapidly decrease the snow pack. The months with the greatest snowfall are March and April; April is generally the month with the greatest snow depth, and only July and August are snow-free at Ruxton Park and Lake Moraine.

Thermal regime

At Colorado Springs, the average annual temperature is 9°C; and at Lake Moraine, 2°C. The wettest months are also the warmest. On average, the highest mean temperatures occur in July: 22°C at Colorado Springs, and 13°C at Lake Moraine. Average maximum temperatures in July are 29°C and 20°C, respectively. The coldest month is January: -2°C at Colorado Springs, and -7°C at Lake Moraine; average minima are -9°C and -13°C respectively. At Colorado Springs, only June, July, and August are completely frost-free; at Ruxton Park, there are no frost-free months.

2.5.3 History: demography, economy, transportation

There have been many studies of the history of the Pikes Peak area, of which the most comprehensive are Carter (1956), Sprague (1961), and Fetler (1966). All contain substantial detailed information which is not directly referenced to items in the bibliographies. Permanent settlement in the area dates back to the mid-19th century. However, the area had been used for centuries by various Indian tribes, and was traversed by Spaniards in the 18th century while the area was still part of the Spanish Empire. Anglo-Americans became aware of the mountain after it was described by Zebulon Pike on his return from a survey of the area in 1806-7. Pikes Peak was first climbed by the botanist Edwin James and two others in 1820. Over the next four decades, the area was important for trapping, and the hot springs at Manitou were first used by Europeans.

By the late 1840s, Pikes Peak was a well-known landmark on the Overland Trail to California. The "Pikes Peak gold rush" did not begin until the late 1850s, driven by the discovery of gold in the Rockies to the west and north, rather than on the massif

itself. Permanent settlement at the foot of Pikes Peak started in 1859, when Colorado City was founded at the east end of Ute Pass, which became a major route into the mountains. Even at this early date, some visitors to the area, including correspondents of New York and Cincinnati newspapers, were aware of aesthetic, rather than economic, attractions of the area (Fetler, 1966: 108, 110). The gold rush ended in 1861, and the population of Colorado City rapidly declined. In March 1860, 245 houses had been completed (Fetler, 1966: 109); by 1870, only 81 inhabitants remained (Fetler, 1966: 135).

During the 1860s, the economy of the area was based on homesteading on the prairies and limited mining in the mountains. The next impetus to its development occurred in 1870, when General Palmer realized that the east end of Ute Pass was a logical location for a settlement along his planned Denver and Rio Grande railroad. He bought 10,500 acres (4250 ha) of land east of Colorado City, on which Colorado Springs was laid out in 1871 (Fetler, 1966: 131-7). That October, the railroad arrived. A new gold and silver boom at Leadville also led to the construction of the Ute Pass highway, partially underwritten by El Paso County, during the 1870s. During this and the next decade, both Colorado Springs and Colorado City grew rapidly, their economy based on cattle and sheep ranching to the east and mining to the west. The population of the county grew from 987 in, 1870 to 21,239 in 1890 (Census Office, 1883; 1895). Figure 2.13 shows the population of the area and its communities since 1870.

The railroad permitted a further source of income to the area: tourism. As early as 1873, a 137-page guidebook to the area had been printed (Anon, 1873), and stories about Pikes Peak, and its caves and hot springs, were printed in newspapers throughout America. No data are available on the contribution of tourism to the local economy in the 1870s and 1880s. However, the sector's ' importance is shown by the construction of the first road to the summit of the Peak in 1887, together with various facilities along the road and at its termini. In the same year, construction of the Colorado Midland railroad through Ute Pass to Leadville began, providing easier access to the lower terminus of the Pikes Peak road. The road was improved to allow carriages in 1889, but soon experienced competition from the cog railroad, completed in 1891. On the west side of the mountain, El Paso County developed a road, primarily for tourist traffic, as far as Clyde.

During the 1890s, tourism continued to contribute to the local economy, but was of little importance in comparison to mining. A new gold rush began in 1891 with the discovery of gold at Cripple Creek and Victor, southwest of Pikes Peak. By 1899, the development of this mining district led to the establishment of Teller County from western El Paso County; in 1900, Teller County had 29,002 inhabitants, El Paso County had 31,602 (Census Office, 1901). The new boom also made viable the construction of a new railroad along the road to Clyde and on to Cripple Creek (the "Short Line") in 1900-1, to compete with the Colorado Midland.

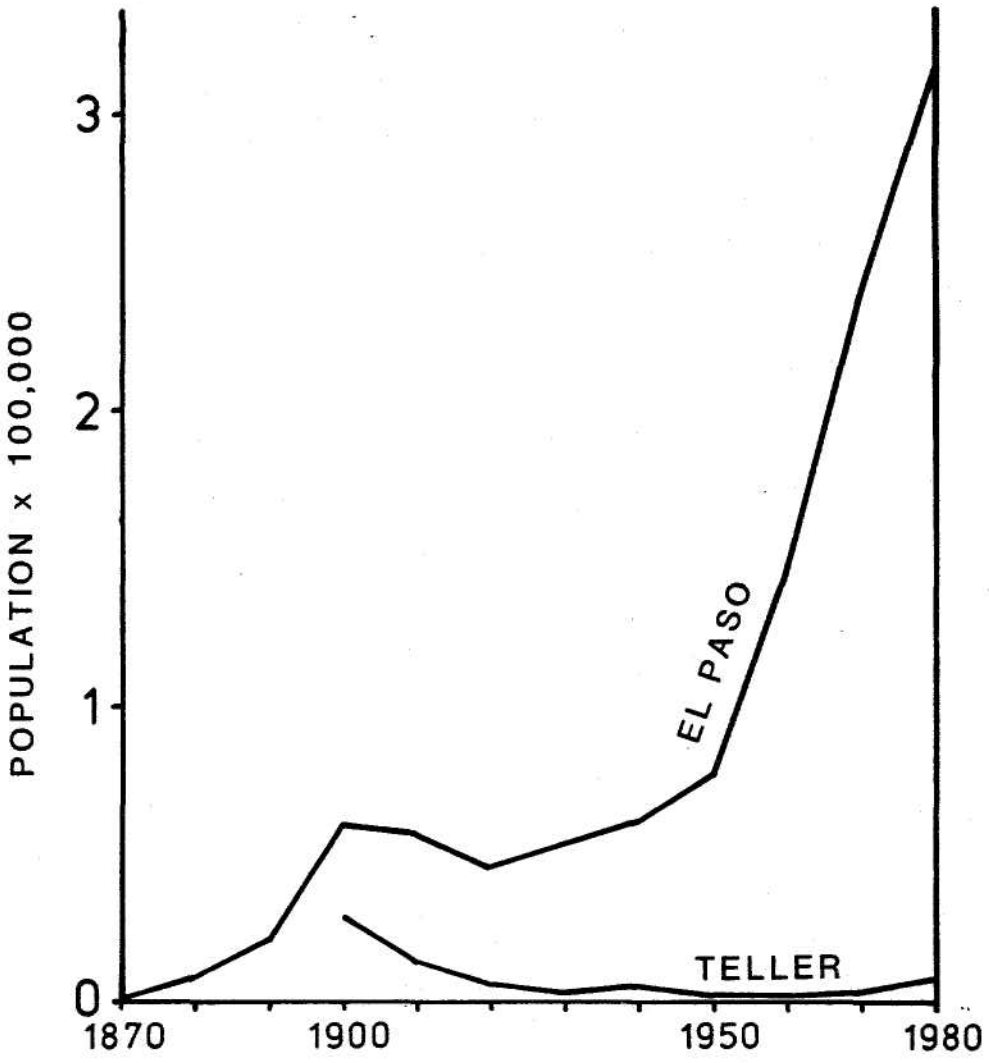


Figure 2.12: Pikes Peak study area: population 1870 - 1980

Sources: Census documents

The new boom greatly stimulated Colorado Springs' economy: by 1908, though it had five percent of Colorado's population, it had nearly a quarter of the bank deposits (Carter, 1956: 23). However, 1900 was the year of Teller County's greatest gold production (Henderson, 1927: 541); by 1910 the boom was over, and the county's population had halved to 14,351. Meanwhile, the population of El Paso County, with a more diverse economy, had continued to grow to 43,321 (Bureau of the Census, 1913). During this period, the City of Colorado Springs ensured that it would have enough water for continued development by buying land and building reservoirs, tunnels, and pipelines on Pikes Peak. Such activities continued intermittently until 1960 (Farmer, 1987: 14-15) .

During the first two decades of this century, Colorado Springs not only provided services to the surrounding region, but was also of growing national importance as a center for tourism and the treatment of tuberculosis. The first automobile was driven to the top of Pikes Peak in 1901, and by 1916 the road had been upgraded for regular automobile traffic. In 1911, it was announced that an aerial tramway would be built to the top of the mountain within a year (Rocky Mountain News 11/12/11). This never happened, but in the meantime the Short Line and Midland railroads were carrying tourists, as well as ore. In 1914, 12,000 people went on "scenic wildflower excursions" around the mountain (Shoemaker, 1917b); it was estimated that 200,000 people visited the area (Duthie, 1914).

Even during the First World War, the area remained important for recreation. In 1917, it was proposed as a national park because of its outstanding scenic value and easy access from all of America's major cities by both rail and road (Timberlake, 1917). The decreasing importance of mining is shown by the further halving of Teller County's population by 1920 (Bureau of the Census, 1921), the closure of the Midland railroad west of Divide in 1918, and the bankruptcy of the Short Line in 1920. In 1922, the right-of-way reverted to its previous status as a scenic highway, emphasizing another factor in the demise of the railroads: increasing automobile ownership. During the 1920s, the Colorado Springs Chamber of Commerce began to actively promote road construction (Carter, 1956); the Ute Pass highway was now part of the transnational Ocean-to-Ocean Highway. Facilities for more active recreation on the mountain also began to be developed after the War, with the construction of the Barr trail from 1918-21. This was the first trail built specifically for hiking to the summit, and formed the beginning of an extensive trail network which supplements the many trails which have developed along pipelines, and old tourist and logging roads (Ormes, n.d.).

During the 1920s and 1930s, the economy of the Pikes Peak area was primarily based on summer tourism, which permitted gradual population growth. In 1930, the first year for which statistics are available for employment sectors, 62% of the workforce was ik the service sector. The proportion had increased to 69% by 1940

(Bureau of the Census, 1932; 1943), as shown in Figure 2.14. However, while the dominance of this sector was marked in El Paso County, primary activities remained dominant in Teller County, whose population increased after three decades of decline. This was partly linked to the rise in gold prices in 1934, mandated by Congress, which led to increased mining; and thus to increased traffic on the Midland railroad, which in turn benefitted Colorado Springs. The latter was also cushioned from the Depression by the fact that many people with retirement incomes had moved there (Carter, 1956: 36).

By the end of the 1930s, the citizens of Colorado Springs had decided that summer tourism did not provide an adequately stable economic base, when combined with revenues from an unreliable mining sector and a moribund agricultural sector. The Second World War provided an escape from this dilemma, which has had lasting effects. In 1942, the City purchased 60,000 acres of land and sold it to the federal government for military training. Military training continued year-round throughout the War on both this land (Camp Carson) and Pikes Peak. However, this was effectively just another boom which ended in 1945 when Camp Carson was deactivated. After the War, the Chamber of Commerce actively encouraged light industry, attracting 60 companies between 1946 and 1950 (Carter, 1956: 41-3). Thus, from 1940 to 1950, while the proportion of employment in the service sector in El Paso County declined to 66%, the manufacturing proportion doubled to 26%. Furthermore, the population grew by a third, in contrast to Teller County, which lost over half its population as mining went through another bust cycle (Bureau of the Census, 1952) .

The economic base of the Pikes Peak area began to develop towards its present composition with the beginning of the Korean War in 1950, when Camp Carson was reactivated. In 1954, Camp Carson became a permanent installation and was renamed Fort Carson. In the same year, the Ent Air Force Base also became permanent, and the Air Force Academy was established. The federal government is now the major regional employer, and many civilian jobs are related to the military establishment, which also includes the headquarters of the North American Air Defense Command. However, summer tourism continues to be an important component of the area's economy. In contrast, winter tourism at two small ski areas, opened in 1948 and 1958, has had limited success because of unreliable snowfall and competition from other areas. Population growth in El Paso County doubled by 1960, and has continued to be rapid, with most employment in the service sector. In Teller County, the population remained almost constant from 1950 to 1970, as the proportion employed in the primary sector declined. Subsequently, manufacturing and service industries, including tourism, have provided increasing employment, and the population more than doubled between 1970 and 1980 (Bureau of the Census, 1961; 1973; 1983).

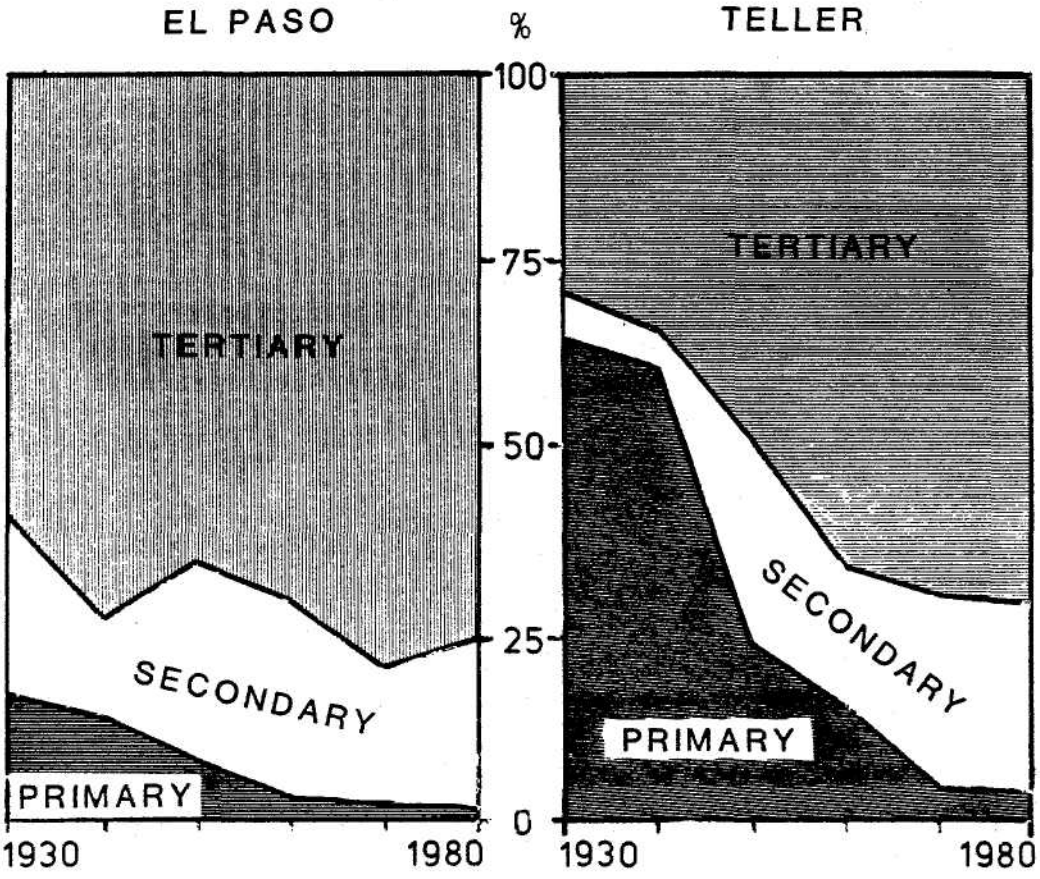


Figure 2.13: Pikes Peak study area: employment structure 1930-1980

Sources: Census documents

2.5.4 Forest ownership patterns

Most of the study area is part of the Pike National Forest, administered by the US Forest Service: 33,664 ha (77%) of the total of 43,721 ha. The other principal landholder is the City of Colorado Springs, which owns about 5250 ha, primarily around the reservoirs on the north and south slopes of the Pikes Peak and northwest of Manitou Springs. Most of this land was bought from the federal government from 1896 to 1902 (Farmer, 1987). Smaller areas are owned by the State of Colorado, in the Bear Creek drainage (520 ha); the Bureau of Land Management; and many private owners. Only the National Forest land is considered in the study.

Over a third of the National Forest area (12,617 ha), in the watersheds of Colorado Springs, Manitou Springs, Cascade, and Victor, has been set aside to store and conserve the water supplies and protect them from pollution. These areas are defined in an easement granted to the City of Colorado Springs in 1890; a Special Act, passed by the federal government in 1913 (37 Stat 684); and cooperative agreements made between the Secretary of Agriculture and the respective cities between 1914 and 1930. These documents limit the activities in these watersheds. In general, they permit the Forest Service to manage the forests, including reforestation and cutting. The cities agree to help in fire patrol and suppression, and that the construction of transportation and communications facilities will not interfere with the objective of protecting the watershed. Use of these areas is restricted to Forest Service and municipal employees, except in special cases. One of these is the easement along the Pikes Peak highway, granted to the City of Colorado Springs.

2.6 Summit: study area

2.6.1 Physical setting

The study area (Figure 2.15) is on the west slope of the Continental Divide, and is defined by the boundaries of Summit County. The west side of the area is defined by the crest of the Gore Range, whose highest peak is Mount Powell (4125 m); the highest peak of the Williams Fork Mountains, to the northeast, is Ptarmigan Peak (3797 m). The highest peak on the Continental Divide along the south and southeast sides of the area is Grays Peak (4349 m). The other major feature of the area is the Ten-Mile Range, between the Upper Blue and Ten-Mile Creek valleys; its highest peak is Quandary Peak (4347 m). The area is drained by the Blue River and its tributaries, of which the largest are the Snake and Swan Rivers and Ten-Mile Creek, all rising in the south end of the area and flowing into Dillon Reservoir. The Blue River south of this reservoir is known as the Upper Blue; the part to the north, including Green Mountain Reservoir, is the lower Blue, which leaves the area at an altitude of 2374 m. All other access routes to the area cross passes, including Ute (2903 m), Vail (3231 m), Fremont (3450 m), Boreas (3499 m), Hoosier (3517 m), and Loveland (3655 m). The study area's settlements and infrastructure are shown in Figure 2.16.

The soils of part of Summit County have been described by Miles and Fletcher (1980). While the survey principally concentrated on soils in the valleys, two of the major soil complexes are those which are found under most of the forests. These soils vary from mildly alkaline to strongly acidic. Most have developed on glacial drift, with the exception of the Leadville series, which occurs on sandstone outcrops in the southern part of the area. All of the soils, even on steep slopes, are described as deep, well drained, and moderately permeable.

2.6.2 Climate

The climate of the area is continental, with great annual and diurnal temperature fluctuations. Long-term climatic data are available from the Colorado Climate Center for three valley stations: Green Mountain Dam (2359 m), Dillon (2764 m), and Breckenridge (2920 m). These stations are not typical of the conditions experienced by the area's forests, many of which are above the altitude of Breckenridge. In addition, snow depth data are available from the Soil Conservation Service (SCS) for a number of stations for January to June.

Precipitation

Average annual precipitation increases with altitude, from 394 rani at Green Mountain Dam to 484 mm at Breckenridge. The SCS data show that total snowfall increases with altitude; this is probably also true for total annual precipitation. The

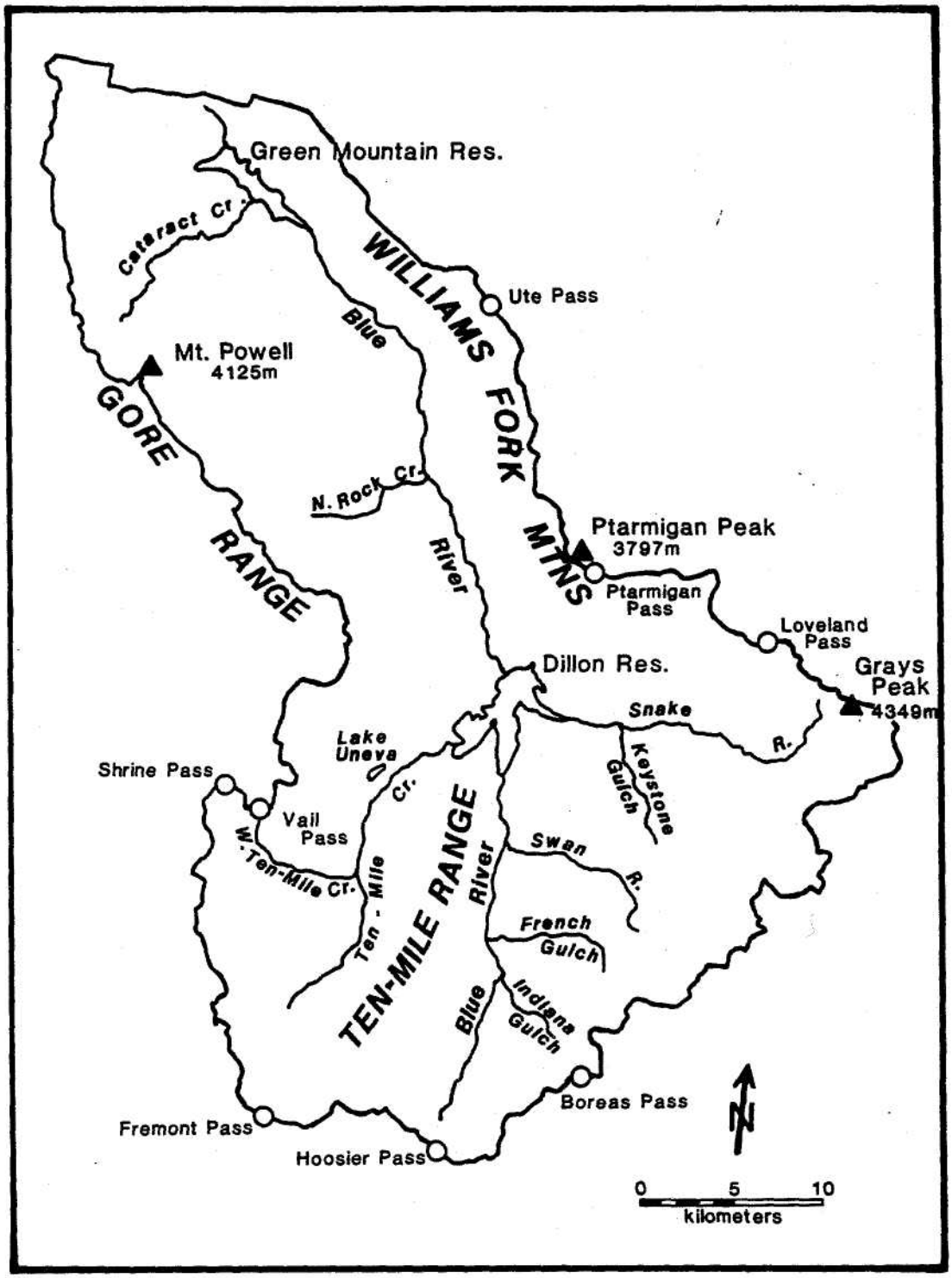


Figure 2.15: Summit study area: physical features

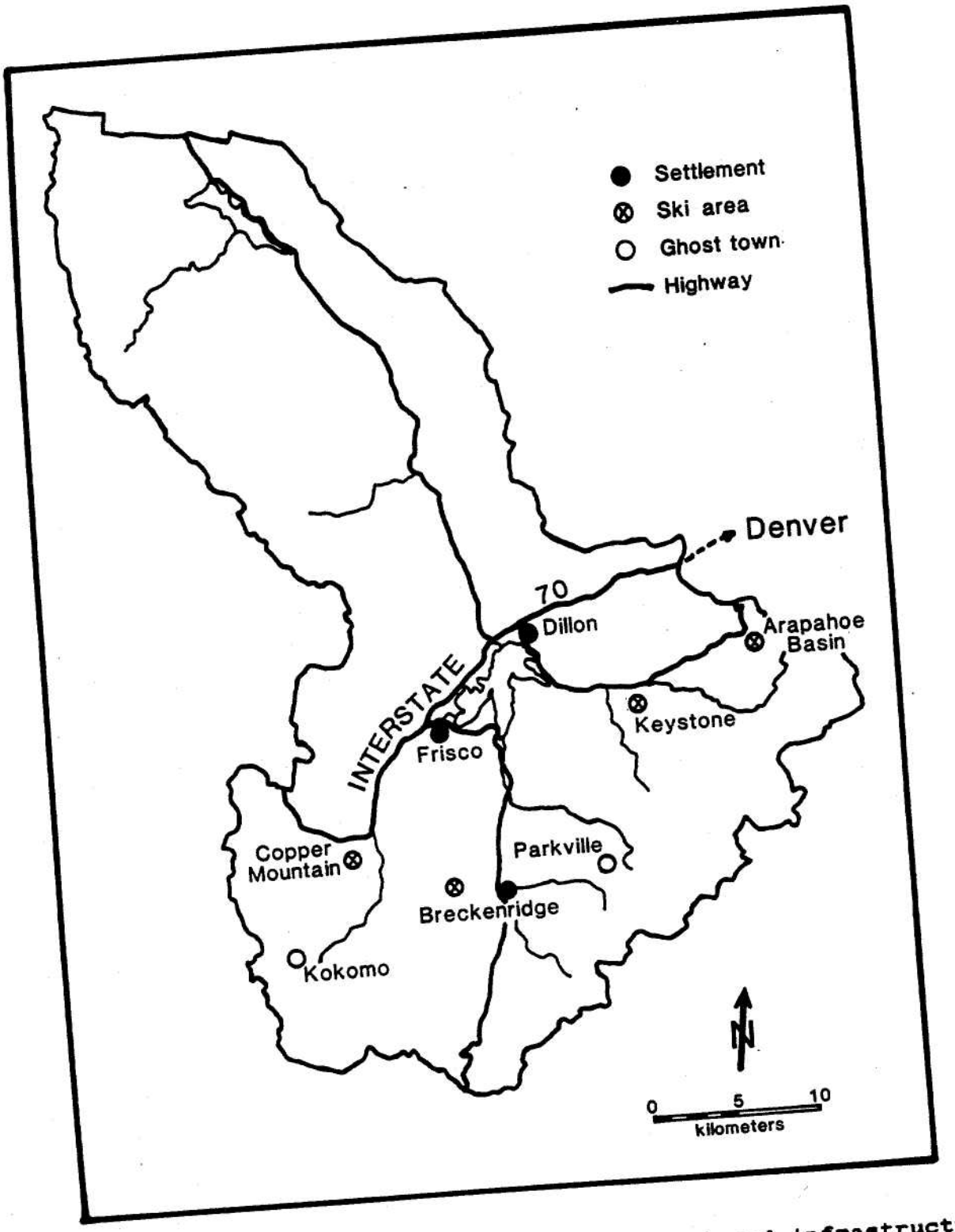


Figure 2.16: Summit study area: settlement and infrastructure

precipitation maximum occurs with the summer storms and rain showers of July and August. This is not marked; in general, the variability of precipitation between months decreases as altitude increases. The month with the greatest snowfall is March, when storms from the Pacific Northwest are most frequent. The time of greatest snow depth varies from early April to mid-May, becoming later with altitude.

Thermal regime

Temperature data are only available from Green Mountain Dam and Dillon, where the average annual temperatures are 13°C and 11°C respectively. The wettest months are also the warmest. On average, the highest mean and maximum temperatures occur in July: 17°C and 27°C at Green Mountain Dam; and 13°C and 24°C at Dillon. The coldest month is January: mean monthly and minimum temperatures are -8°C and -15°C at Green Mountain Dam, and -9°C and -18°C at Dillon. At both of these stations, only May through October are frost-free.

2.6.3 History: demography, economy, transportation

The history of Summit County has been the subject of a number of studies, including Gilliland (1980) and Pritchard (1982). Studies of individual communities include Emore (1983), English and English (1983), Gilliland (1984), and Sharp (1971). Before the era of permanent settlement, the area was utilized by Ute Indians and, from 1812, by trappers. In 1859, placer gold was discovered along the upper reaches of the Blue and Swan Rivers. The mining district was the basis of the new towns of Breckenridge and Parkville; the county had an estimated population of 8,000 by the next summer. The changing population of the county and its communities is shown in Figure 2.17. By 1862, there were four toll roads into the county (Walter, 1976: 104), but the easily-accessible gold had begun to run out; by 1870, the county's population had declined to 258, although some gold extraction continued (Rocky Mountain News 8/8/72).

The next boom started with the discovery of gold and silver ore deposits in 1878. By 1880, the county's population was 5,459, divided between a number of mining camps in the southern part of the county, of which Breckenridge was again the largest (Census Office, 1883). During this early phase of this second boom, access to the county was still by road, with six stage-coach lines crossing the passes on its south and east boundaries (Walter, 1976: 105). In the early 1880s, railroads were built into the area. The first to arrive was the Denver and Rio Grande (D *&* RG) from Leadville, constructed over Fremont Pass in 1880 and then along Ten-Mile canyon, reaching the new town of Dillon in 1882. The Denver, South Park and Pacific (D, SP *&* P) railroad was completed from Como over Boreas Pass to Breckenridge in 1882, to Dillon in 1883, and along the D & RG right-of-way up Ten-Mile canyon to Leadville in 1884. The railroads were not used solely

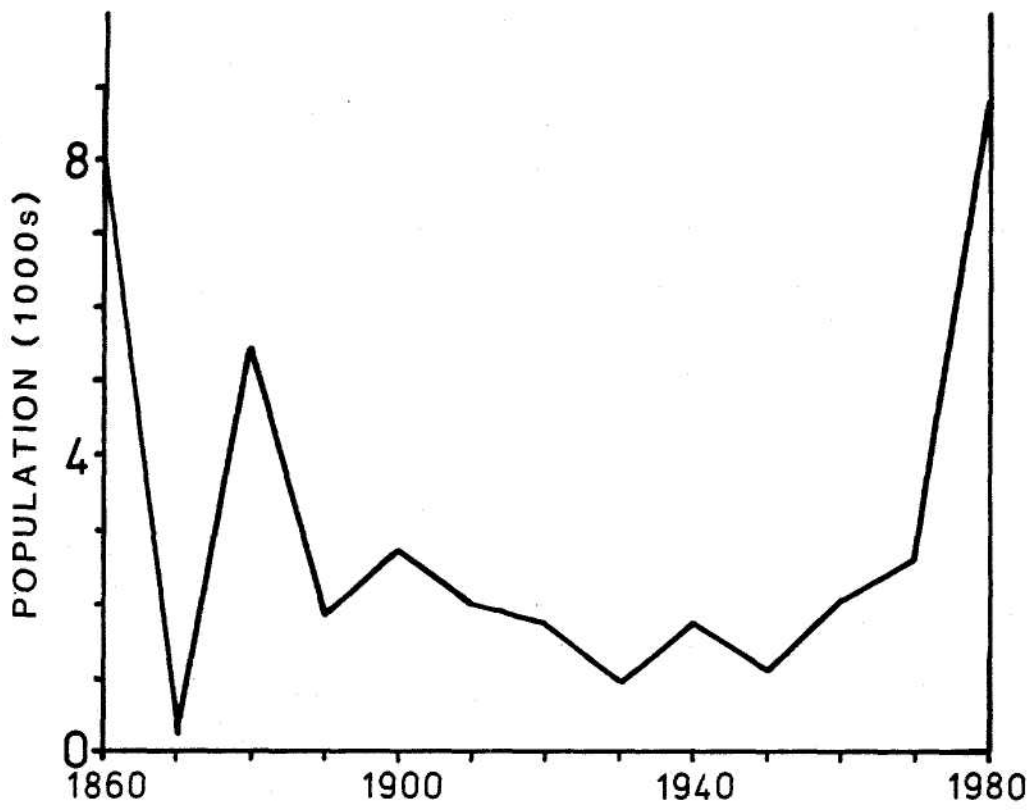


Figure 2.15: Summit study area: population 1860 - 1980

Sources: Census documents

by the mining industry; some visitors came for the scenery, and the two railroads planned a summer resort at Lake Uneva (Gilliland, 1980).

The second boom, based on hard-rock mining rather than placer gold, lasted somewhat longer than the first. However, by 1890, the county's population had shrunk to 1,906 (Census Office, 1895). In the early 1890s, the price of silver dropped considerably (Henderson, 1927: 541). In 1897, the county was the nation's largest gold producer (English and English, 1983: 82), but by 1900 most of the mining camps had disappeared; the county's population was 2,744 (Census Office, 1901). The turn of the century was also the time of the greatest number of ranches in the county. The earliest ranches had been developed along the Blue River and its tributaries, to supply the mining industry, but few lasted more than five years. The first patent along the Lower Blue was in 1883, and ranching grew in importance as mining became less reliable as a source of income; many mining families started ranches, particularly after 1910 (Clawson, 1984).

During the first four decades of this century, the population of Summit County and all of its settlements declined. Between 1898 and 1942, gold dredges operated in the valleys of the Blue and Swan Rivers and French Gulch (Pritchard, 1982). In 1925, the Climax mine opened on the south side of Fremont Pass, providing some employment for Summit County residents. However, ranching, combined with limited hardrock mining and logging for railroad ties and mine timbers, provided the economic base of the area. In 1911, the D & RG railroad ceased service, and the Colorado and Southern (formerly the D, SP *&* P) decided to run only goods trains. After a ruling by the Colorado Supreme Court, passenger service resumed in 1913, but the line was finally abandoned in 1937 (English and English, 1983). In 1930, the first year for which data are available, primary activities were dominant, accounting for 62% of employment (Bureau of the Census, 1932). Figure 2.18 shows the distribution of employment in this and subsequent census years. Although rail service disappeared from the area during this period, road access was improving, thus limiting isolation. By 1929, the road north to Grand County was open year-round (Heaton, 1929). The Shrine Pass road was passable to cars from 1931 (Lundell, 1931). In 1932, the Loveland Pass road was completed (Lundell, 1932) and, after frequent periods of closure for repairs, was first open year-round in 1938. That year, 600-700 cars crossed the pass (Harlan, 1938), and the summer population of the area increased substantially in that and subsequent years.

In 1940 and 1941, the other major roads out of the county, to the south and west, were completed (Jauch, 1941). The county's 1940 population was nearly double that of 1930, mainly the result of another boom: the construction of the Green Mountain Reservoir. Thus, nearly half of the employment was in the secondary sector (Bureau of the Census, 1943). After the dam had been completed, and a brief period of mining for strategic minerals for military

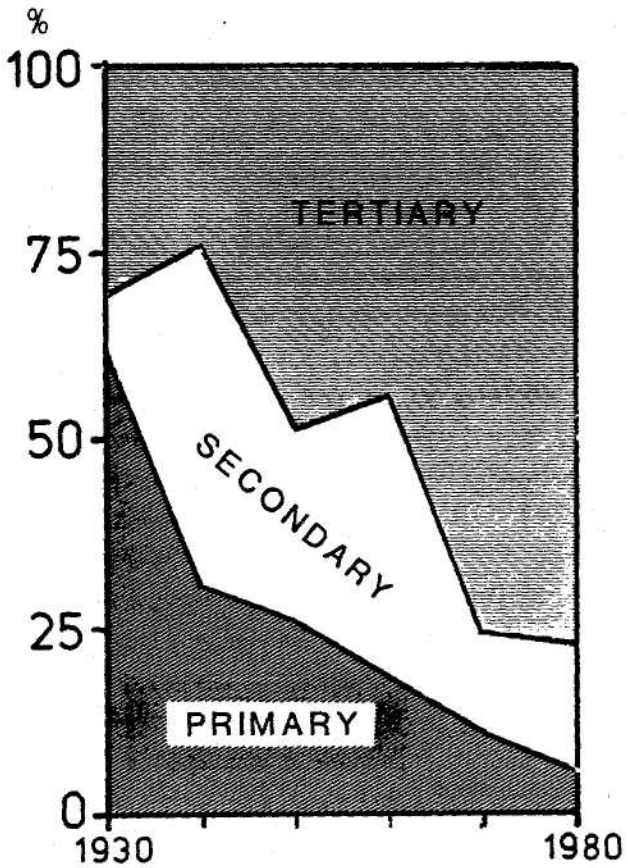


Figure 2.16: Summit study area: employment structure 1930 - 1980

Sources: Census documents

purposes was over, the county mainly returned to the mixture of activities which had sustained it before the War. However, the ranching industry had begun to decline, both because many of the county's largest ranches had been flooded by the reservoir, and because of the loss of rail service for transporting livestock and produce. In addition, increasing numbers of summer tourists were coming from the Front Range, permitting growth in Dillon and Frisco, which were substantially larger than before the War. However, although almost half of the workforce was in the service sector by 1950, the county's population had declined to almost pre-War levels (Bureau of the Census, 1953).

Although the late 1940s were generally a period of limited economic growth, a new industry started which subsequently transformed the area's economy: skiing. Organized recreational skiing in Summit County dates back to the beginning of this century (Gilliland, 1980), and ski runs had been prepared before the War on both Hoosier and Fremont Passes (Harlan, 1939). However, the first uphill transport was provided in 1946 when Arapahoe Basin opened. During the 1950s, both summer and winter recreation increased, as discussed in Chapter five and, in the latter part of the decade, another boom occurred: the construction of Dillon reservoir. As a consequence, the county's population had almost doubled by 1960, with most of the growth again in Dillon (where the construction crews were mainly based) and Frisco (Bureau of the Census, 1961).

The creation of Dillon reservoir has had a considerable influence on the development of the county. On one hand, it flooded much of the remaining good ranching land. This, combined with increasing land prices and financial insecurity, has led to the further decline of the ranching industry (Clawson, 1984). On the other hand, it provided opportunities for summer recreation which, combined with the developing skiing industry, have provided a new economic base for the area; since 1960, at least two-thirds of the county's employment has been in the service sector (Bureau of the Census, 1961; 1973; 1983). The second ski area to open was Breckenridge, in 1961. Breckenridge's population had been almost static since the late 1920s, but the new industry permitted growth: 39% from 1960 to 1970, a period in which the county's population grew by 28% (Bureau of the Census, 1973). The 1960s were also marked by the closure of the Wellington Mine, the last in the county, in 1964.

The rate of growth in the 1960s was eclipsed by that of the 1970s: between 1970 and 1980, the county's population more than trebled (Bureau of the Census, 1983), and subsequent annual growth has averaged 4.5% (Summit County, 1985). One stimulus to growth was the opening of two new ski areas; Keystone in 1970, and Copper Mountain in 1972. Probably more important, however, was the completion of the Eisenhower Tunnel on Interstate Highway 70 in 1973. This substantially improved access to the area, making it unnecessary to drive across Loveland Pass on the Continental Divide from the cities of the Front Range. As

discussed in Chapter five, the tunnel's completion permitted a rapid increase in winter recreation, which is now significantly more important to the economy than summer recreation. Two further stimuli were the rapid growth of these cities - the data presented for in Figure 2.13 for El Paso County provide an example - and Denver's improving access by air from the rest of the nation. All of these factors have combined to produce an economy based on recreation and tourism; Frick and Rubinstein (1982) estimate that tourism is the source of over 90% of local employment. This is visibly exemplified by the ski areas and other tourist infrastructure, together with extensive accommodation, permanent housing, and second-home developments.

2.6.4 Forest ownership patterns

Nearly all of the forests of Summit County are administered by the Dillon Ranger District of the Arapaho National Forest, whose boundaries are identical to those of the county. The National Forest lands occupy 126,315 ha: 80% of the county's area. This includes 48,272 ha of unforested land, mainly above timberline. The National Forest boundaries were essentially drawn around the boundaries of the forest area which existed at the turn of the century. However, in the southern part of the study area, these include many parcels of private land, mainly mining claims. Areas of privately-owned forest, whether on mining claims or on old homesteads in the valley bottoms, are not subject to federal policies, and are not considered in this study.

2.7 Comparison of study areas

Having described the study regions and areas individually, their similarities and differences are discussed below. This is necessary, because a comparative analysis of the development, implementation, and effects of forest policies must be based on a clear understanding of the parallels between study regions and areas. Similarly, differences must be taken into account since, if these were too great, the analysis could be meaningless. In terms of physical geography, the Alps and Rockies are comparable as young, temperate mountain systems which were glaciated during the last ice age. Consequently, all four study areas have relatively undeveloped, rapidly-drained soils, poor in nutrients. These characteristics, combined with a severe climate, considerably limit rates of tree growth and the range of species which can survive. The climate of both areas is described as "continental"; however, that of the Rockies is more so, with lower precipitation, and greater diurnal and annual temperature ranges. Pikes Peak contrasts with the other areas because of its irregular snow cover.

The difference in climates is also reflected by the fact that fire is a major natural ecological factor influencing the distribution of tree species in Colorado while in the Alps, where humidity is generally greater, it is not. The influence of anthropogenic fires on the forests of Colorado before European settlement is uncertain; however, the period of early settlement was marked by a large number of fires. In the Alps, people and their livestock have been major influences on the forests for centuries; a primary result has been the lowering of the timberline throughout the region by 200-300 m. Thus, as discussed in Chapters three and five, the forests of all four study areas have been subject to high levels of anthropogenic change, particularly during the last century.

Tree species in both regions are susceptible to both biological hazards (e.g., insect infestations, diseases, grazing, browsing) and natural physical hazards (e.g., windstorms, avalanches, rockfalls, floods) which can significantly affect successional change at various scales. However, an important difference between the two regions is that populations of game animals, protected by federals legislation, have a major effect on forest regeneration and growth in the Alps, as discussed in Chapter five. This factor is not important in Colorado. Finally, acid rain now plays a role in forest dynamics in the Alps, while it does not appear to do so in the Rockies. However, because of the considerable uncertainty about the influence of this factor and its recent recognition, it will not be considered in this study.

Turning to the study areas in the two regions, there are clearly some significant differences. The greatest difference between the areas in the Alps and those in Colorado is that the latter are an order of magnitude larger than the former. The reasons for this relate to relief and the density of settlement and use in the two

regions. Both of the Swiss study areas are characterized by steep-sided valleys with relatively narrow floors. The historic land use pattern was as described for the Aletsch area, with permanent valley settlements, and seasonally-occupied settlements on the slopes and Alp. terrace above. These were linked by a well-maintained, dense network of trails which passed through the forests. During the many centuries of human use, many areas of forest were cleared to provide timber or for grazing. Consequently, the forest as a whole was divided, through intensive use and by ownership, into relatively small blocks with well-defined edges. Typically, each of these has a specific name. Since the introduction of scientific forestry in the late nineteenth century, management has continued to be at a very small scale.

The scale of the landscape in the Colorado study areas is much greater. In the Summit area, valley floors are wider, and the relief of many of the mountain slopes is less. The Pikes Peak area is a single massif, much of which is characterized by steep slopes. The few settlements in both areas date back only to the mid-nineteenth century, and are all in the valley bottoms. The network of maintained trails and roads in the forests is far less dense than in the Alps. With the exception of the Pikes Peak road, major highways are restricted to a few valleys. Since the turn of the century, management has generally been very extensive; the forests of both areas have each been under the supervision of a single forester. Areas of intensive development are very limited: for instance, the ski areas in Summit County and the three routes to the summit of Pikes Peak.

A further set of contrasts between the two regions concerns the patterns of land ownership and use. The ownership pattern in the Swiss study areas is a mixture of private and public. Publicly-owned forests belong to the local community or corporations. In contrast, the public forests of the Colorado study areas are owned by the federal government. While this dichotomy would appear to cause severe problems in comparing policies for managing the forests in the two regions, these problems are alleviated by the fact that the Swiss forests fall within federal jurisdiction, as discussed in Chapter three. Privately-owned forests adjacent to the Colorado study areas, which are not subject to federal jurisdiction, are not considered in this study.

Some differences in forest land use have been discussed previously. However, it is important to note that the pattern of skiing developments is rather different in the two regions. In the Alps, most downhill skiing facilities are above timberline, mainly in the zone which was forest before anthropogenic deforestation. The lift networks have typically been developed piecemeal by a number of small corporations, whose shareholders may be local or from outside the area. Cross-country skiing is generally limited to the valley bottom, below the lower edge of the forest. Consequently, skiing is not of great concern to

foresters except in regard to damage to standing trees and regeneration by skiers.

In contrast, most skiing facilities in Colorado are below timberline. While the base areas of downhill ski areas are on private land, most ski runs and lifts are on land leased from the US Forest Service by the large corporations which run each area. Consequently, downhill skiing is a direct concern of the US Forest Service, as is cross-country skiing, most of which takes place on National Forest land. Similarly, foresters in Colorado are responsible for the development and maintenance of hiking trails, while in the Alps they are the concern of communal bodies. As a result of these differences, recreational use of the forests of the Swiss areas has been considered in this chapter; while it is considered in Chapter five for the Colorado areas. Finally, use of the forests by livestock has been important in both regions; this is no longer a major use, and will not be considered further.

As discussed in Chapter one, the choice of study areas was based on a number of criteria, including the availability of information and the desire to assess the influence of socio-economic factors on the development and implementation of forest management policies. From the descriptions of their histories, the study areas can be divided into two distinct pairs. The primary difference between these pairs relates to the development of access to major population centers. One pair of areas - Davos and Pikes Peak - was characterized by early linkage to a well-developed transportation network. In Davos, good road access was completed in 1859, and a railway in 1890. Similarly, the railroad arrived in Colorado Springs in 1871, the Ute Pass highway was completed in the same decade, and additional railroad lines were built in the 1890s.

In contrast, the Aletsch area was not linked to the national railway network until 1915, and a primary highway was not completed until 1955. The history of transportation to Summit County is somewhat different. It was connected to the regional railroad network in the 1880s. However, it was at the end of the line and, as soon as the railroad companies' profits began to drop, they tried to leave. One line provided limited services until 1937 but only because of government intervention. In the meantime, highway connections to adjacent areas were being made, with year-round access to the Front Range from 1938. However, easy access did not occur until 1973, with the completion of the Eisenhower Tunnel on Interstate 70.

The two pairs of areas can also be characterized in terms of the development of their economies and population. In the Davos and Pikes Peak areas, there was rapid population growth in the late nineteenth century as a service center developed. An important factor of this growth in both areas was tourism, linked initially to the healthy mountain climate. Around Pikes Peak, mining was a more critical factor during the booms of the late nineteenth

century. Davos continued to grow rapidly until the beginning of the First World War; the population of the Pikes Peak area declined after the turn of the century. The loss, however, was from Teller County, dependent on mining; the population of El Paso County continued to grow.

After the first phase of rapid population growth, rates of growth were slow in both areas until the end of the Second World War. Subsequently, the population of the Pikes Peak area has grown substantially. This has not been true in Davos, where the potential area for construction is limited by topography and the desire to maintain agriculture. Furthermore, construction in the last three decades has mainly provided tourist accommodation, especially second homes, rather than new housing for permanent residents. The stimuli to growth have also been different in the two areas. In Davos, winter tourism is the basis of the economy, combined with summer tourism, commerce, and conferences. The economy of the Pikes Peak area depends strongly on government employment and its position as a manufacturing and regional service center; summer tourism is no longer dominant, and winter tourism has never been successful because of the lack of reliable snow and competition from other areas. In both areas, employment has been dominated by the service sector at least since 1930.

The main similarities in the pattern of development of the Aletsch and Summit study areas are that employment in both areas was dominated by the primary sector at least until the Second World War, and that tourism has come to dominate the economy since the 1960s. A major difference, however, is that while the rapid growth of tourism is the first boom in the Aletsch area, it is the fourth in Summit County. The previous booms, each lasting less than a decade, related to mining, around 1860 and 1830; and to the construction of the Green Mountain Reservoir, around 1940. However, for the first half of this century, livestock grazing was the basis of the economy of the Aletsch area, and important in Summit County, where mining continued to contribute to the economy.

The rapid change in the two areas' economies was due to the combination of the new availability of a market for tourism, made possible by improved access, and the realization that the natural resources necessary to supply this market were available. In both areas, winter is the main tourist season; in Summit County, there is an unlimited range of summer activities as well. The development of a service economy was more rapid in Summit County, where the service sector came to dominate employment in the 1960s; this did not occur until the 1970s in the Aletsch area. In addition, while there has not been substantial population growth in the Aletsch area, this has occurred in Summit County. Both areas are characterized by a large stock of accommodation and second homes which are not used to capacity for much of the year. These have required the local communities to invest heavily in infrastructure during the period of growth which now, as also in the Davos area, appears to have slackened off. Consequently, the

secondary sector has continued to provide a significant proportion of employment.

In summary, the comparative analysis presented in the remainder of this study is based on the similarities between the study regions in terms of physical characteristics; considerable anthropogenic influences on the forests; and federal jurisdiction over forest management and use. The study areas form two distinct pairs, characterized by comparable trends in the development of access, population, and economy. Consequently, the analysis will consider and contrast the development, implementation, and effects of forest management policies both within and between regions, and between the members of each pair of study areas: Davos and Pikes Peak; Aletsch and Summit County.

3. EARLY DEVELOPMENT OF POLICIES FOR MOUNTAIN FORESTS

This is the first of three chapters tracing the development, implementation, and effects of forest management policies in the two study regions. This chapter, based on a review of pertinent literature, considers the development of policies up to the introduction of effective federal legislation around the beginning of this century. As discussed further in Chapter six, the introduction of this legislation can be interpreted as recognizing that the forests were common-property resources of national importance, providing not only market goods for local consumption, but also public goods at local, regional, and national scales.

In this chapter. Policy development is placed in context by examining changes in both the condition and uses of the forests and their perceived importance for providing various outputs. Policies at all levels from local to national are discussed; however, the influence of human activities at the local level (i.e., the study areas) is primarily considered in Chapter five. This chapter includes six sections. The first three sections present policy development in Switzerland at the communal, cantonal, national levels respectively. The two subsequent sections present the development of policies for Colorado and for federal lands in the U.S. as a whole. The final section compares policy development in the two regions.

3.1 Swiss communal regulation before 1798

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At the end of the last ice age, forests completely covered the Swiss Mittelland. Over the next few millenia, the forests were cleared as settlement and agriculture expanded; by 1200 A.D., the forest cover had been reduced to 40 percent of its former area (von Fellenberg, 1981). By this time, there had also been considerable deforestation in the Alps, although it was probably not as substantial as in the Mittelland, where the population pressure has always been greater, and harvesting is easier. The inhabitants of the Swiss Alps have long been aware of the long-term importance of their forests not only as a source of wood but also for protecting people and property from natural hazards, such as avalanches, floods, and rockslides. The first documented evidence of this dates back at least to 1298, when the Valaisan Commune of St. Maurice passed an order regulating the utilization of forests and pastures (Perrig and Fux, 1945).

The growing awareness of the need to regulate forest utilization is shown by a growing number of orders which individual Communes made from the early 14th century onwards. Many of these were probably restatements of earlier orders (Schuler, pers. comm. 1987). The most common form of order, dating from 1337, was the Bannbrief, which prohibited or limited certain or all uses in specific areas of forest (Bannwald) owned by the Commune.

Eventually, over 300 Swiss forests were subject to Bannbriefe. For some of these forests, wardens (Bannwarte) were employed to enforce the orders; the first in 1530 (Trorap, 1980b). In the Davos area, the first Bannwald was declared in 1496; by 1777, 26 had been declared, covering nearly a third of the forest area, especially above settlements (Gunter, 1980).

In spite of the recognition of the importance of the forests and growing numbers of regulations, the increasing requirements of the population for food and forest products led to extensive grazing in, and clearing of, the forests, particularly from the 15th century onwards. As a result of these activities, timberline was lowered by 200-300 m (Langenegger, 1984), and some high valleys were entirely deforested; attempts at reforestation were rare and generally unsuccessful (Tromp, 1980a). By the mid-16th century, a permanent wood deficit had developed, and the scope of local regulations expanded to limit sales, consumption and export of wood and wood products. For instance, in the Aletsch area, orders were made in 1515 (Morel) and 1525 (Greich) to limit the use of the forests (Perrig and Fux, 1945). The first limitation of clearing by the Commune of Davos was in 1595; by 1695, the Commune had stated its responsibility for protecting all private forests, which include over 80 percent of the forest area. Such measures had doubtful success in Davos (as discussed in Chapter five), or elsewhere in the Alps, since policing was inefficient. Huge quantities were used locally for agricultural and domestic purposes, firewood, and construction; and much wood was exported. The destruction of villages by fire was not an uncommon event, and rebuilding required yet greater quantities of timber.

Consumption continued to increase not only locally for construction, fuel, and agriculture, but also in neighboring countries as populations expanded and industrialisation developed in the 17th, 18th, and 19th centuries (Auer, 1956). Swiss alpine timber was used for fuel in the manufacture of glass, charcoal, lime, and steel, and also for ship-building throughout Europe (Tromp, 1980a; EAFV, 1985). The export of wood was facilitated by the many rivers flowing through the Alps and out of Switzerland, and provided an income to the owners of many forests - primarily monasteries, bishops, and members of the nobility - who usually lived in cities outside the mountains (Schuler, 1984). Increasingly, the inhabitants of the mountains had to walk far to find the wood they required, and were sometimes reduced to using peat, and even dried manure, for fuel (Ott, 1974). Throughout this period, natural disasters, particularly floods, increased in number and severity (Tromp, 1980a). The phase of independent communal regulation effectively ended in 1798, when the government of the Napoleonic Helvetic Republic took ownership of the forests from both the Communes and private landowners.

3.2 Swiss cantonal regulation before 1902

The history of Swiss cantonal regulation, prompted by similar concerns as prompted early communal regulation, extends back to the early sixteenth century, when the cantons were still sovereign states. The history of policies which regulated the cutting and sale of wood in the 13 states of the early Swiss Confederation (1520-1798) has been presented by Schuler (1980). However, the majority of the area of these states was in the Mittelland. The state of Bern was foremost in regulation, passing forest orders in 1592, 1725, and 1758, to encourage the maintenance of the forest area, new planting, and reforestation (Fankhauser, 1893). After the dissolution of the Helvetic Republic in 1803, responsibility for forestry reverted initially to the Communes, but soon to the Cantons; twelve passed forest legislation between 1800 and 1848 (Hagen, 1974).

During the early nineteenth century, domestic and industrial use and exports of Swiss alpine timber grew substantially, and prices rose (Tromp, 1980a). Yet this period was also marked by the development of public awareness, throughout Switzerland, of the importance of retaining forest cover in the Alps. The main impetus came from the first Swiss foresters, such as Kasthofer and Zschokke, who were mainly trained in Germany, and expended considerable energy on public education (Schuler, 1984). Their efforts were enhanced by concrete examples of the effects of deforestation and mismanagement; there were many natural disasters, particularly in the 1830s. During the same period, the the forests' aesthetic and recreational qualities were recognized by many authors (Hagen, 1974).

When the Confederation of Switzerland was constituted in 1848, the Cantons' responsibility for forestry was embodied in the federal constitution. Cantonal regulation by Valais and Graubunden, and its relationship to forestry in the Aletsch and Davos study areas, respectively, will be discussed as indicative of regulation between the end of the Helvetic Republic and 1902, when all Cantons were required to have their forestry legislation approved by the federal government. Hough (1878: 371) describes these Cantons' regulations as among the best in Switzerland at the time; some mountain Cantons had no, or few regulations.

3.2.1 Valais

Discussions about, and the history of, legislation for the forests of Valais are summarized by Perrig and Fux (1945), Wuilloud (1981), and Kempf (1985). Regulation in this canton was particularly important, since it is bisected by the glaciated Rhone valley, which is both an export route and has steep slopes conducive to various natural hazards. The first cantonal forestry police law dates from 1803 when general jurisdiction over the forests was taken by the Canton from the Communes. Considerable restrictions were placed on the cutting of timber (particularly

larches), and the cutting of small trees and the export of wood were banned. This was followed by a law on the protection and improvement of the forests (1826), in which the Communes were encouraged to plant trees and provide protection from avalanches and flooding; financial assistance from the Canton was made available for the protection of roads.

The 1827, 1829, 1832, and 1836 laws, on the sale of forests and the cutting, transport and export of wood, gradually increased the level of cantonal supervision of forestry and wood exports. These laws limited volumes of timber that could be cut, turned into charcoal, transported on the Rhone, and exported. By 1850, it had become apparent that, without a forest service, the existing forestry legislation was rather ineffective. Consequently, the existing legislation was superseded by a general forestry law, placing all forests under cantonal jurisdiction and establishing a department of forestry, consisting of forest inspectors. Communes were required to employ forest guards, whose appointment had to be approved by the Canton. In 1873, a new forestry law was passed, extending the previous law and creating the post of cantonal forest inspector above the regional inspectors.

3.2.2 Graubünden

The history of forest regulation and legislation in Graubünden is described by Günter (1980) and Rageth (1983). The first cantonal forestry regulations date back to 1822, when the Canton empowered itself to arbitrate complaints about deforestation. In 1827, the export of wood was prohibited, and the Canton took over competence for harvesting permits from the Communes. In 1836, all forests in the canton were divided into one of two classes. Those in the first class were important to protect roads and prevent flooding; a permit was required for clearing, and reforestation was mandatory. In 1839, the Canton passed its first forestry regulations and appointed a forest inspector and two regional foresters; a bailiff was to be appointed for each Commune. In 1858, a second set of cantonal regulations came into existence, placing all forests under cantonal jurisdiction, and dividing the canton into forest districts. The cantonal regulations were revised again in 1877, after the passage of the federal Forest Police Law in 1876, and again in 1886 and 1899.

3.3 Development of the Swiss Forest Police Law

The first attempt at national-level regulation in Switzerland occurred during the Helvetic Republic, when forestry was put under central direction, and each Canton was required to make a forest inventory (Grossman and Krebs, 1965). As described above, responsibility then reverted to the Communes and, as forest management became a political issue, the Cantons took over jurisdiction. In 1842, the Schweizerischer Forstverein (Swiss Forestry Association: SFA) was founded. It had few members, all trained abroad, since there was no training in forestry in Switzerland until 1855, after the 1848 federal constitution gave the Confederation competence to establish training in forestry and to construct public works (Tromp, 1980a). The members of the SFA soon decided that cantonal regulation was not going to be adequate to ensure the future of the mountain forests, and turned their attention to federal policymakers. Thus, one of the SFA's first products was its 1856 report to the Federal Council (Bundesrat), describing the dangers of mountain deforestation for water supplies and soil stability. The report also proposed that surveys of mountain forests should be prepared by cantonal forest services (where these existed), and in other cantons by a group of experts (Tromp, 1980a).

In 1858, the Bundesrat sponsored a survey of the conditions of the mountain forests, which was made by two hydraulic engineers, one geologist and two foresters. One of the latter was Elias Landolt, the President of the SFA and the first professor of silviculture in Switzerland. After three summers of fieldwork, the forestry report was published by Landolt in 1861. It is a measure of its general interest that, a year later, the original 360-page report was condensed to a 63-page version for general consumption (Tromp, 1980a). The main findings were as follows (Hough, 1878; Schoeffel, 1978):

- there is a direct relationship between deforestation and the irregular discharge of rivers;
- because the source areas of the most important rivers are in the mountains, mountain deforestation affects the whole country;
- the forests were overused: annual utilization (3.3 million m^3) was 32 percent greater than increment (2.5 million m^3);
- the forests had lost their resistance to avalanches and rockfall because of uncontrolled cutting;
- the treeline had been lowered, and regeneration of stands, particularly at high altitudes, was no longer guaranteed because of excessive and unauthorized grazing;
- ■■■■■-■ cantonal forestry legislation and manpower were insufficient to provide adequate management;
- the beauty of the landscape is affected by deforestation;
- for the economic survival of communities and industries, and also for the best possible uniformity of river discharge, improved management, resulting in a sustained supply of timber and firewood, is vital. Necessary changes cannot be brought about by prohibiting wood exports.

The accuracy of some of these findings was emphasized in 1868, when very severe floods caused over 14 million francs in damage and 50 deaths (Bloetzer, 1978). More than 3 million francs were donated, both in Switzerland and abroad, for the restitution of damages, of which 1 million was designated for a special fund for preventive measures (Hagen, 1974). Protective construction and afforestation projects had already been started in 1866 by the SFA, with assistance from Communes and the federal government. The experience of these projects provided the basis for the SFA's 1869 application to the Bundesrat to develop fundamental principles for maintaining mountain forests and watercourses, since the existing cantonal legislation was inadequate to fulfil this function (Schuler, 1984). This application resulted in the creation of the post of construction inspector in the federal Department of the Interior in 1870. This individual was responsible for projects in the Rhine, Rhone, and Jura basins, the SFA's construction projects, and the management of the special fund set up after the 1868 disasters. In 1871, channel alterations and construction relating to mountain streams, and the afforestation of their catchment areas, were declared to be public works of federal interest, and an annual sum of 100,000 francs was set aside for these purposes (Hagen, 1974)•

In the same year, the SFA applied to the Bundesrat to include an article concerning forestry and hydrological engineering in the "high mountains" in the federal constitution, specifying federal superintendence over these activities. The proposal was adopted as article 24 of the revised constitution passed in 1874. At the instigation of the experts who drafted the constitutional amendments, a federal forest inspectorate was created in 1875, affiliated to the federal Department of the Interior. Once federal responsibility for mountain forestry had been defined, the SFA submitted a draft Forest Police Law to the Bundesrat. The use of the word "Police" refers to federal superintendence of forests in the public interest, which may interfere with individuals' privileges and property. The objective of the law wets the creation of a healthy, resilient and, as far as possible, continuous mountain forest, to prevent damage from avalanches; protect settlements, transport routes and cultivated land from rockfall and avalanches; avoid soil erosion; and regulate water flows (Schoeffel, 1978).

Fifteen months after the SFA's draft had been proposed, it was passed as the 1876 Forest Police Law. This was not the first forestry protection law in the Alps; others had been passed in Bavaria and Austria in 1852 (Mayer, 1982) and France in 1860, (*Douguedroit, 1981). The most* important themes of this first Swiss federal forestry law, which placed the mountain and pre-alpine forests under federal superintendence, are as follows: - forests are classified into protective and non-protective, according to their functions. While this separation was assigned to the Cantons, the Bundesrat withheld the right to examine and approve these decisions. All mountain forests are

now classified as protective;
- the total forest area must not be decreased without cantonal consent; felling in protective forests requires a special permit from the Bundesrat;
- cleared and logged areas must be reforested; alternatively, a corresponding area, nearby, must be afforested;
- within protective forests, rights to additional uses (particularly grazing and the collection of forage), where responsible for the deterioration of forest condition, may be regulated, and at times discontinued or abolished;

to improve forest condition, the activities of state, communal and corporation forests are to be regulated through the introduction of management plans and on the basis of sustained yields which may not be exceeded without cantonal permission;
- afforestation of bare land to create protective forest can be demanded by cantonal or federal authorities; private land can be appropriated for this purpose.
- all forests must be surveyed;
- distribution of use or property rights in state, communal, and corporation forests, and the sale of these forests, are prohibited.

In brief, although the Confederation was empowered by article 24 of the constitution to regulate forestry as a whole, federal legislators limited themselves to issuing generally binding rules for forestry, retaining competence to review certain cantonal decisions, but leaving the Cantons considerable autonomy in regulating forestry management (Bloetzer, 1978). The Law emphasized the conservation and improvement of the protective function of the forests, particularly against flooding and avalanches. While the Law's scope, particularly with reference to protective forests, made major inroads into the principles of private land ownership, it received relatively little opposition. This can be attributed to the widely-recognised importance of maintaining forests in the public interest (Schoeffel, 1978).

It is also quite possible that there was little resistance to the Law because its implementation was left to the Cantons. The Law contained few specifics regarding the financial support of mountain forestry. The exceptions were for reforestation and afforestation; in all cases, work had to be undertaken by Cantons and approved by a federal forest inspector before the federal government would transfer subsidies to the Canton. Thus, although the Bundesrat promoted forestry, it provided few incentives. Also, the restriction of federal superintendence to only the forests of the "high mountains" presented problems which had been pointed out before article 24 had been introduced into the constitution: it was difficult to define the "high mountains", and many of the Mittelland's Cantons had inadequate forestry legislation in spite of similar conditions to those in the Alps; forest management should be national, rather than regional, in scope (Bloetzer, 1978).

In 1884, three Cantons presented a memorial to the Bundesrat, asking for financial support for forestry projects in the Jura, which was not covered by the Forest Police Law. This was followed in 1886 by a petition to revise the Law. In response, the Bundesrat ordered the forest inspectorate to investigate the condition of the Jura forests; the study was expanded in 1887 to the Mittelland's forests at the urging of the SFA. Also in 1886, a commission of the Nationalrat (National Council) had found that conditions in the mountain forests were generally similar to those reported to Landolt in 1861. Thus, the 1876 Law had not had its intended results; the Commission recommended that it include greater federal regulation, and be made applicable to all the Swiss forests in order to guarantee water flows as well as preventing floods. This required another amendment to the constitution, removing the specificity of article 24 to the "high mountains". This amendment was introduced in 1892 and passed in 1897 (Bloetzer, 1978).

In 1902, a new Forest Police Law was passed (Schoeffel, 1978). While the principal themes of the 1876 Law remained, the new one:

- stated federal responsibility for the wages of forestry personnel and for forest surveys;
- provided federal financial support for forest management through grants for access roads in public protective forests;
- encouraged consolidation of private forests; and
- required Cantons to bring their forestry legislation into agreement with federal legislation, to submit legislation to the Bundesrat for approval, and to develop forest services.

This Law provided a greater emphasis on the use and management of the forests than its 1876 predecessor, with far greater support from the federal government. It remains the basis for the management of the forests of the Swiss Alps.

3.4 Early Colorado State forest policies

Colorado was first recognized as a Territory in 1861. The only laws of the Territorial government pertaining to forestry concerned the prevention of wildfire. In the early 1860s, "the mountain-sides were found covered with thick forests." By 1870, it was estimated that "certainly one-third, possibly one-half [of the forests] in all the settled portions of the Territory [were] dead - killed by fire. . . . Some of this destruction [was] fairly attributable to accident, more of it to culpable carelessness, and yet more to criminal design". Large areas of forest were felled, with the timber often lying unused; only the best timber was used. Timber for mining camps and other settlements was becoming increasingly scarce, and prices were rising (Hough, 1878). In 1874, the Territory's governor recognized the importance of the forests and the risks posed by uncontrolled use and fire (Rocky Mountain News, 1/7/74).

In 1876, Colorado became a State of the Union, and was the first State to include a provision regarding forestry in its constitution, adopted that year. Section 6 of Article 18, on "Preservation of forests", reads:

> "The general assembly shall enact laws in order to prevent the destruction of, and to keep in good preservation, the forests upon the lands of the state, or upon lands of the public domain, the control of which shall be conferred by congress upon the state".

This unusual provision can be traced back to the efforts of Frederick Ebert, a Denver member of the constitutional convention who had trained as a forester in Germany. He had persuaded the convention to appoint a committee on "Forest Culture" which proposed a wide range of activities for the protection, use, and administration of the public forests, which were still part of the "public domain", under the jurisdiction of the federal' government (Morrill, 1927). The proposals, which reflected Ebert's German training, were not included in the constitution, as he had recommended; Section 6 represented the limits of his success in influencing forest policy.

In addition, Ebert drafted a memorial which was sent by the convention to the U.S. Congress. This reflects the current attitudes in Colorado - at least of state legislators - to the forests. The aim of the memorial was to ask Congress to transfe- jurisdiction over the forests in the public domain to the State Such action was necessary because "the rapid increase of our population, the spread of industries, the building of extensive railroads, the reckless devastation of timber in cutting and transporting it, and the frequent fires mostly caused by carelessness, and often raging for months, threaten to soon destroy our forests" (Wilson, 1876).

These conditions were perceived to be likely to lead to a number of results, including timber famine, floods, loss of water for irrigation, and irregular streamflow and rainfall. In

consequence, there appeared to be considerable risk that all aspects of the economic life of the state - forestry, mining, agriculture, industry, and construction - would suffer. The justification for transfer was that the federal government was making no attempt to protect the forests and that it was in the State's best interests to do so. As discussed below, the first point was basically true, but Congress decided to ignore the memorial. Yet people in Washington were aware of the conditions of Colorado's forests: "In 1869 fires prevailed extensively among the mountains in Colorado. ... It is estimated by well-informed persons that fully one-third of all the timber accessible among the mountains in the State has been burned over and killed by fire within the last six years" (Hough, 1882).

In spite of the State's professed interest in forest management, no more memorials were sent to Congress, and no forestry legislation was passed until 1885. This law created the posts of Forest Commissioner and designated county commissioners and road overseers as forest officers, to act as a police force "to prevent depredation and fire, and to encourage and promote forest culture" (Ensign, 1885). However, the legislature still was not supportive in practical terms; no appropriations were made for these officials' activities. The passage of the law resulted from the activities of the Colorado State Forestry Association (CSFA), which was founded in 1884. It was "composed chiefly of civic-minded urban businessmen and a handful of teachers and scientists" (McCarthy, 1977), including Edgar Ensign, who was active in publicizing the importance of forest management, particularly in a series of thirteen articles in the Colorado Springs Gazette from October 1884 to February 1885.

Ensign became the first president of the CSFA, and played a crucial role in drafting the forestry bill, submitting it to the legislature, organizing petitions in its support, and lobbying legislators (Story, 1977). He was subsequently appointed Forest Commissioner. In his first report (Ensign, 1885), he identified illegal cutting of timber as a major problem in the public forests, but described the cutting of railroad ties as the major source of destruction. National awareness of the condition of Colorado's forests continued to grow, particularly as the 1886 meeting of the American Forestry Congress was held in Denver, with visits to other parts of the state. The Congress' resolutions identified the importance of preserving forests to ensure reliable streamflow, and recommended that public domain forests should be ceded to the states, perceptions that are repeated throughout Ensign's second report (Ensign, 1886). This also included a survey of "intelligent persons. . . who were well acquainted with the forests and streams of their particular localities", who identified various factors as "special dangers threatening forests", especially fire, railroads, lumbering, and wood for fuel.

In 1887, the legislature decided to provide a salary and travel money for Ensign. The major part of his next report described

"destructive agencies": forest fires, use of timber by railway and telegraph companies, charcoal manufacture, ore smelting, mining, and manufacture of lumber (Ensign, 1888a). Fire, though a major cause of destruction, was perceived as decreasing in comparative importance. The growing use of timber for railroad ties was viewed with great concern, especially as young, growing trees were mainly used; the use of dead trees was recommended. Large amounts of waste, remaining after logging, increased the danger of fire. Charcoal manufacture was also an important industry, employing about 3,500 people; mostly using young timber, particularly from public forests. A survey of charcoal manufacturers elicited responses from only a third of the respondents; "the statements given were usually very meagre. As in many other instances involving a large consumption of timber, the responsible parties exhibit a reluctance to furnish information which they fear may be used to their prejudice". The charcoal was used for smelting; also a growing industry. Mining continued to use huge quantities of wood; supplies had been exhausted in many areas.

Ensign resigned in 1890, frustrated by lack of response to his proposals for legislation, forest management, and policing (Ensign, 1888a) . The state government continued to pay only token attention to forestry, and did not appoint a new Commissioner; forestry was not mentioned again in a speech by a governor until 1895, and none ever actively sought forestry legislation (McCarthy, 1977).

3.5 Development of U.S. Forest Reserve and Organic Acts

Ensign's resignation as Forest Commissioner of Colorado derived from his realization that the Colorado legislature was going to do nothing to protect or manage the public forests, although many members felt that they should be administered and actively protected by the state (Ensign, 1886). The CSFA had despaired of state administration in 1886, asking Congress "to take measures to save the federal forests" (Morrill, 1927). By 1890, when Ensign focussed his attention on obtaining federal protection of the public forests, over 200 bills to give such protection had been introduced in Congress; some had passed in either the House or the Senate (Dana and Fairfax, 1980; Kirkland, 1971).

In 1891, Congress passed the Creative, or Forest Reserve, Act as Section 24 of the General Revision Act. Section 24 reads:

> "That the President of the United States may, from time to time, set apart and reserve, in any State or Territory having public lands bearing forests, in any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations, and the President shall, by public proclamation, declare the establishment of such reservations and the limits thereof" (26 Stat. 1103; 16 USC 471).

This was not the first federal forestry legislation, and Ensign was not the Creative Act's prime proponent. However, he had certainly been instrumental in its development, particularly through his "Report on the Forest Conditions of the Rocky Mountains" (Ensign, 1888b). This was one of a series of reports on forestry and forests prepared under the auspices of the federal government before the Act's passage, of which the earliest and most wide-ranging are those of Franklin Hough (1878, 1880, 1882); both his 1878 and 1882 reports described forest conditions in Colorado, as cited above. Hough's reports were made possible by his appointment to "study and report on forest supplies and conditions" in a rider attached to the 1876 agricultural appropriations bill (Steen, 1974). His work was supported by small amounts from the general appropriations bills of the next four years (Clepper, 1971).

The development of early federal forest policy has been discussed in detail by many authors (Fernow, 1913; Ise, 1920; Cameron, 1928; Smith, 1930; Dana, 1956; Kirkland, 1971; Miller, 1973; Wengert et al., 1979), and will be considered only briefly here, with emphasis on Colorado's forests and the role played by Coloradans. Two organizations were crucial in promoting the cause of forestry at the federal level: the American Association for the Advancement of Science (AAAS) which sent a memorial, supported by President Grant, on forestry and forest preservation to Congress in 1874; and the American Forestry Association (AFA), founded in 1875. The 1874 memorial eventually resulted in Hough's appointment in 1876, after two failed bills, which were "less the victim of Congressional opposition than of indifference"

(Clepper, 1971). In 1877, the Commissioner of the Land Office instituted a corps of special agents to "suppress depredations of timber on the public lands." They were not very successful, having almost no power and being spread very thinly; for instance, they recovered timber worth less than two percent of the market value of stolen timber between 1881 and 1887, barely covering the costs of administering the program (Fernow, 1888).

The next piece of federal forestry legislation with relevance to Colorado's forests was the 1878 Free Timber Act, which allowed residents of various western states, including Colorado, to cut timber on mineral lands for building, agricultural, mining, or other domestic purposes. This Act reflects the interests of a very different group of individuals than those in the AAAS, the AFA, or the CSFA. It was introduced by Colorado's Senator Chaffee, and pushed through in the House by Colorado's Patterson, among other western representatives (Ise, 1920). Conservationists in Colorado were mainly urban professionals from the Front Range, as well as intellectuals and educators. The congressional delegation, in contrast, was strongly supportive of, and responsive to other groups: miners, cattlemen, farmers, and homesteaders (McCarthy, 1977). These groups had a very different perception of Colorado's forest resources: they appeared to be inexhaustible, ready to be used by westerners rather than burnt by forest fires, and of no apparent interest to the federal government in the foreseeable future (Ise, 1920).

The Free Timber Act was thus an attempt to allow use of the forests for the economic development of the western states. While it included a clause giving the Secretary of the Interior control over licenses to cut timber, its effect was to permit unrestrained use of forest resources, particularly since "mineral lands" were undefined, and there were never more than 55 agents to enforce its provisions nationwide (Ise, 1920: 65). Even before the Act was passed, both Commissioner of the General Land Office (GLO) Williamson and Secretary of the Interior Schurz advocated its repeal because they realized that it could not be effectively implemented.

The Act was amended by the 1891 General Revision Act, becoming applicable to all public lands in Colorado, after many unsuccessful efforts by various western congressmen, including Colorado's Representative Symes and Senator Teller, from 1880 onwards (Egleston, 1888). Teller, a mine owner, seems to have had little interest in forest preservation, and never mentioned the subject in his annual reports as Secretary of the Interior from 1882 to 1885. An example of his support for consumptive use of forests during this period was his interpretation that the Right-of-Way Act's provision allowing railroads to take timber for construction "adjacent to the line of road" applied within fifty miles of the track (Ise, 1920).

Notwithstanding the passage of the Free Timber Act in 1878, the conservationist movement began to have some influence in Congress

from the 1870s onwards. Like today's environmentalist movement, it included groups with various objectives (Gilligan, 1953). One group was based primarily in the East, although it had some Western support, particularly in California where the Sierra Club was formed in 1892. The primary objective of this group was preservation of forests for their aesthetic, recreational, wildlife, and wilderness values (Nash, 1982). Another group viewed the forests primarily in economic terms, as reflected in the 1876 memorial sent by the Colorado constitutional convention to Congress. This group was predominant in the West, but had many eastern proponents who had been involved in the development of governmental control of eastern forests (Cameron, 1928).

In spite of their differences, conservationists generally agreed that the federal government should regulate the use of public forests; they had considerable support from Secretary of the Interior Schurz in the late 1870s. The first evidence of their lobbying was a bill introduced in the House "by request" in 1876 "for the preservation of the forests of the national domain adjacent to the sources of the navigable rivers and other streams of the United States" (Dana, 1956). A more far-reaching bill, proposing the formation of a forestry corps to protect public forests, was introduced in the Senate in 1878 (Kirkland, 1971).

During the 1880s, a considerable volume of information regarding forestry in Europe and the conditions of the western forests was published by government sources and in magazines and newspapers (Ise, 1920). The Public Land Commission (PLC) was created in 1879, and presented its first report in 1880; Colorado was one of the states visited. Forests are discussed in many of the 74 pages of testimony by Colorado residents in the Commission's report. The conditions and use of the forests are much as discussed in Ensign's and Hough's reports: use of only the best timber; huge harvests for mining, railroads, and charcoal manufacture; many fires, often intentionally set; and little regeneration. A constant theme was that forests should be leased or sold to local people, since buyers were available and willing; something stressed by one of the special agents, who was quite overwhelmed by his duties (Public Lands Commission, 1880: 308-310).

The federal Division of Forestry was established as part of the Department of Agriculture in 1881, and given statutory recognition in 1886, when Bernhard Fernow, a German immigrant trained as a forester, became its chief. However, Fernow was understandably skeptical of his Division's efficacy for administering the public forests while the Department of Interior had jurisdiction over them (Fernow, 1887). Publications of the Division of Forestry, GLO, PLC, and AFA during the 1880s stressed the continuing theft and overcutting of timber, and fires in the public forests of the West. The most complete of these reports was Ensign's (1888b), covering Idaho, Montana, New Mexico, Utah, and Wyoming as well as Colorado. However, most of the report was based on correspondence, rather than personal observation; the

information for Colorado is essentially the same as in his report as Forest Commissioner (Ensign, 1888a).

In 1890, President Harrison presented memorials, submitted by the AAAS and the AFA, urging the adoption of a national forest policy, to Congress. These memorials emphasized the importance of the public forests of the West for supplying timber and, especially, for providing a reliable water supply for agriculture and settlement (Wengert et al., 1979). However, in spite of the growing political support for federal forestry legislation, most authors agree that the Creative Act passed primarily because it was part of a very long bill submitted to Congress at the end of a session (e.g., Ise, 1920; but see Dana and Fairfax, 1980).

Section 24 was added to the 1891 General Revision Act while it was being considered by a conference committee with conservationist leanings; a procedure contrary to the rules of Congress. The final bill was not even printed before Congress passed it; Section 24 was never debated in the Senate, and encountered little opposition in the House (Kirkland, 1971). Thus, as in the Colorado legislature, there was no overwhelming support for forestry in Congress; this critical piece of legislation passed as the result of a "long chain of peculiar circumstances" (Ise, 1920). Under its provisions, President Harrison set aside 4,849 square miles (12,558 sq. km) of forest in five reserves in Colorado by the end of 1892, including the Pikes Peak Timber Land Reserve (288 square miles; 746 sq. km).

The proclamation of all of the Colorado reserves originated with petitions from local residents, usually with assistance from Edgar Ensign, to Secretary of the Interior Noble. The idea of federal reserves was not strongly supported by Colorado state politicians; for instance, Governor Routt refused to support the proposal for the White River reserve, and House Speaker Eddy mounted a major campaign against it after its proclamation. Eddy had long supported management of Colorado's forests by the state for the benefit of local people (Ensign, 1886). Within the state, urban and agricultural interests from both the Front Range and the Western Slope were generally in favor of the reserves, while many miners, cattlemen, and homesteaders, such as the members of the Western Colorado Congress, were opposed. In effect, the division stemmed from the fact that the former were primarily concerned for their water supplies; the latter regarded the reserves as representing a loss of freedom, limiting their use of public land for timber, grazing, and mining. In Congress, Colorado Representative Bell introduced an unsuccessful bill to abolish two of the reserves in 1893 (McCarthy, 1977).

Although there was opposition to the Creative Act and the reserves in both Colorado and Congress, it was not. particularly substantial. The main reason is probably that the Act had very little effect without appropriations for its implementation; logging and fires continued unabated in the reserves. This fundamental weakness was noted by President Cleveland, who

proclaimed two reserves just after being elected in 1892, but would not proclaim any more without legislation to protect them; a sentiment shared by the AAAS, the AFA, and officials of the Department of the Interior (Kirkland, 1971). By 1897, the year in which McKinley became President, 27 bills dealing with forest reserves had been introduced in Congress (Dana, 1956), culminating in the Organic Act:

> "to improve and protect the forest within the boundaries [of reserves], or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber. . . [though] it is not the purpose of. . . the Act. . . to authorize the inclusion therein of lands more valuable for the mineral therein, or for agricultural purposes, than for forest purposes" (16 USC 475).

Bills to protect and administer the forest reserves were introduced from 1892, one by Senator Townsend of Colorado (Ise, 1920). The Colorado delegations of the early 1890s, however, were generally opposed to protection, particularly Representatives Bell and Shafroth and Senators Wolcott and Teller. The latter was in a particularly strong position, as a member of the Public Lands Committee, of which he had been a member in 1891; though he was not a member of the conference committee which introduced the Creative Act. The bill which formed the basis of the Organic Act was first introduced by Representative McRae of Arkansas in 1893. It proposed that timber on the public domain should be sold to the highest bidder at not less than appraised price; that troops should be used to protect the reserves; and that agricultural land within the reserves should be made available for agriculture. The bill was strongly opposed by westerners, including the entire Colorado delegation, who felt that timber should be freely available for local use and that the bidding system would lead to exploitation, and probably over-use, by logging companies. In addition, to accept the bill would implicitly recognize the legitimacy of the reserves. The bill was shelved (McCarthy, 1977).

In 1894, Secretary of Interior Smith asked the Secretary of War to provide troops to protect the reserves, as had already been dome for some of the national parks. He refused, in spite of widespread support for the idea (Kirkland, 1971). The McRae bill was revived, and passed the House after major amendments, allowing non-local concerns to buy only dead and mature timber and almost unrestricted mining. Even Bell voted for it, but it was killed in the Senate, where Teller proposed another bill, which emphasized that, while the reserves were important for water supplies, their timber should only be for local benefit. Teller's bill passed the Senate, but the House never voted on it. The amended McRae bill was re-introduced in both 1895 and 1896, passing the House with the support of Bell and Shafroth, but did not pass the Senate on either occasion (Ise, 1920).

By 1896, President Cleveland, together with Interior and Agriculture officials and the AFA, who all supported the amended

McRae bill, were very frustrated with the lack of progress in forestry legislation. Pressure from all of these sources led Secretary Smith to create a commission of the National Academy of Sciences to develop a national forestry policy (Kirkland, 1971; Steen, 1976). Congress obliged by providing $25,000, and the Commission spent three months in the West, visiting most of the existing 16 reserves, including those in Colorado. On their return, the Committee made a number of recommendations, some of which found their way into the Organic Act (Wengert et al., 1979). They also proposed 13 new reserves (none in Colorado); which Cleveland proclaimed ten days before he left office. This resulted in considerable outcry in the West, though many westerners supported Cleveland's unilateral action (McCarthy, 1977). The Senate responded by amending the 1896 Sundry Civil Appropriations Bill to authorize the President to modify or abolish forest reserves. Congress passed the amended bill; Cleveland vetoed it (Ise, 1920).

Since Cleveland's veto left the government without funds, President McKinley called a special session of Congress as soon as his term began. The appropriations bill was reintroduced, and Senator Pettigrew of South Dakota added an amendment with respect to the forest reserves which would temporarily suspend Cleveland's 13 reserves; allow free use of timber, prospecting, and mining by local people; and protect the forest to provide reliable supplies of water and timber. The amendment was nearly shelved because its introduction violated standard procedure, ana was further revised during its passage through both houses; the debate split along East-West lines, with westerners strongly in favor. While the House rejected the amendment in spite of Bell and Shafroth's substantial efforts (McCarthy, 1977), it survived the conference committee almost unchanged. The conference report passed both the Senate and the House, and the amendment became the Organic Act (Kirkland, 1971), although no funds to carry it out were appropriated until the 1898 Sundry Civil Appropriation Act passed (Cameron, 1928).

3.6 Early policy development; comparative analysis for the Swiss Alps and Colorado Rockies

In brief, the constellation of conditions leading to the development of the first policies for the forests of the Swiss Alps and the Colorado Rockies appear to have been rather similar, in spite of significant differences in forest ownership patterns and natural conditions of climate and ecosystem development. The length of period of policy development in the Alps was significantly longer; in 1861, when Colorado was just being settled and became a Territory, the Swiss Confederation, composed of states which had previously been independent for centuries, was already 13 years old. While the inhabitants of the Swiss Alps had been aware of the effects of heavy utilization of wood from, and grazing in, their forests for centuries, a laissez-faire economy persisted and grew stronger into the nineteenth century, linked particularly to industrialization and the spread of railroads. The results were increasing prices for, and scarcity of, timber, and frequent natural disasters: avalanches, floods, and rockslides. Wood scarcity also led to higher prices in the Rockies, but disasters tended to be of a different kind - fires - reflecting the arid environment of this region; though interruptions of the hydrological cycle were also recognized to result from deforestation.

While a general awareness of the importance of maintaining mountain forest cover clearly developed in the Alps before the advent of scientific forestry, it was not until trained foresters began to invest their energy in public education that any sort of coordinated policy development began in either region. Initially, such individuals worked alone; for instance, Kasthofer, Landolt, and Zschokke in Switzerland, and Ebert and Ensign in Colorado. The concept of forestry which all of these individuals espoused had been developed in Germany; a concept to which U.S. citizens involved in making federal policy, such as Schurz, Fernow, and Pinchot, also subscribed. Following the first efforts of these individuals, professional associations were formed at both local and national levels. While these associations often gave their initial emphasis to developing regional policies, they soon realized that coordinated national-level policy was necessary.

The major obstacle which had to be overcome in developing federal policy for the forests of the Swiss Alps was that most of the forests were owned by Communes which had a long history of local autonomy. The arguments of the early foresters in favor of protecting the forests were undoubtedly instrumental in convincing some of the mountain Cantons to pass forestry legislation, though this can also be seen as a continuation of the earlier communal policies, in an era where Switzerland's integration into the international economy was putting ever greater pressure on the forests. However, the SFA recognized, soon after its foundation, that coordinated national policy was vital. As in the U.S., the first federal action was to support studies of forest conditions.

It may be recognized as fortunate that the release of Landolt's report in 1861 was followed, within a decade, by proof of his most critical findings. The forestry profession capitalized on the disasters of 1868, managing to amend the constitution within six years, thus allowing the passage of the Forest Police Law in 1876. According to recent authors (e.g., Schoeffel, 1978), there appears to have been little opposition to the development of a forest policy which ran counter to cherished concepts of property rights and local autonomy. However, though the 1876 Forest Police "Law provided a basis for protecting the forests, it did not ensure their long-term management because the Cantons were left too much discretion, and the federal government assumed little financial responsibility for forestry. Long-term management was only made possible by the continued efforts of the SFA and the 1886 commission of the Nationalrat. These resulted in the constitutional amendment of 1897 and the passage of the 1902 Law, providing for substantial federal financial support for forestry, and greater coordination of cantonal forestry legislation and administration.

The introduction of federal policy for Colorado's forests was aided by the fact that the federal government still had jurisdiction over the majority of the forests, as was true in most of the western states. Had this not been so, the Creative and Organic Acts would never have been passed; as it was, there was considerable opposition to forest reservations from Colorado politicians at both the state and federal levels. Such opposition reflected the mood of large parts of their constituencies, who were interested in the utilization of the forests for short-term economic growth, and felt that the forests would be best administered by the State of Colorado for the people of Colorado, In contrast were the "conservationists", whose main interest was the continued supply of water for agriculture and urban centers and, to a lesser extent, of wood for various uses; they recognized that uncontrolled logging and fires had removed most of the valuable timber within a few decades of settlement.

Although the public relations efforts of the early American foresters were not buttressed by the natural disasters which helped to accelerate the pace of Swiss legislation, such events and legislation could be cited as proof that federal legislation was needed for the forests of the Rockies. The argument that forests were necessary to protect watersheds and provide reliable water supplies eventually won over even the congressmen initially opposed to reservation. However, it must be recognized that the Organic Act was a compromise, which included many concessions which were initially unpalatable to both the forestry profession and congressmen (mainly from the East) with conservationist leanings. The passage of the Creative and Organic Acts resulted partly from political legerdemain; both were amendments to major bills and were introduced in unorthodox fashion. As in Switzerland, the initial legislation, though of apparent good intent, suffered from lack of financial support; no funds were

passed to implement the Creative Act, and funds to implement the Organic Act were not appropriated until a year after its passage.

Thus, at the turn of the century, local opposition to federal jurisdiction over the forests of both study regions had been overcome, and federal legislation existed to protect and manage these forests, with the avowed intention of ensuring reliable supplies of both wood and water. Forestry was a growing profession, supported and encouraged by governments, who also provided financial support to police the forests. The significant pieces of legislation - the 1902 Forest Police Law in Switzerland and the 1897 Organic Act in Colorado - officially guided forestry in both regions well past the middle of the twentieth century. The remainder of this study will consider how the implementation of these laws and the policies which followed them affected the forests of the study regions and their outputs.

4. POLICY DEVELOPMENT FOR FEDERALLY-PROTECTED FORESTS

This chapter considers the development and implementation of policies for the management of the forests of the study regions and areas since the introduction of the effective federal legislation described in the previous chapter. For each region, the presentation is divided into three parts. The first describes the organization of the primary agency (Colorado) or agencies (Switzerland) responsible for developing and implementing policies for forest management. In addition, it must be recognized that many other entities are involved in these activities: including legislators, other government agencies at all levels, and representatives of industrial, environmental, and other public and private organizations. The second considers the development of national policies and their implementation through the development of regional policies. For the Swiss Alps, these consist of cantonal legislation and policies. The third considers the implementation of national and regional policies for planning through the development of plans for the management of forests in the four study areas.

For the Swiss Alps, the analysis considers the period from 1902 to the present. Section 4.1 presents the organizational structure of the forest management agencies, followed by a discussion of federal and cantonal legislation and policies. Section 4.2 discusses past and current forest management plans for the Swiss study areas. For the Colorado Rockies, the analysis is divided into two parts: before and after 1960. This distinction is made because, in 1960, a major change in legislated policy for the management of the National Forests of Colorado took place. This is in contrast to Switzerland, where, as mentioned in the previous chapter, the 1902 Forest Police Law is still the legislated basis for forest management. Thus, section 4.3 presents the evolution of the organizational structure of the US Forest Service, and discusses federal policies and the implementation in Colorado until 1960. Section 4.4 discusses plans for the management of the Colorado study areas until 1960. Section 4.5 discusses the development of federal legislation and policies, and their implementation in Colorado since 1960, and section 4.6 discusses plans for the management of the Colorado study areas since 1960.

For the Swiss Alps, the analysis is based on the review of literature and government policies, and interviews. For Colorado, the analysis is based on comparable sources, and also archival research, permitting a more detailed analysis of the ways in which changing demands on the forests influenced regional policy development. The final section of this chapter is a comparative analysis of policies and plans for forest management in the two regions during this century.

4.1 Development of legislation and policies for the management of the Swiss mountain forests, after 1902

As discussed in the previous chapter, the 1902 Forest Police Law provided not only objectives for the management of the Swiss mountain forests, but also some financial support to ensure their implementation. While the Bundesrat retained primary responsibility for the supervision of the forests, the Cantons were responsible for developing legislation, policies, financial support, and manpower to carry out the objectives of the Forest Police Law. This main purpose of this section is to outline the development of both federal and cantonal legislation and policies since 1902; their implementation in the development of management plans and activities pursuant to these will be considered subsequently. First, however, the structure of the organizations which develop and implement policies will be outlined.

4.1.1 Organizational structure of forest management agencies

Forest management policies are developed and implemented by a hierarchy of agencies of federal, cantonal, and local governments. The federal agency is the Federal Office for Forestry and Landscape Protection (Bundesamt fur Forstwesen und Landschaftsschutz; BFL), which is part of the Department of Interior; there is also a federal forestry research institute (Eidqendssische Anstalt fur das forstliche Versuchswesen: EAFV). The BFL acts in both *advisory*.....and regulatory capacities, developing policies but also ensuring that they are adhered to. Each of the BFL's six forest inspectors is responsible for forestry in between four and seven cantons.

Each canton's forest service consists of a forest inspectorate, headed by the cantonal forest inspector, and regional forest offices; a regional forester is in charge of each region (Kreis). The inspectorate primarily develops policies and has jurisdiction for permitting activities which do not have to be referred to the BFL. The regional foresters are responsible for ensuring compliance with federal and cantonal laws, and also for providing assistance with planning and management to district (Revier) foresters; The latter are generally not cantonal employees, usually being employed by the owners of the forests they manage. There is "considerable variation between cantonal legislation regarding the employment of district foresters; assistance for wages and training may or may not be provided and, in some cantons, forest owners are legally required to employ a forester. District foresters may be part- or full-time, and responsible for private, cooperative, or communal forests. In some cases (e.g., Aletsch), one forester is responsible for the forests of a number of Communes; in others, the Commune may employ many foresters (e.g., three in Davos). District foresters' responsibilities are to implement forest management plans, with assistance from members of the cantonal forest service.

4.1.2 Development of federal legislation and policies

The 1902 Forest Police Law is still the primary piece of legislation guiding forestry in Switzerland. However, many of its provisions with regard to mountain forestry have been changed through partial revisions and laws. The first of these was the 1923 resolution, through which federal grants for access roads and other wood transport facilities were extended to private non-protective forests, to provide an extra stimulus to their owners for improved utilization of timber. In 1929, federal compensation to the owners of forests subject to property restrictions was raised. Limits for federal grants for access roads and other wood transport facilities were specified, and provision of these grants was linked to cantonal grants.

In 1945, the regulations for the consolidation of private forest lots were extended so that public forests could also be included in the process. Previously, only jointly-owned lots had been eligible. In 1951, increased federal grants for afforestation and construction in avalanche hazard zones and protecting transport infrastructure were made available, tied to the provision of cantonal grants. In 1953, federal grants for the wages and insurance of forestry personnel were cancelled; Cantons became entirely responsible. The 1955 law provided for subsidies for measures to protect forests from damage and diseases dangerous to the public. To encourage the establishment of protective forests, financial support was given for fencing and other measures to protect plantations from grazing animals. Seeds and plants to be used in existing forest and for afforestation were restricted to those of known provenance which were suitable to the site.

In 1969, revisions were made with respect to federal grants for afforestation, and the construction of control structures, access roads, and other wood transport facilities. The law on investment credits for mountain forestry, of the same year, provided for no- or low-interest loans to improve the conditions of public and private forestry enterprises through planning, rationalization, and the purchase of vehicles, machines and other equipment. The 1971 law delegated jurisdiction for clearings in protection forests, up to 30 ares in area, to the Cantons, which also had to develop guidelines for dealing with such applications. The most recent piece of legislation was the 1984 resolution, which provided for federal grants, linked to cantonal grants, for measures to protect forests against the effects of air pollution, diseases and pests. The transport and harvesting of affected wood were both included, as is the removal of trees downed or broken by natural hazards.

In summary, the revisions of the past eight decades changed the overall policies with regard to the mountain forests in two main directions. First, additional financial support was provided for various activities intended to improve the management of the forests through rationalization of ownership, increased access,

protection against natural hazards (e.g., avalanches), and the exclusion of damaging animals and diseases. Second, more responsibility was given to the Cantons, for both policy implementation and financial support. However, it should be noted that the ratio of federal: cantonal funding for forestry projects varies between Cantons, depending on both the financial resources of the Canton and the viability of its forestry programs.

The first regulations pursuant to the Forest Police Law came into operation in 1903. They have three main components: means for implementing the general requirements of the Law, regulation of specific activities, and legal definitions. The first consider such subjects as education, defining forest functions, and regional division of the forests. The second include reforestation, control of game populations, protection against disease and pests, and construction. Of the many legal definitions, one of the most important is that for protective forest: "of importance for the gathering and supply of water, the cleansing of air, the recreation and health of the population, and landscape protection".

This is a much wider definition than found in the Law: " forests located in the catchment areas of mountain streams, as well as those which through their location are able to afford protection against damaging climatic influences, avalanches, rock- and ice-fall, landslides, and extreme water-levels". The change in definition reflects the changing perceptions of the forests' outputs: essentially, from protection to a wider range of public goods, including recreation and water and aesthetic quality. The current version of the regulations dates from 1971, although there have since been minor revisions. Most of these, including the most recent (1985), are with respect to federal contributions for education and training, as well as forestry activities, including afforestation, control structures, access development and consolidation.

Management of the mountain forests are also affected by the civil and penal codes, and other pieces of federal legislation, as discussed by Schoeffel (1978). A few of these bear specific mention because of their direct influence on forest management. Foremost among these is Article 699 of the civil code, which guarantees public access to all forests. The 1925 law on hunting and bird protection, which states that forestry officials are obliged to maintain a population of game animals which is healthy and adapted to local conditions. If there is a surplus which might cause severe damage to the forest, the population must be reduced. The BFL has a section dealing specifically with the interactions of game animals and forests; however, as discussed in Chapter five, the 1925 law has not prevented game animals from causing substantial damage. A principal reason was the provisions of the 1876 federal hunting law, which provided considerable protection to game animals; this law has recently been revised.

Another law which might have been expected to have major impacts on mountain forestry was the 1974 law on investment assistance for mountain areas. This applies to investments for the development of infrastructure, e.g., traffic access; grants for forest access projects can be provided. The aim of the law is to improve the conditions of life in mountain areas through directed investment assistance to communes, public corporations and individuals. However, most of the assistance has gone towards improving the infrastructure of settlements (Guller, 1986).

4.1.3 Legislation and policies for Canton Valais

As discussed in the previous chapter, Canton Valais was one of the first to develop forestry legislation in the 19th century. In 1902, the 1873 law was still in force. However, it had been revised in 1880 after the passage of the 1876 Forest Police Law, and new regulations had been passed in 1881. Subsequent to the passage of the 1902 Forest Police Law, a new forestry law was passed in 1910, with regulations in the following year. In general, the law mirrored the federal Forest Police Law (Perrig and Fux, 1945).

By the late 1960s, it had become evident that the existing legislation was inadequate to deal with the severe and growing problems of forestry in the Valais (Wuilloud, 1981). In 1971, a partial revision of the 1910 law was made, increasing financial support for forestry and tightening controls on felling. In 1982, a commission was formed to totally revise the legislation and, in 1985, a new forest law came into force. The primary aims of the law are to preserve the forests and ensure their maintenance for the safeguarding and improvement of protective and welfare functions. Secondary aims are: to increase the potential yield of the forests and encourage their management in the interests of owners and the public; and to maintain and preserve the cultural landscape and a healthy environment.

The primary aims provide the basis for binding management plans, which must be prepared for all public forests, according to the instructions of the cantonal forest service. While private forests do not require management plans, only 5 m^3 for personal use can be removed each year without forest service permission. Also, necessary measures can be demanded of the owners of these and public forests if their protective functions or adjacent land is endangered. All logging requires a permit, whose granting must consider natural conditions and economic requirements, particularly those of tourism. An equivalent area of land must be reforested after both logging and loss of forest cover resulting from natural events. The regeneration of the forest is further encouraged by fencing, a general restriction of forest grazing, and the duty of forest owners to minimize damage by game.

The cantonal administration supports forestry in many ways. First, it is responsible for the wages of the cantonal forest

inspector and regional foresters, and contributes to all forestry training. District Foresters are paid by their employers; usually a group of Communes. Grants of 10-30% are available for improving access; transport facilities; exclusion of grazing; consolidation of property; preparation of management plans; conversion of low forest into high forest; and other improvements to which the Bund also contributes. Grants of 10-25% are available for the construction of protective structures; planting windbreaks; required use and reforestation of forest after natural destruction; and the control of fires, diseases, and pests. Hone of these grants are necessarily dependent on other (e.g., federal) contributions.

A further group of assistance measures are available for protective forests, for maintenance and felling which results in deficits. The Canton contributes 20 to 60% of the costs after the deduction of income and federal subsidies; the Commune in which the forest lies must contribute 20-40%, except in special cases. In addition, owners of land or industrial property which is protected by forests can be called upon to provide contributions towards all of the measures covered by government subsidy. Another source of funds is the forest reserve fund, into which all public forest owners must pay at least 10% of the net profits of all timber sales. Finally, the cantonal government assists forestry by encouraging forestry research, forestry and wood-products trade organizations, and the use of local wood.

Assistance for forestry is not only available from the cantonal government. Forest owners have the right to ask Communes for contributions towards actions necessary for forests to fulfil their functions in two general cases. First, where the forests are excessively stressed or damaged by the public. Second, where special management actions are required, or desired management practices cannot be carried out, because of recreational use of the forests. Similarly, where management is made more expensive or difficult, or impossible, because of the existence of roads, railways, electric services or other structures, forest owners have the right to compensation.

4.1.4 Legislation and policies for Canton Graubunden

In 1902, forestry in Canton Graubunden was still guided by the regulations passed in 1899. These were subsequently revised in 1905, to bring them into accordance with the 1902 Forest Police Law, and again in 1942 (Rageth, 1983). The first, and current cantonal forest law dates from 1963, and is supplemented by regulations from the same year. The primary function of the forests of the canton, as defined in this law, is protection. However, within the restrictions of maintaining this function, they should be managed to ensure the highest possible yield. Management plans are required for all public forests greater than 20 ha in area, and must define annual allowable yields which must not be exceeded without governmental permission. The contents and

revision of management plans are the subject of many additional instructions and orders (Brosi, 1983). A permit from the forest service is required before any felling in public forests, and a deposit must be made in advance, for necessary subsequent actvities. Such deposits can also be demanded before clearing in private forests. Cleared areas are to be replanted when necessary; both artificial and natural reforestation are to be protected from browsing damage. All forest owners are required to control possible sources of damage.

Financial contributions by the cantonal government include the wages and insurance of the cantonal forest inspector, regional and district foresters and communal forestry personnel. However, Communes and public corporations whose forests are managed by foresters are expected to make a yearly contribution, based on the yield and productive area of their forests; the Canton will pay no more than 25% of the wages, and a third of the insurance, of communal foresters. Further cantonal financial contributions are for federally-approved forestry projects. The total federal and cantonal contribution may not exceed 95% of total costs; the Canton is responsible for half of the interest. Cantonal contributions of 10-30% are available for improving access; control structures and afforestation in the source areas of mountain streams; consolidation of private forest; and control of pest epidemics and forest fires. Contributions of 10-20% are available for all activities (including construction and afforestation) necessary for protection against natural hazards and browsing by livestock; afforestation after damage from fire, insects, snow pressure, windthrow etc.; and repair of control structures.

4.2 Management plans for the Swiss study areas

4.2.1 Aletsch

The first series of management plans for the communal forests of the Aletsch area were prepared between 1885 and 1895. These plans were revised between 1924 and 1942, according to the 1923 instructions for the management of public forests (Perrig and Fux, 1945). The plans have not been updated since. The twelve plans, one for the forests of each Commune, provide some direction for the management of about three-quarters of the forest area. However, the prescriptions which were developed forty to sixty years ago are not of significant relevance today, as the forested area has increased by about a fifth (Bellwald and Graf, 1985) and the economic base of the area has changed so much in the meantime, as described in Chapter two. Nevertheless, annual levels of extraction are still compared to the allowable yields in the plans.

The first part of the plans describes physical conditions in the area, ownership, proportions of tree species, previous management, reserves, and the distribution of timber trees in three classes: 16-26 cm, 28-38 cm, and >40 cm dbh. The second part prescribes the optimal management methods, allowable yearly yields, allowable secondary uses, and times and methods of wood extraction and transport, and proposes changes in access. Subsequently, each compartment (up to twelve in a single forest) is described in terms of physical and soil characteristics, stand structure, previous and proposed use; allowable yields are also given. At the end of each plan is a record of extractions in each compartment since the plan came into effect.

With the passage of the 1985 forest law, new guidelines for planning are being developed, and management plans will be prepared for rationally-defined districts, rather than individual communes. The forests of the canton will be categorized according to their most important function. Four major categories are being developed: protection from natural hazards, nature protection, tourism, and production. Within the first, there are three sub-categories, in order of importance: access routes and year-round settlement, summer settlement, and pastures and forest. The primary category of each forest will define the basis for management; other functions will be considered in a hierarchical manner.

Within the plan for each district, objectives will be set for a 20-year period for the forests, together with access and labor force requirements. Prescriptions for each forest compartment will be made, based partially on an assessment of the ability of protective forests to fulfil their functions. It is intended that the district forester should submit annual plans to the regional forester before the active season starts. The preparation of plans is tied to the availability of personnel to carry them out;

at present the cantonal forest service is severely understaffed (Werlen, pers. comm., 1986).

4.2.2 Davos

Management plans for the some of public forests of the Davos area have been prepared since the early years of this century (Gunter, 1980). However, there were none for private forests which account for most of the forest area. The early plans include data on afforestation, previous extraction, and the size structure and reserves of the forests. The latter were used to define maximal levels of extraction.

In March 1984, the Commune of Davos approved a forest order which stated that all forests within the commune, both public and private, should be managed according to a single plan. Operations included in the order include the removal of timber which is not removed or given away by forest owners; reforestation, forest maintenance, and protection against game on behalf of forest owners and communal reforestation projects; clearing along hiking trails in collaboration with the local tourist bureau; assistance in the construction of trails and protective structures against landslides and avalanches; and maintenance of publicly-owned structures related to forestry. In 1985, the Commune voted to underwrite the costs of these activities and of the construction of forestry roads to provide access for both public and private forests.

Subsequent to these passage of these policies, the current management plan for the Davos area (Teufen, 1985) was prepared. The plan considers all forests, both public and private. It begins with a general overview of the environment of the area and forest ownership. The second chapter concerns previous management, including historical harvest levels, afforestation, grazing, and conflicts between forestry and other activities, especially tourism. This is followed by two chapters detailing the method of forest inventory, its cost and results. There are also descriptions of stability as related to forest structure, and of damage by game. The inventory is the basis for proposed silvicultural measures over a 20-year period (1985-2004).

Management prescriptions are given separately for 16 sub-districts within the forest, varying in size from 119 to 522 ha. Each sub-district is described in terms of species and forest structure and stability; improvements in access are also discussed, in relation to a pre-existing concept. Different type; and degrees of use, ordered in terms of importance, are specified for individual areas within each of these sub-districts. The area, reserves, and levels of extraction are given for each of these areas. Finally, the organization of forestry operations (with manpower requirements) and the wood market are discussed.

4.3 Development of policies and plans for the management of Colorado's National Forests, 1897-1960

The passage of the Organic Act in 1897, and the first funding for activities necessary for its implementation in 1898, represent the beginning of the management of Colorado's National Forests. However, at this time, only part of the area in today's National Forests was included in forest reserves, all established in 1892. One of these was the Pikes Peak Timber Land Reserve, which includes the Pikes Peak study area. Colorado's other National Forests were established by President Roosevelt in 1902, 1905, 1906, and 1907 (Shoemaker, 1944). The Summit study area was initially part of the Leadville Forest Reserve, established in 1905.

As discussed in the previous chapter, reservation is necessary, but not sufficient, for management; funds, manpower, and objectives are all needed. The first purpose of this section is to examine the official policies intended to guide the management of these reserves, as mandated in federal legislation and policies promulgated in Washington. The second purpose is to identify the actual policies which were developed and implemented in Colorado, and to establish and, as far as possible, explain the relationships between the two sets of policies: national and regional. In this section, as for the remainder of this study, the discussion primarily considers three outputs: timber, recreation, and protection from natural hazards (principally fire). The end point of the sectionis 1960, when new legislation established new goals for the management of National Forests. In order to provide the background for this discussion, however, it is necessary to briefly describe the organizational structure of the Forest Service and its development: subjects described in considerable detail by many authors, including Ise (1920), Smith (1930), Pinchot (1947), Dana (1956), Steen (1974), Robinson (1975), and Frome (1984).

4.3.1 The development of the organizational structure of the Forest Service

In 1897, the existing Forest Reserves were administered by the General Land Office (6L0), part of the Department of the Interior. The lowest level in the hierarchy was the forest ranger, who reported to the forest supervisor in charge of the reserve. Reserves were grouped into districts, overseen by superintendents who reported to the GLO in Washington, which occasionally dispatched inspectors to the forests (Dana, 1956). In Colorado, the first officers were appointed in 1898 (Denver Times, 8/8/98; Shoemaker, 1958). Surveys of the reserves were undertaken by the U.S. Geological Survey, also part of the Department of the Interior. One of the first surveys was of the Pikes Peak reserve (Jack, 1900); the results are presented in Chapter five as the first detailed information on the forests of the area.

At the same time, the Department of Agriculture's Division of Forestry, renamed the Bureau of Forestry in 1901, was still in existence. The Bureau, headed from 1898 by Gifford Pinchot, was only able to provide advice for the management of the reserves, and also for the management of private forests. However, the influence of the Bureau was greater than its mainly advisory capacity might suggest. When a Forestry Division was created within the Department of the Interior in 1901, the Bureau prepared the mandate given to it by the Secretary of the Interior. The first head of the Division was a forester on secondment from the Bureau, who resigned in 1903 to resume an academic career (Steen, 1976: 61).

During this period, the principal activities of the forest officers were law enforcement (mainly against trespass) and fire suppression and prevention, and it has been argued that the lack of trained foresters was of limited importance for the managemen- of the reserves (Pyne, 1982: 230-2). However, it should also be noted that, in Colorado as elsewhere, forest officers were often political appointees, whose sponsors expected them to look after private economic interests (Riley, 1910b; Ise, 1920: 190; Rakestraw, 1979: 73). For instance, the Supervisor of the Pikes Peak Reserve in 1902 was probably appointed to look after railroad interests; there was often considerable conflict between such appointees and other officers who were trying to fulfil the official goals of the Division (Horgen, 1923; Shoemaker, 1958).

From the beginning of his tenure, Pinchot attempted to have the administration of the reserves transferred to his agency. From 1901, the concept of transfer was supported by both the Secretary of the Interior and President Roosevelt (Steen, 1976). The first transfer bill, considered by Congress in 1902, failed. Over the next three years, Pinchot widened his base of support, and also expanded his Bureau, which grew from 11 employees in 1898 to 821 in 1905 (Cameron, 1928: 30), when the Transfer Act finally passed. In the same year, the Bureau of Forestry became the Forest Service, and in 1907 the reserves were renamed National Forests, emphasizing the fact that they were public property (Dana, 1956). During this period, political appointees were removed, being replaced with trained foresters from the rapidly-proliferating schools of forestry. Forestry was now a profession; the professional association, the Society of American Foresters, had been founded in 1900 (Ise, 1920; Clepper, 1971).

One of Pinchot's principal beliefs was that the administration of individual National Forests should be left, as far as possible, to the people who knew them best. In 1908, the Forest Service was decentralized, resulting in a structure that has persisted almost unchanged until today, even if the loci of decision-making have changed with more recent legislation. With decentralization, rangers were given more administrative work and encouraged to develop their links to the public in and around their districts. Above the ranger is the supervisor, who is accountable for all

that happens on his National Forest. The next level of the hierarchy is the district (renamed region in 1930), of which there were six in 1908 and nine today (Steen, 1976). Colorado has remained in Region two throughout; the current nomenclature will be used throughout this study to avoid confusion with ranger districts, the lowest level of the National Forest System. The highest level of this system is the Washington office. While the National Forest System, which undertakes day-to-day administration and management of the National Forests, is the largest part of the Forest Service, there are four other major divisions: Administration, Programs and Legislation, Research, and State and Private Forestry. At the top of the structure is the Chief (Frome, 1984).

4.3.2 Federal policies and their implementation in Colorado

For the first sixty years of this century, the management of the National Forests of Colorado was primarily guided by the 1897 Organic Act and a letter sent by the Secretary of Agriculture to Pinchot on the day the Transfer Act was signed in 1905. The letter, written by its recipient, outlines three main themes: decentralized administration, with discretion exercised locally to fit local conditions; a sound technical basis for conserving and using the forests; and commitment to the economic stability of communities in and near National Forests (Dana and Fairfax, 1980: 82). These policies were further expanded in the pocket-sized "Use Book", first published in 1905, which later became the Forest Service Manual. The Use Book was named by Pinchot to underscore his utilitarian philosophy towards the National Forests (Steen, 1976: 78).

The principal uses of the forests defined by the Organic Act were to provide timber and water. Exploration for, and the extraction of, minerals was also permitted, and agricultural lands were to be excluded (16 USC 475). Conflicts over grazing and agricultural use were significant in Colorado until about 1913 (Voss, 1931; McCarthy, 1977). The protection of the forests from fire was also specifically mentioned in the Act (16 USC 551). In general, the primary users were to be those living locally: "bona fide settlers, miners, residents, and prospectors" could have free timber for almost any use (16 USC 477). All of these principles were mentioned in Pinchot's letter, which began by stating that "all land [in the National Forests] is to be devoted to its most productive use for the permanent good of the whole people." The use of the forests to maximize public benefits was stated as follows: "where conflicting interests must be reconciled the question will always be decided from the standpoint of the greatest good of the greatest number in the long run" (Dana, 1956: 143).

The primary means for ensuring that the National Forests would provide the various outputs over the long term was to be planning. The Division of Forestry had started making plans for

both private and public forests soon after Pinchot took over and. after the Transfer Act, he required working plans for all timber sales on the National Forests. His utilitarian planning process reflected the European origins of American forestry, emphasizing silviculture and including four main components: preparation of detailed inventories of resources; monitoring the condition of the resources; determination of sustainable use levels; and exclusion of use from specific areas where necessary to protect the watershed and other resources (Wilkinson and Anderson, 1985: 23). To some, the utility of such plans was questionable: "they were interesting silvicultural studies rather than plans, and were but seldom capable of being applied to American lumbering" (Cameron, 1928: 223).

At the same time, the primary duty of Forest Service officers was to protect the National Forests from fire (US Forest Service, 1907: 31); a management activity which, unlike harvesting and reforestation, was not specifically considered in Pinchot's planning process. As Pyne (1982: 101, 231-2) comments: "[Pinchot's] formal training in France and Germany could not have led to a program of systematic fire protection. The fire scenes of western America and western Europe were irreconcilably different. . . . Forestry's vaunted technical skills amounted to little in the actual practice of fire control. . . . Forestry as an intellectual discipline could only lend theoretical support to the generally accepted proposition that wildfires ought to be controlled."

The belief that European principles of forestry were applicable throughout North America was not limited to the Washington office; they were also the basis for the forestry being taught in schools throughout the nation. In Colorado, one of the early foresters stated that these principles merely needed to be adapted for utilitarian forestry to succeed (Morrill, 1909). Yet, as late as 1917, written plans, based on detailed inventories and estimates of current and future demand, were the exception rather than the rule (Lowell, 1917). As discussed below with respect to the study areas, the prescriptions in these plans, where they existed, were of little practical importance. In general, there was little active management (e.g., thinning, reforestation) in Colorado's National Forests; harvesting was principally dependent on local demands, tied closely to the fortunes of the railroad and mining industries. Until the 1940s, the Forest Service's role in Colorado, as elsewhere in the nation, was primarily custodial, stressing watershed protection and fire prevention (Wilkinson and Anderson, 1985: 135). Planning for the latter also began slowly; as late as 1927, there were no written fire plans for Colorado's National Forests (Waha, 1927).

Given these facts, and considering the important role of fire in the ecology of the forests of Colorado and many other states, what were the policies of the Forest Service for managing this natural hazard? For the first five years after the Forest Service was established, there was more exhortation than policy. Lack of

appropriations limited manpower, equipment, and the development of access (Pyne, 1982: 236). In 1910, fires burned about five million acres on the National Forests, including three million in Idaho and Montana, and killed 85 people. As a result, fire protection's importance in National Forest management was greatly reinforced, especially after the passage of the 1924 Clarke-McNary Act, which provided for planning and funding for fire protection, in cooperation with the states. Fire protection was thus regarded as a cornerstone of forest management both within and outside the Forest Service; in 1941, it was stated that "we have been so industrious in our crusade against fire that the public generally recognize us as a fire organization than a forest organization" CConarro, 1942: 57). The history of national-level fire policy has been discussed in detail by Gisborne (1942), Schiff (1962), and Pyne (1982).

As discussed in Chapter three, the loss of forests to fire had been recognized as a problem in Colorado since the first permanent settlement in the 1860s, and had been a significant factor in the development of legislation for the protection of the forests. In 1903, the Colorado legislature passed a law which made all sheriffs and deputies fire wardens (Stone, 1910). From the first days of the Forest Service's existence in Colorado, the cooperation of the public in preventing, reporting, and extinguishing fires was sought (Riley, 1909). The primacy of fire prevention in forest management at this time is shown by its inclusion as the first topic in the first address to the Colorado Scientific Society by a regional forester (Riley, 1909). In addition to relying on both the public and Forest Service officers to prevent and put out fires, a substantial infrastructure of roads, trails, and telephone lines was being installed.

In 1909, the majority of forest fires were from railroad locomotives, followed in importance by campers and lightning (Hover, 1909). In 1910, when the fire situation for Region two was summarized after the massive fires in the northern Rockies, the report was less optimistic than Riley's (1909) address; personnel, trails, equipment, telephones, and lookout stations were all deemed insufficient. However, several railroad companies were cleaning up their rights-of-way and sending out patrols, and were willing to transport men and equipment for fighting fires (Redington, 1910). Riley (1910a) emphasized to his staff the need for public education on the means and importance of fire prevention. Subsequently, every publication relating to Colorado's National Forests seems to have had some information about preventing fires.

During the next decade, the road and trail network in the National Forests was considerably extended, primarily for protection against fire, and lookouts were built (Riley, 1915). Fire prevention was still regarded as the most important activity of the Forest Service and, at least in Colorado, education programs had been successful in persuading the public that fire

prevention was of benefit to the public (Wheeler, 1917) . By 1927, there was an extensive network of voluntary fire protection in Colorado, with at least ten volunteers to each Forest Service officer (Waha, 1927). Some of these, such as the 700 members of the Colorado Springs Fish and Game Protection Association, may have been motivated less by providing a public good than in preserving their own recreational interests.

Although the Forest Service had persuaded the citizens of Colorado to become directly involved in fire prevention and suppression, response remained more or less *ad hoc,* since written fire plans had not been prepared, though relevant charts and maps were available (Waha, 1927). The lack of plans and of attention given to prevention were recognized by the Chief of the Forest Service (Greeley, 1926). In the late 1920s and 1930s, the fire prevention and suppression policies mandated by the Washington office were becoming increasingly complex (Pyne, 1982). At least in the latter part of this period, there appears to have been some tension between Region two and the Washington Office; no one from the region was invited to the major 1936 fire conference, and the regional forester felt that many of the conferees' recommendations, meant to be applied nationally, were inapplicable for the region (Thompson, 1937).

In retrospect, Brown (1942: 97-98) considered that, in Region two. Forest Service officers, especially rangers, had spent too much energy in the crusade of "preaching the gospel of fire prevention", resulting both in the crusade's "loss of fire" from boredom and in insufficient emphasis on other activities. He concluded that the net result of the crusade had been that, though the general public agreed that "Preventing Fires was a good thing. . . . they do not readily bridge the gap and carry it into action." While the number of railroad fires had increased substantially (mainly because of decreased traffic), the number of fires from campers and smokers was increasing greatly; as discussed in Chapter five. The reason was the rapid rise of recreation; as the rangers lost their enthusiasm for the crusade, the forests were being used by increasing numbers of people unindoctrinated about the importance of fire prevention. Brown's (1942) conclusions remained generally applicable for the next two decades.

"Recreation" includes many activities - including camping, fishing, hiking, hunting, sightseeing and, more recently, skiing and snowmobiling - which has led to many varying perceptions of the type and volume of facilities needed; and thus also to conflicting policies and actions. In the official policies of the Forest Service, recreation was recognized as only an incidental use of the National Forests until after World War I. It was not mentioned in the Organic Act and only in passing in the first editions of the Use Book, in tune with the utilitarian philosophy of Fernow and Pinchot. Consequently, this use was not planned for, although Pinchot had some aesthetic appreciation, believing that strips of uncut forest should be left along important roads

(Cate, 1963: 34); a typically European practice. The overall history of recreation in the National Forests has been discussed by Maughan (1932), Ellison (1942), Gilligan (1953), and Cate (1963), among others.

In 1910, immediately after Pinchot left the Forest Service, Chief Graves' representative at the American Academy of Political and Social Science clearly recognized that recreation was a growing and legitimate use of the National Forests (Cleveland, 1910). Yet most members of the Forest Service, especially in the Washington office, did not concur with this conclusion for many years; the impact of recreational use was a matter with which supervisors and rangers coped as best they could (Cate, 1963). However, recreational use - at this time, mainly hunting, fishing, and summer homes - was mentioned in Graves' annual reports from 1912 (Maughan, 1932: 23).

In spite of the antipathy of many in the Forest Service to recreation. Congress was persuaded by 1915 that this was a legitimate use of the National Forests, and authorized the Forest Service to grant permits to build summer homes, stores, and hotels (16 USC 497). This decision may also be seen as a way (albeit not very successful) for the federal government to make money; the Forest Service had run at a loss ever since its creation (Steen, 1976: 91). Around the same time, three factors began to stimulate the Forest Service to consider planning for recreation: the formation of the National Park Service, in 1916; the arrival of automobiles as a reliable and affordable means of transport; and federal highway building programs (Gilligan, 1953: 72; Cate, 1963: 57).

In 1916, Graves hired Frank Waugh, a landscape engineer, to survey the recreational use of the National Forests. The original report to Graves (Waugh, 1917) was published by the Forest Service in 1918, though some of the language was somewhat moderated. Waugh described recreation use, like watershed protection, as "a public utility of great value" (Waugh, 1918: 27). One of the emphases of his report was the attempt to put an economic value on this use, to provide a comparison with the primary, consumptive uses of timber, forage, and water; similar activities have continued to the present day (e.g., Peterson and Randall, 1984). He estimated that recreation on the National Forests was worth at least $7.5 million annually. He also emphasized that recreation was a paramount, if not exclusive use on some National Forests; and that clear planning and policies for recreation were vital (Waugh, 1918: 28-35).

In his 1919 annual report, Chief Graves formally recognized that recreation should be considered in management planning for the National Forests; and in 1921, Chief Greeley declared recreation a major use of the National Forests, and had the Manual redrafted to reflect this change in policy (Wilkinson and Anderson, 1985: 314-5). However, this use was not legitimized until 1960, and Congress, many Secretaries of Agriculture, and many foresters

continued to regard it as unsuitable and in conflict with the uses outlined in the Organic Act and Pinchot's utilitarian philosophy. Thus, support for recreation from the Forest Service's highest level did not mean that adequate funds were available, and Forest Service personnel willing to spend their time, to plan and develop recreational facilities in the National Forests, to manage rapidly-increasing levels of recreational use (Maughan, 1932; Gilligan, 1953; Cate, 1963).

As discussed in Chapter two, recreational use of parts of Colorado's National Forests, including both Pikes Peak and Summit County, had begun while they were still part of the public domain. In the early years of this century, recreationists were primarily local residents or visitors travelling on railroads; little management was required. By 1909, 100,000 people were visiting the Pike National Forest each year; this use was increasing at ten percent annually (Horgen, 1923: 58). However, Regional forester Riley did not mention recreation as a use of the National Forests in his address to the Colorado Scientific Society (Riley, 1909). Nevertheless, in 1915 he stated that "a very definite recreation policy. . . . has been in effect for a number of years. . . . much is being done to develop the National Forests" (Riley, 1915).

Cate (1963: 43) identifies Riley as one of the prime movers towards the development of a national-level policy for recreation. This is not surprising as, with 667,097 visitors to Region two's forests in 1916 (Waugh, 1917), he undoubtedly wanted some support from Washington. Riley was faced with a dilemma. Fire prevention was still regarded as the primary responsibility of the Forest Service, and improved prevention required the construction of roads and trails. Yet increased access resulted in increased visitation, particularly with growing automobile ownership. Furthermore, it was Forest Service policy to mark all trails and roads, and to provide maps identifying camping sites, fishing streams, and scenic areas. Finally, the cabins built for fire protection, some with the help of the Colorado Mountain Club, were left open for anyone to use (Riley, 1915). All these factors not only encouraged recreational use, but also led to increasing risks of fire.

In 1916, the Pike National Forest was described by Region two's Information officer as "the greatest recreation playground of America"; 400,000 visitors were recorded that year, two-thirds of the total for Colorado's National Forests (Hutchinson, 1916). By 1917, the same forester was formally in charge of recreational matters; a full-time recreation specialist was not employed in the Washington office until 1919 (Cate, 1963: 54). At Region two's 1917 supervisors' meeting, it was stressed that the National Forests were public property, used by increasing numbers of people (Shoemaker, 1917a; 135, 137; Stahl, 1917: 163). The regional policy was clearly to encourage recreational use; supervisors were exhorted not to "consider recreation work as a kind of side issue, to be handled at odd times when there is

nothing much else to do". In contrast, the recreational possibilities of the National Forests were to be promoted, and careful planning and development of facilities was needed (Hutchinson, 1917: 121-3).

The 1919 publication "Vacation days in Colorado's National Forests" again shows Region two's much stronger perception, in comparison to the Washington office, of recreation as one of the major uses of the National Forests: "These National Forests were created primarily to insure a permanent supply of timber and to protect the water supply. . . . The aim of the Forest Service. . . . . is to make them national playgrounds" (US Forest Service, 1919c: 4). However, although recreation was clearly a public benefit of the National Forests, two major problems were recognized: sanitation and fire. Ways of dealing with both of these problems were described in detail in this document and subsequent ones aimed at recreationists, and provided the basis for many discussions and internal documents over the next decades.

During the 1920s, recreational use of Colorado's National Forests increased substantially, reaching 2.34 million in 1930 (Johnson, 1931). According to the 1928 publication "National Forests of Colorado", recreation and wildlife were now officially included in Pinchot's principle of forest management to derive "the greatest possible contribution to the general public welfare." However, careful planning for recreation was required; "Conflicts with other activities must be avoided and different types of recreation provided for" (US Forest Service, 1928: 1, 8). This was the official policy; however, the reality of planning and managing recreational facilities was not as bright.

In comparison to other regions in the National Forest System, recreation planning in Region two was of very high quality. However, in coordination and execution, the region was surpassed by the others. Recreation planning had received too little attention in comparison to timber and range management, and recreation plans were too general (Johnson, 1930). It appears that the promotion of recreation had perhaps been too successful, particularly with respect to summer cottages and resorts; more care had to be taken in visual and sanitation planning, and permits should be limited (Spencer, 1930a). Nevertheless, the demand for recreation was unmistakable, and could not be ignored because the National Forests were public property; recreation would eventually be the dominant use of the majority of Colorado's National Forests (Spencer, 1930b). From the early 1930s, Forest Service promotion of recreation opportunities placed less stress on developed sites (Johnson, 1934).

The first detailed national study of recreation in the National Forests (Maughan, 1932) included surveys of supervisors' ratings of the importance of recreation (in comparison to timber, watershed protection, and grazing) and of recreational developments in each forest. In Colorado, only one National

Forest rated recreation as second in importance, after watershed protection: the Pike, which received a third of the recreational use of Colorado's forests. Recreation was rated third in five forests, and fourth in eight; only three forests saw recreation as increasing in comparative importance in the future (two to second in importance). Supervisors made many comments about lack of funds needed to provide necessary improvements for recreational use (Maughan, 1932: 36, 150-1).

Across the nation, there were few plans for individual National Forests, although these were meant to exist; regional plans, while describing facilities, did not consider present or future demand or describe necessary developments (Maughan, 1932: 101-2). On one hand, this may have been fortunate, since levels of recreational use fluctuated widely during the depression years of the 1930s. On the other hand, New Deal programs provided large volumes of manpower and funding for developing recreational facilities (Cate, 1963: 116-125). Yet, by 1937, detailed planning was still under consideration in Colorado, rather than being realized. One of the reasons cited at the supervisors' meeting was the volume of recreation-related paperwork required by the Washington office (US Forest Service, 1937).

During World War II, recreation planning was of limited importance; both Forest Service personnel and visitors were at low levels. Immediately after the War, however, levels of use started to rise rapidly, and the Forest Service soon realized that planning would also have to consider winter recreation, which had started before the War, particularly since almost all potential and existing sites in Colorado were on National Forest lands. A strong multiple-use philosophy existed in Colorado: "The Forest Service takes the position that watershed protection, timber production, livestock grazing, wildlife production, recreation, and human uses are all legitimate factors in forest management. It is our intention to give each and every one of these uses its full and proper place in our administration. . . [and] to keep these varied uses in proper balance and not allow any one of them to overshade the others" (Spencer, 1946).

The fact that the National Forests had multiple uses had been evident in Colorado for decades. However, the concept of multiple use really only appeared at the national level in 1933, with the publication of "A National Plan for American Forestry" (The Copeland Report: US Senate, 1933). It was better received outside the Forest Service than within (Steen, 1976: 202-3). Before the War, however, conflict between uses on the same piece of land rarely occurred, so there was little need for coordinated planning for different resources (Wilkinson and Anderson, 1985: 28) .

The meteoric growth of recreation after the War was one of the main factors which made coordinated planning necessary; demand for timber and other resources was also increasing rapidly. Essentially, "there was no longer sufficient land to accommodate

all uses without conflict" (Dana and Fairfax, 1980: 205). In addition, many of these uses were not recognized in the Organic Act, which still officially guided the activities of the Forest Service. Nevertheless, National Forests began to prepare plans which attempted to coordinate all uses; though based mainly on intuition, without uniform standards. Pressured by interest groups of many persuasions, the Forest Service realized that a wider legislative mandate was vital, and in 1956, the first bill recognizing multiple resources was introduced in the Senate (Steen, 1976: 304).

The 1956 bill did not pass and, over the next years, supporters of the bill worked to persuade, first, recalcitrant members of the Forest Service and, later, members of opposed interest groups and Congress that the concept was of public benefit (Cate, 1963). In 1960, the Multiple-Use Sustained-Yield Act was passed, providing recognition that "the national forests are established and shall be administered for outdoor recreation, range, timber, watershed, and wildlife and fish purposes" (16 USC 528). Yet, as with the key legislation of the 1890s, its passage was based on an "unusual combination of favorable circumstances", particularly "favorable relationships in the Department of Agriculture and on the Hill"; there was also support from a wide base of user groups (Cate, 1963: 249).

4.4 Policies and plans for the management of the forests of the Colorado study areas, until 1960

According to Philips (1924a), "The early history of the Forest administration is more or less one of hearsay. . . . The big job ... was to put a stop to cutting of timber and having settlers remove fences from enclosures which had been appropriated for individual use." These statements refer to the Pike National Forest, but were probably applicable to National Forests throughout Colorado; the early rangers' duties involved policing, rather than forestry, often with a considerable element of personal risk (Horgen, 1923; Shoemaker, 1958).

Once the jurisdiction of Forest Service officers was more or less accepted, two major changes in logging practices occurred. First, only selection cutting was allowed, rather than the previous indiscriminate approach. However, in contrast to the previous policy of allowing only dead trees to be cut, sales of large green trees were now permitted. Second, slash disposal became mandatory. Both of these policy changes, and the need to build roads to provide access for logging, led to increased timber prices (Martin, 1915; Shoemaker, 1915). It is not clear whether specific plans existed for these activities; none could be found. From 1914 onwards, land classifications of many parts of both study areas were undertaken. These, however, were descriptive, describing past, current, and potential uses, rather than prescriptive.

4.4.1 Pikes Peak

The earliest extant document describing the purposes of the National Forest on Pikes Peak was published by the Forest Supervisor in 1911. He stated that the forest should be "a "protection forest," valuable primarily as a conserver of water rather than for lumber" (Fitzgerald, 1911: 646). Apart from fire prevention, the main activity of the Forest Service on Pikes Peak for the next three decades was reforestation, which had begun in 1906. The two main purposes of this program were erosion control and stream regulation (Duthie, 1914; Stahelin, 1941). The implementation and results of this program are discussed in Chapter five.

From early in the twentieth century, recreation was generally regarded as almost as important as watershed protection (Heizer, 1909; Shoemaker, 1915, 1917b; US Forest Service, 1916). From 1915, the development of trails was considered from a recreational as well as an administrative (i.e., fire prevention, logging, reforestation) viewpoint; the Forest Service advertised recreational opportunities in its publications from 1917 (Horgen 1923: 58-9). However, timber production remained a consideration; Shoemaker (1917b) listed it second in importance to watershed protection, and Philips (1924b) complained that, although logging was necessary in some places, it was doubtful whether it would

occur, because of public opinion that it would destroy "scenic values". He proposed that advertising by recreational concerns should carry information which would have the effect of "overcoming any opposition or preventing opposition to a conservative handling of our resources." Yet, by this time, recreation had been heavily promoted, both by the Forest Service (US Forest Service, 1919) and private operators, and was undoubtedly second in importance only to watershed protection.

The earliest extant plans for Pikes Peak concerned general silvicultural practices for the Pike National Forest as a whole (US Forest Service, 1917a). The first subject discussed was cutting priorities: first, local residents and communities, followed by small railroads and mines and, last, large railroads and mines and the competitive market. Other sections discussed the various uses of the major species, methods to improve regeneration, and methods of slash disposal to minimize fire hazards. Around 1920, plans were made for the coordinated development of recreational facilities (Horgen, 1923); another recreational plan for the whole National Forest was completed in 1942. Timber inventories were undertaken on Pikes Peak in the 1920s (Keithley, 1929; Stanley, 1931), resulting in estimates of allowable cut and, during the 1930s, timber surveys were made using funds and manpower made available by various New Deal laws. However, in contrast to the parts of the National Forest north of Pikes Peak, the data from these surveys were not used to prepare timber management plans for Pikes Peak. Prior to 1951, a National Forest management plan and fire plan were completed (Roeser, 1952b). Copies of neither of these plans could be found.

While the various reforestation projects were doubtless the subject of detailed plans, the first plan which specifically considered the management of the forests of Pikes Peak was the 1952 timber management plan for the Pikes Peak working circle (Roeser, 1952a); this may be the ranger district multiple-use plan to which Nelson and McNutt (1954) refer. The plan begins with a statement of management objectives; watershed protection and recreation, respectively, were identified as primary and secondary. Harvesting of timber and other forest products was subsidiary, although logging and thinning, intended to increase timber reserves and minimize losses from insects and disease, were to take place when these did not conflict with the major objectives. Following the management objectives, and a short description of the area's physical characteristics, are descriptive sections with brief statements of policy, concerning: harvestable timber, based on unreliable growth and yield data; transportation; reforestation; stand improvement; protection against fire, insects, and disease; land exchange; and local communities' use of forest products. The next section states policies for the coordination of the various uses of the area and with other agencies and landowners. The final sections describe policies for estimating allowable cut, and marking and cutting timber sales.

The nap that accompanies the 1952 plan shows a few small "mature timber" units, and even fewer "immature timber" units, all on the west and south sides of the mountain. The remainder was classified as "inaccessible and recreation/scenic", "grass, brush, and subalpine", aspen, or "erosion control", in terms of decreasing area. The areas in these categories remained generally unchanged on the 1955 timber management plan which was prepared when the Pikes Peak working circle was expanded. However, the first category was expanded by adding the areas of aspen, and some was reclassified as "erosion control", mainly in the south-east section of the area. The last plan completed in the period under consideration was the 1958 recreation plan for the Pike National Forest (Grover, 1958).

4.4.2 Summit

The earliest statements of policy relating to the study area refer to the Leadville National Forest as a whole, dating from 1911, when "the protection of the timber, soil and forage {was] conceded to be the most important work of the Forest officers." Use of timber was the first consideration in forest management, but watershed protection was also significant. Long-term considerations were paramount. Trails and roads were to be built, partially for recreational purposes (Shoemaker, 1911). By mid-decade, watershed protection was identified as of first importance. The market for timber had almost disappeared, except for local use, since the quality was low and unable to compete with West Coast lumber (US Forest Service, 1917). However, recreation, particularly camping and fishing, was now viewed as a major use; to provide this, the forests had to be protected from fire, and many trails had been constructed (Clark, 1915; Martin, 1915). After the passage of the 1915 Act, the development of summer homes, rather than backcountry use, was emphasized (Clark, 1916). However, this was more for the part of the National Forest outside the study area; the upper watershed of the Blue River was principally known for its big game (Denver Times, 2/9/21).

Although an annual chronology of events occurring on the Dillon Ranger District exists from 1926, planning activities were not mentioned until 1959. However, plans were being made; the first being the 1926 working circle plan, based on a 1924 inventory, whose main purpose was to identify the availability of timber which could be cut and subsequently removed on the Colorado and Southern railroad. A copy of the plan could not be found, and the volume estimates in it were reduced substantially in the 1940s (Heaton, 1946) although, as discussed in Chapter five, harvests had been very low in the intervening period. In 1929, the Dillon Ranger District was transferred from the Leadville to the Arapaho National Forest. The area was considered in early Arapaho National Forest plans, including a 1939 general erosion control plan and a 1944 fire emergency plan, revised in 1950 (Hergenreder, 1982).

In 1947, new timber management plans for the forests of the study area were completed (Kutzleb, 1947a; b). The Dillon working circle encompassed most of the area; the Gore and Williams Fork ranges formed a small portion of the Middle Park working circle. Both plans have the same format; the subsequent discussion principally refers to the Dillon plan. The plan begins with short sections describing the historical use, physical characteristics, and economic situation of the area. Following this are general descriptions of the forests, generally based on limited and extrapolated data. The policy sections stress the production of timber; the objective of the plan was to maximize sustained-yield timber production, in spite of limited markets. While watershed protection remained an important value, little emphasis was placed on recreation; distance and limited access from population centers were regarded as factors which limited demand, although some growth was foreseen. The final sections describe policies for logging and sales, and propose thinning and reforestation. At the end of the plan are appendices describing the forests' age structure, timber reserves, and estimated yields, and proposed roads. Although the plan was meant to be revised in 1958, this did not occur; the next timber management plan for the forests of the study area was the 1961 plan for the Arapaho National Forest, discussed below. In the meantime, as described in Chapters two and five, recreation had become the major use of the area; a recreation plan was prepared in 1955.

4.5 Development of US federal legislation and policies, and their implementation in Colorado, since 1960

While the Multiple-Use Sustained Yield (MUSY) Act explicitly recognized that the National Forests were to be managed for a variety of uses, including recreation, the very broad definition of multiple use in the Act provides the Forest Service with little direction for managing the National Forests to fulfil its objectives (Nelson, 1985: 54). Yet 1960 was a pivotal year for the management of the National Forests in that the Act gave statutory recognition to the multiple-use concept. Based on this, the Forest Service instituted a more organized planning effort for all of the resources recognized in the Act in 1961 (Wilkinson and Anderson, 1985: 31). Two types of plans were developed. The first considered all resources in a two-stage process, in which multiple-use planning guides were prepared for each geographical subregions within each region. The guide for the western Colorado subregion was completed in 1963. The planning guides were then used as the basis for ranger district multiple-use plans. The second dealt with individual resources, such as timber and recreation; these were written at the National Forest level.

The implementation of the Multiple-Use Sustained Yield Act and the development and implementation of subsequent federal legislation and policies affecting the National Forest System have been considered in detail by various authors, including Dana and Fairfax (1980), Hewett and Hamilton (1982), LeMaster (1984), and Wilkinson and Anderson (1985). Consequently, these changes will be discussed only briefly below. One indication of the increasing complexity of National Forest management is that, while 71 Acts of Congress relating to this subject were passed from 1872 to 1959, 76 were passed in the following 23 years (US Forest Service, 1983a) . Similarly, the pocket-sized 1907 Use Book has evolved into the seven-foot-long Forest Service Manual (O'Toole, 1988: 20). The next major law affecting National Forest lands was the 1964 Wilderness Act, which established a National Wilderness System and provided means for expanding it. Following the Wilderness Act came the 1969 National Environmental Policy Act (NEPA). Unlike the legislation discussed previously, NEPA applies equally to all federal agencies.

NEPA affects the management of the National Forests in two main ways. The first is that an Environmental Impact Statement (EIS) has to be filed for every proposed federal action "significantly affecting the quality of the human environment" (42 USC 4332). The EIS requires analysis of avoidable and unavoidable impacts of the proposed action and alternative actions, and consequently should be based on detailed knowledge of the affected resources. As a result, the Forest Service began to collect and analyze large quantities of basic information about the resources of the National Forests which had previously been lacking (Wilkinson anc Anderson, 1985: 33). The second is that, according to the guidelines of the Council for Environmental Quality, established

by NEPA, other government agencies and the public are to participate in the development and review of each EIS.

As Dana and Fairfax (1980: 241) point out, "NEPA may be associated with intensifying and institutionalizing the public involvement process." One result of this is that Forest Service policies and plans can be challenged in court; the agency lost its almost total immunity from judicial oversight (Wilkinson and Anderson, 1985: 72). To bring Forest Service planning into line with the EIS requirements, a new approach was established in 1973. The Chief developed broad policies, which were interpreted in Planning Area Guides for geographical subregions of each Region. These gave direction for individual National Forests' land use plans which, in turn, guided the preparation of unit plans for areas within the Forest. In Colorado, these unit plans were typically for areas smaller than a ranger district.

Taken together, the effects of the MUSY and Wilderness Acts and NEPA were: to acknowledge that the Forest Service had to manage the National Forests for a variety of resources; to involve the public and other agencies in planning; to increase the collection of data concerning National Forest resources; and to institute planning approaches which were directed at the local level from higher levels in the Forest Service organization. These were all major changes affecting the management of the National Forests and the allocation of financial and manpower resources within the Forest Service, and represented a considerable change from the locally-based approach to management which had existed since the beginning of the century. Yet, during the 1970s, the "statutory authority for the agency was effectively rewritten" (LeMaster, 1984: 175), leading to even greater changes in the agency and its management of the National Forests.

The first major forestry law of the 1970s was the 1974 Forest and Rangeland Renewable Resources Planning Act (RPA). Like the Organic and MUSY Acts, this was supported by a wide variety of industry and environmental groups (LeMaster, 1984: 45). Its main effect was to emphasize national-level planning, mandating the preparation of a "national renewable resource program", to be updated every five years, subject to review by Congress. The program is based on a comprehensive assessment, prepared every ten years, of "present and anticipated uses, demand for, and supply of renewable natural resources. . . through analysis of environmental and economic impacts, coordination of multiple use and sustained yield opportunities. . ., and public participation" (16 USC 1600).

The RPA specifies the provision, management, or improvement of not only the "renewable" resources specified in the MUSY Act, but also wilderness, and water, air, and aesthetic quality. The act emphasizes cost-benefit analyses of investment alternatives, to maximize economic efficiency in the allocation of resources; an approach which assumes that values can be obtained and compared for all outputs of the National Forests. As Dana and Fairfax

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(1980: 325) point out, the RPA is "an overwhelming expression of faith in the utility of accumulating and analyzing data"; it continued the trends of the legislation of the 1960s by expanding the range of resources to be considered in National Forest planning; emphasizing national, rather than local, planning; requiring the collection of even more data on National Forest resources; and stressing public involvement. In addition, for the first time, economic efficiency analyses were introduced as a primary basis for planning, in spite of the "fundamental conflict" which some authors describe between this and one of the other major goals of forest planning: public participation (e.g., Clawson, 1983: 255).

Two years after RPA was passed, and before it was implemented in any more than a rudimentary fashion, it was amended by the 1976 National Forest Management Act (NFMA). A primary impetus behind NFMA was a 1973 judicial decision, upheld on appeal, that clearcutting violated the 1897 Organic Act. This decision was applicable only to part of the southeastern United States but, in 1975, was extended to Alaska and, implicitly, the rest of the nation. The potential implications were that sales of timber from National Forests could be decreased substantially, and thus that employment in many communities dependent on logging would be severely affected (LeMaster, 1984: 55-7). Consequently, the timber industry and the Forest Service wanted the decision legislatively overturned, and the environmental groups which had forced the decision wanted to maintain their gains (Dana and Fairfax, 1980: 328).

The main changes that NFMA made to RPA concern timber management, a reflection of NFMA's history. However, the act further changed the Forest Service's approach to planning and management in two significant ways. First, interdisciplinary teams were to prepare plans for each unit of the National Forest System, considering the potential for change in all of the resources mentioned in RPA. Second, an independent committee of scientists was to develop regulations to specify how the act should be implemented, subject to public comment. The regulations were published in 1979, after 982 comments had been reviewed; and significantly revised in 1982, after the committee had reconvened and prepared a draft which elicited 2020 comments (LeMaster, 1984: 156-9).

Taken together, RPA and NFMA require, and have resulted in, the production of a large number of policies for managing the resources of the National Forests. The main emphasis of RPA is on setting national targets for the production of resources over the five-year period considered in the program document. The first of these was produced in 1975, the second in 1980, and the most recent in 1986. The targets are then divided up between regions and National Forests. Each year, the Forest Service is required to submit to Congress a report on the success of the units of the National Forest System in achieving these goals. The planning direction provided by NFMA and its regulations is rather different, placing emphasis on planning at the regional and,

particularly, the National Forest levels. Regional guides are developed "to provide national and Regional direction to individual National Forests. . . for land and resource management planning" (US Forest Service, 1983b: 1-1). The land and resource management plans for each forest are thus based on direction from the regional guide; the Forest Service Manual; inventories of the local supply of, and demand for, the resources considered by RPA; and estimates of the values of these resources. Values for market goods can be derived from recent trend data; for public goods, they can be administratively assigned or derived from empirical studies (Peterson and Randall, 1984).

One of the initial ways in which these variables are combined is through the use of linear programming models such as FORPLAN (Iverson and Alston, 1986), which use economic efficiency measures to compare alternative management strategies. The application of these models is subject to constraints, derived from both the RPA program and local considerations. In addition, the results provided by these models are sensitive to changes in the values of outputs (e.g., Ashton, 1986) and discount rates (O'Toole, 1988). The development of the plans is an iterative process, in which modelling is only the first stage in formulating the alternatives; FORPLAN has been described as "the means to. . . the beginning of public involvement in the development of strategic plans" (Beuter and Iverson, 1987: 88). Subsequently, subjective judgements are used to account for unvalued outputs and equity considerations. Finally, an alternative is chosen which is supposed to maximize "net public benefits" (Iverson, 1985). This alternative then has to be approved by the Regional Forester, but is still subject to public appeal.

The regional guide for Region two was completed in 1983, and describes regional planning as "a pivotal process for conveying management direction from the national to the local level and for conveying information from the local to the national level" (US Forest Service, 1983b: 1-1). In other words, it is meant to provide a link between the two approaches to planning mandated by RPA and NFMA. However, these approaches essentially operate simultaneously in opposite directions. While the RPA approach is "top-down", with targets being set nationally and divided up locally, the NFMA approach is more "bottom-up", like that of the pre-MUSY Act era, considering local conditions as a primary factor determining management. The attempt to reconcile the two approaches has been described as an "uneasy compromise" which has resulted in "confusion and dissension" in the Forest Service (Wilkinson and Anderson, 1985: 79, 82).

4.6 Plans for the management of the Colorado study areas since 1960

As discussed above, the introduction of many new pieces of federal legislation in the 1960s and 1970s resulted in a great expansion in the data collection and planning activities of the Forest Service. Very few plans were made specifically for ranger districts: the unit for planning was either larger (region or National Forest) or smaller. Since the passage of NEPA, all plans and planning guides have been accompanied by environmental impact statements, which are all considerably thicker than the plans themselves.

The land management plans for the eastern and western Colorado subregions of Region two, prepared after the passage of the MUSY Act, were the first documents to provide overall guidance for managing the forests of the study areas. Ostensibly, these were meant to apply from 1960 to 1970. However, the eastern plan was not completed until 1961; the western plan was not completed until 1963, and supplements were still being added in 1973. The plans were divided into three main parts. First, the management situation was described in terms of the resources of the region's forests. Second, general management direction was provided for each of these resources. Third, altitudinal management zones were defined. The plans as a whole were presented in generalized, qualitative terms. These plans were superseded by a regional multiple use guide in 1974.

The management of the study areas is now directed by the regional guide (US Forest Service, 1983b), prepared according to the 1982 NFMA regulations. The first part of the guide is a brief overview of the planning process for the National Forest System as a whole. This is followed by a description of the regional situation. This briefly outlines the physical, biological, and socio-economic characteristics of the region, followed by descriptions of individual resources. The largest part of the guide provides management direction for each of these resources, and briefly describes other activities, including cooperative forestry and research programs. The final part of the guide outlines monitoring and evaluation activities to assess whether activities are meeting the goals set in the guide.

4.6.1 Pikes Peak

In 1960, a recreation development plan was prepared for Pikes Peak (Leissler, 1961). The implementation of this plan was to be coordinated with the land management plans for the Pikes Peak ranger district, prepared between 1961 and 1965 (Anderson, pers. comm., 1988), and the eastern Colorado subregion. Copies of neither of these plans were located, but they were presumably similar to the contemporary plans for the Summit area, described below. Like these plans, the recreation development plan used very generalized, non-site-specific terms to define management

problems and policies and the coordination of recreation with other resources. The land management plans officially guided management into the 1970s.

In 1972, a multiple use land management plan for the study area was completed (Lynch, 1972). The plan, based on a detailed inventory of resources and demands, was a pilot project for a new approach to planning, stressing the management of ecosystems, rather than resources. However, it was never implemented; subsequent management of the area was based on the 1974 land use plan for the Pike and San Isabel National Forests. This gave very general prescriptions for resource management on Pikes Peak, which was divided into roadless, watershed, and esthetic zones.

The 1974 plan was superseded in 1985 by the land and resource management plan for the Pike and San Isabel National Forests (US Forest Service, 1985). This is arranged under the same headings as the regional guide, and partitions the study area into management areas, each with specific management directions. The watershed areas subject to agreements with the local cities are to be managed to protect or improve water quality or quantity. Much of the area south of North Cheyenne Canyon is designated for motorized and non-motorized recreation. The other main emphasis, on both the west and south sides of the area, is wildlife habitat management; both in aspen stands which are also to be managed to produce wood, visual quality, and plant and animal diversity; and in conifer stands which provide winter range for big game. In the summary of proposed timber sales from 1984 through 1993, a few small sales are proposed for the study area, mainly clearcuts of aspen and shelterwood cuts of conifers.

4.6.2 Summit

From 1961 onwards, management of the forests of the study area was subject to the prescriptions of the timber management plan for the Arapaho National Forest (Brown, 1961). This defined timber management practices in considerable detail. It includes no data specific to the study area, and only proposes logging in two compartments of the study area, to the northwest of Green Mountain Reservoir. This was to supply a proposed mill at Kremmling, which was to be used as a market for lodgepole pine poles. The period covered by the plan was from 1962 to 1971.

After the 1963 subregional land management plan had been prepared, this was used as the basis for a plan for the study area. The subregional plan was in a looseleaf binder: statements regarding the management situation and direction within the ranger district were added in 1965, 1968, and 1969. All of the statements are very brief, generalized and not site-specific. A few quantitative data on recreational use and timber inventory are included. Recreation was identified as the main activity of Forest Service personnel; but water was described as the most valuable resource. Timber harvesting was identified as of little

importance because of the lack of access to potential sawtimber stands and because large areas were being set aside for recreational and aesthetic reasons.

In 1973, the administration of the Dillon ranger district was transferred to the White River National Forest. However, it remained in the Arapaho National Forest, and was included in the 1975 timber management plan for the forest (Stiger, 1975). The primary objective of the plan was "to provide guidance for the protection and enhancement of recreation, wildlife and scenic beauty". "Optimum sustained production of usable wood" was also mentioned as a goal. A wide range of intensive management practices were proposed, over the following decade, to fulfil these goals and begin to change the age-class distribution, dominated by >120-year old trees, to one with a more even distribution of age-classes. Apart from the Gore Range - Eagles Nest wilderness, designated in 1975 and occupying 33,484 ha (26% of National Forest land), harvests were proposed at locations throughout the study area. Nearly all of these were identified as requiring "specially-designed treatment of the timber resource to achieve landscape or other key resource objectives."

In the 1970s, land management plans were also prepared for parts of the study area, including the Snake River Basin (in 1974), and the Williams Fork Mountains (in 1978). These were superseded by the land and resource management plan for the White River National Forest (US Forest Service, 1984), implemented in 1984 and arranged under the same headings as the regional guide. This partitions the study area into management areas, each with specific management directions. Nearly the whole of the area to the west of the Lower Blue, including the Wilderness area, is to "protect and perpetuate [essentially] natural conditions"; the lower edge of the forest is identified as big game winter range. The Williams Fork Mountains are mostly designated for primitive and semi-primitive recreation. The latter permits clear-, shelterwood, and selection cutting. A small area at the north end of the Mountains is designated for the production of wood fiber and roundwood. The southern half of the area includes the ski areas; the remainder provides a mixture of motorized and non-motorized recreation, depending on the current existence, of roads. Timber harvesting is not mentioned as a major activity in any of these areas. In the 1981-1990 timber sale action plan at the end of the plan, two main types of harvests are proposed for the study area: clear-cuts of lodgepole pine stands to control mountain pine beetles (75% of proposed harvests); and shelterwood cuts in spruce-fir forests, sometimes combined with lodgepole pine harvests, to improve forest health and increase diversity. The proposed average annual cut is 5,030 thousand board feet (MBF).

4.7 Comparative analysis of policies and plans for forest: management: in the twentieth century

Since policies and plans for forest management are principally developed and implemented by members of the government agencies described in sections 4.1.1 and 4.3.1, this analysis begins by comparing these agencies. For both regions, the agencies are organized hierarchically, with overall direction from the headquarters of a national agency in the federal capital. For Colorado, this has been the case only since 1905, when the Department of Agriculture took over administration of the forests. A principal difference between the study regions is that there is only one agency, staffed solely by federal employees, for Colorado's National Forests, while the situation is more complex in Switzerland. The federal agency is relatively small in comparison to the cantonal forest services, whose employees implement federal legislation, formulate and oversee the implementation of cantonal policies, and develop plans for publicly-owned (mainly communal) forests.

To a greater or lesser extent, these plans have been implemented by foresters employed by public forest owners who, in turn, supervise communal members or contractors. However, public forest owners are not always legally obliged to employ either full- or part-time foresters. Consequently, the employment of forestry personnel has often depended on the potential profitability of management activities and the existence of government subsidies. Although the political commune is likely to have the financial resources to pay for forest management, its members may not be members of the civil Commune, and thus do not necessarily benefit directly from forest management activities. However, members of political communes are now beginning to realize that communal forests (and also private forests, which often do not have to have management plans) provide public goods which are important for the future of their communities, and are beginning to assist with the employment of district foresters and support forestry in other ways, as discussed in Chapter five. In contrast, each ranger district in Colorado's National Forests has always had a few staff, whether or not the district has made (or is likely to make) a profit. Yet, since the employment of these individuals depends on government appropriations, the situation is somewhat comparable to Switzerland.

Turning to the policies for the management of forests in the two study regions, the most critical change in emphasis during this century has been a philosophical evolution: from the sustained-yield concept towards an approach which considers the widerange of forest outputs described in Chapter one. Early US Forest Service policy, as defined by Pinchot, still influences current policy, and was based on three principles. One of these -planning for sustainable use, based on detailed inventories - has direct parallels with Swiss federal, and until recently (as discussed below) cantonal policies. In both cases, this orientation can be traced back to the common heritage of 19th-

century German forestry. A second principle was a large degree of regional and local autonomy. In Switzerland, this was initially less marked, but this century has seen increasing devolution of responsibility from the federal to the cantonal level of government. Changes have also taken place in the United States but, as discussed below, they have been more complex. The third principle - maintenance of the economic stability of local communities - has been of low importance in Swiss policy. This can be related to two factors: the emphasis of legislation on the forests' protective, rather than productive, function, and the general antipathy of Cantons and Communes to federal regulation.

The evolution of management for a wide range of outputs developed more rapidly in Colorado than at the national level. From the first years of protection, Colorado foresters realized that their forests were more important for protecting watersheds than as a source of timber. As discussed for the study areas in Chapter five, there was little accessible mature timber. This is one likely reason that inventories and plans were not made for many of Colorado's National Forests for many decades although, according to national-level policy, the management of these forests was intended to be based on "scientific" silvicultural management. When a guaranteed market was available, however, timber management plans were developed. One instance is the 1926 plan for the Summit study area, prompted by the existence of railroad and mining markets. In contrast, a timber management plan was not prepared for Pikes Peak until 1952.

Through the 1950s, management was primarily custodial, emphasizing the provision of wood for limited local use and the suppression of forest fires. Fire, the principal agent of change in Colorado's forest ecosystems, was regarded as a hindrance to management, rather than as a tool which could be used for management. This attitude, which was successfully disseminated from the forestry profession to the public, resulted from a complex combination of factors, particularly the massive fires of 1910 and the sustained-yield principle, developed in a time and place where forests were important for wood production and fire was a rare and catastrophic occurrence. The success of the Forest Service's fire education program has remained a limitation on forest management to the present.

Along with watershed protection and limited wood production, the other forest output which gained early recognition in Colorado was recreation. Both watershed protection and recreation were outputs which, in various ways, Colorado foresters were forced to consider because of public pressure. However, recreation was not recognized in federal legislation and, in spite of attempts which have been made to estimate its value since 1918, was not easily compared to other, legislatively-recognized, outputs since it is not a market good. It was only gradually accepted as a valid output by many foresters and national-level policy-makers until, with the rapid post-war rise in demand, it appeared in the MUSY Act in 1960. However, demands on some of Colorado's forests had

been high since the second decade of this century. The growth in recreation was initially a trend to be coped with, rather than planned for, but planning and management to provide this output were in existence well before the law passed. In comparison, recreation has not been a concern of Swiss forestry until very recently, primarily because the development and maintenance of recreational facilities are usually the responsibility of the political commune, rather than the civil Commune.

The passage of the MUSY Act clearly demonstrated the evolution of national-level policies, but policies developed subsequently also began to decrease local autonomy through the introduction of regional planning. The three subsequent major laws of the 1960s and 1970s - NEPA, RPA, and NFMA - confirmed this evolution, with many public goods being recognized as legislatively-recognized outputs. Requirements for making inventories for all outputs, and assessing demands for them, have been of great benefit for permitting the provision of these outputs to be considered in the development and implementation of forest management plans. However, the three laws also introduced critical new factors to forest management: public participation, economic efficiency analyses, computerized planning, and nationally-set targets for the production of outputs. In addition, RPA and NFMA acted to decrease regional and local autonomy through the introduction of complex planning processes driven, first, by national objectives and, second, by local conditions. The net result has been that an increasing amount of Forest Service manpower and other resources is spent on planning and fulfilling other requirements of these laws and their associated policies, rather than on managing the forests for the outputs whose provision these policies are meant to ensure.

In contrast to the major laws which were enacted in the U.S. from 1960 to 1976, one federal law has been paramount in Switzerland during this century. However, this does not mean that Swiss policies have not changed since 1902. At the federal level, policy-makers' perceptions of the outputs provided by forests have clearly changed. This can be shown, for example, by the definition of protective forests in the 1965 regulations, which emphasize the provision of not only protection from natural hazards, but many more public goods than in the 1902 law. A comparable evolution can be seen from the many revisions of the Forest Police Law and the recent revision of the federal hunting law. However, some recent policies, like the 1876 Forest Police Law, have been stimulated by "disasters"; for instance, the recent resolutions providing subsidies for management activities related to trees affected by air pollution and insect epidemics. Similar stimuli to national-level policy development have not occurred in the U.S. although, as discussed in Chapter five, special appropriations have been made to deal with insect epidemics.

An evolution can also be seen at the cantonal level, in the objectives of the cantonal forestry laws. For instance, in the

1985 Valais law, the production of sustained yields of timber is viewed as of lesser importance, compared to the provision of a wide range of public goods, than in the 1963 Graubuden law. It is difficult to assess changes in the emphasis of management plans in view of the small sample available for the two study areas. However, there appears to be a move away from primarily silvicultural plans to those which consider all forest outputs. Examples include the 1985 Davos plan and the guidelines for Valais, based on recent research (e.g., Gordon, 1985). Yet, as discussed in Chapter five, such plans may prove difficult to implement. Although the subsidies provided by both federal and cantonal governments have become available both in increasing amounts and for a greater variety of activities, they have generally been insufficient to permit the proposed levels of management required for forests to provide the desired range of outputs in the long term.

In conclusion, there has been considerable evolution in the scope of policies and plans for the management of the forests of both regions during this century. The primary direction of this evolution has been to decrease the emphasis on producing sustained yields of timber and increase the emphasis on producing other outputs; mainly public goods. The evolution has gone further in the United States, where the Organic Act placed greater stress on timber production than the Swiss Forest Police Law, and the laws of the 1960s and 1970s now consider all forest outputs, including many impure and pure public goods. In addition, in both countries, the evolution generally proceeded faster in the study regions than at the federal level.

A principal difference between the two regions is that the main locus of planning has remained with local foresters in Switzerland, while in Colorado local foresters have lost much of their autonomy since about 1960. Also, local people now have a considerable influence on policy-making in Colorado, through the legislated public participation process. In contrast, local forest owners in the Alps have little influence on policy-making; only its implementation, through decisions whether to support forest management activities, based mainly on economic grounds. Economic criteria are also crucial in decision-making in Colorado, but are related as much to national or regional goals as to local conditions. To a great extent, these goals are based on economic models, which are not used in Switzerland. In both regions, in spite of rather different policy-making structures, both past and existing policies (including legislation, financial resources, and plans) are generally inadequate to ensure that the forests are managed to provide the intended outputs in the long term. In the following chapter, this conclusion is examined with respect to the four study areas.

5. THE INFLUENCE OF HUMAN ACTIVITIES ON MOUNTAIN FORESTS

This chapter brings the focus of the study to the local level, analyzing how the policies described in the two previous chapters have been implemented in the forests of the four study areas. These policies, however, have not been the only factors influencing human interactions with these forest ecosystems; other factors, particularly the demographic and economic changes in the areas described in Chapter two, must also be taken into consideration. In addition, the present structure of the forests has been strongly influenced by human activities prior to the introduction of federal superintendence. Consequently, the first part of the analysis for each study area describes the influence of human activities in this period. For Switzerland, this description is based on a literature review; for Colorado, archival sources were also used.

The second part of the analysis for each study area is based on a wide variety of sources, and covers the period of federal superintendence, up to the present. Wherever possible, quantitative data have been used. However, long series of comparable data are generally not available and, even when data sets appeared comparable, data collection methods were often found to have changed. Two examples are changes in the minimum diameter of trees measured in timber inventories, and in methods of collecting recreational use statistics. Again, apparently comparable data often vary greatly in their reliability, as determined both by review and from interviews. Finally, there were changes in the areas over which otherwise comparable data sets were collected. In addition, data on forest structure rarely consider all trees even when a random sample is taken. In general, only those trees which are likely to be of importance for timber production are included in a survey or inventory. Thus, seedlings and saplings are rarely considered, although these show the extent of recent regeneration and are therefore critical for assessing the future ability of a forest to provide different outputs.

The sources used for the Swiss study areas were the MAB forestry studies, old and current management plans, and interviews. The availability of old management plans greatly influenced the possibility of making detailed analyses of the structure and uses of the forests over long periods. The analyses for the Colorado study areas are based on Forest Service archival and current documents and plans, and interviews. The availability of archival sources for Forest Service material is highly discontinuous. For many variables, more long-term trend data are available for the period before 1960 than afterwards, in spite of the increase in data collection following the MUSY Act and subsequent laws. The main reason is the agency's policy of destroying documents which are not deemed to be of current relevance; even documents archived in the Federal Records Center are destroyed according to a timetable. Consequently, much of the analysis of the

implementation of forest management policies after 1960 is based on interviews. A major exception is forest structure, for which current data are available from RIS (Resource Information System) printouts.

The inputs and analysis of RIS data are described in section 6609.21 of the Forest Service Handbook, which is frequently updated. Data are recorded for sites approximately 16 ha (40 acres) in area. These data can be based on a variety of survey methods, from photo-interpretation to detailed on-site sampling. In the latter case, cores are taken from the two trees closest to the center of each site, to provide ages. If most trees are poles (5-8.9": 12.7-22.6 cm) or sawtimber (>9": 22.9 cm), average data for a site consider trees >5" (12.7 cm) in diameter. Conversely, on sites dominated by seedlings and saplings, a weighted average of all trees is taken. The data used in the analyses of the two Colorado study areas consider each area as a whole, without considering the methods of data collection, and are therefore not replicable random or stratified samples.

Future studies of forest use and management in Switzerland and Colorado should benefit from the increasing standardization of the collection and storage of data relating to this topic. Swiss examples include the Forest Statistics (Forststatistik), compiled annually since 1975, and the National Forest Inventory (Landesforstinventar), begun in 1983, completed in 1985, and regularly updated. Examples for Colorado include the US Forest Service's RIS and Recreation Information Management (RIM) system though, for Colorado, these are not as uniform as the Swiss data at present.

This chapter is divided into two parts, the first considering the Swiss study areas, and the second the Colorado study areas. Section 5.1 discusses the Aletsch study area and section 5.2 the Davos study area. In section 5.3, findings from these two areas are compared. Similarly, section 5.4 discusses the Pikes Peak study area, and section 5.5 the Summit study area. The findings from these areas are compared in section 5.6. Inter-regional comparisons of study areas are presented in Chapter six, in sections 6.3 and 6.4.

5.1 Aletsch study area

5.1.1 Human influences on forests before federal legislation

Very little information is available concerning human use of the forests of the Aletsch study area before the twentieth century. The eastern boundary of the area considered by Kempf and Scherrer (1982), in their study of the forests of the Rhone valley since 1800 is, unfortunately, the western boundary of the study area. However, it is likely that many of the trends in the study area were comparable to those discussed in their study and by Wuilloud (1981), although the greater distance of the study area from major population centers may have resulted in lower levels of demand. The fact that Valais was the first mountain Canton to pass forestry legislation strongly suggests that there was early awareness that high levels of harvest, particularly for export along the Rhone to Geneva and France, would result in long-term disbenefits to both forest owners and those downstream and downhill from the forests.

The timber trade boomed in Valais in the 1820s and 1830s, principally to supply developing industries, including charcoal manufacture, foundries, and glassworks. However, these were mainly west of Sion, some distance from the study area. Both forests in the Rhone valley and along mountain streams (e.g., the Aletschwald) were clearcut. Many Communes, including Morel, sold parcels of forest to logging contractors (Wuilloud, 1981: 79-81). From the 1850s, railway construction also required large amounts of timber for ties, bridges, and fuel. However, the nearest railway to the study area was the Simplon, which reached Brig in 1878; the Furka-Oberalp railway from Brig did not reach the study area until 1915 (Mattig and Zeiter, 1982).

Whatever the industrial uses of wood from the study area during the nineteenth century, the traditional uses of the forest for fuel, construction, and agriculture doubtless continued. Half of Betten was burnt to the ground in 1855, requiring large quantities of timber for rebuilding. The 1885-1895 management plans do not mention levels of use before the 1870s; sustained yields were set on the basis of visual surveys. Data for six of the communes (Betten, Fiesch, Fieschertal, Goppisberg, Greich, Lax) are available for various periods from 1877 to 1891; these show highly variable harvests. The principal use was for firewood, averaging 73% of the harvests; the proportion for individual communes was from 63% to 84% (Table 5.1). In all communes, the sustained yields set in the plans were below the average use of preceding years. The sustained yield was similar to recent harvests only for Fiesch; for other communes, sustained yields were set at 42% to 75% of recent harvests. These disparities suggest that harvests in the 1870s and 1880s had been higher than increment, and that harvests had to be reduced to permit the forests to fulfil the joint functions of production and protection.

TABLE 5.1

ALETSCH STUDY AREA:
HARVESTS IN SIX COMMUNES 1877 - 1891

COMMUNE	PERIOD OF RECORD	MEAN ANNUAL HARVEST (m^3)	PERCENT FOR FIREWOOD	NEW SUSTAINED YIELD (m^3)
Betten	1877-84	600	63	253
Fiesch	1882-91	525	76	495
Fieschertal	1880-89	297	70	206
Goppisberg	1877-84	152	84	96
Greich	1877-84	132	77	79
Lax	1977-84	398	79	297

Source: Tables at end of 1885-1895 management plans

5.1.2 Implementation and effects of forest management policies from 1902

The following analysis of the implementation and effects of forest management policies subsequent to the 1902 Forest Police Law and later cantonal legislation is based on the available management plans written for the public forests of the area from 1924 to 1942; records of subsequent harvests; the MAB forestry study (Bellwald and Graf, 1985); and interviews with foresters concerned with the area (pers. comms: Leu, 1986; Walther, 1986, 1987; Werlen, 1986, 1987). Until 1982, up to four part-time forestry aides, who were nominally communal employees but remunerated mainly by the Canton, were in charge of the area's forests. Their principal activities were to identify and mark the trees which could be felled by each Commune's citizens each year, and supervise felling. Since 1982, the five northern communes (from Martisberg north) have employed a full-time forester; although 80% of his wages come from government subsidies. The forests of the other communes are still supervised by cantonally-supported part-time forestry aides.

The overall level of access to the area's forests for forestry management purposes has always been very limited. There is, however, a relatively dense network of trails which developed over centuries of agricultural use. These are maintained by the communes and lightly used for hiking, as discussed in Chapter two. Many of these trails could be widened for forestry purposes. Improved access was proposed in all of the management plans, in order to permit management of a greater proportion of each Commune's forests. However, as late as 1982, Zuffi (1982) estimated that 75% of the productive forest area had either no or inadequate access. Bellwald and Graf's (1985: 61) analysis showed that the degree of accessibility decreased with altitude. This analysis was based on measurements of the distance of randomly-selected points from a road or logging trail. The average distance of points below 1000 m was 119 m; from 1000 to 1500 m, 211 m; from 1500 to 2000 m, 407 m; and 899 m above 2000 m.

Zuffi (1982) identified a number of problems for the improvement of the access network, including the financial weakness of the Communes, the short (2-3 months) building season, and the erosion of roads, exacerbated by steep slopes and runoff from irrigation channels. All of these problems appear to have existed for decades. The combination of the first two factors is especially important; the potential road building season is also the period of greatest agricultural activity and,since the Communes have always had limited income, they could not afford to employ contractors. A further problem is that many of the most logical routes for roads and trails cross communal boundaries. As there has generally been little cooperation between Commurres, the likelihood that roads would be built was further decreased. The employment of a full-time forester by the northern Communes reflects a new spirit of cooperation, and these Communes are now

submitting joint proposals for road construction to the federal government. In contrast, cooperation is still lacking between the other Communes, so that the new roads being built in the rest of the area are within the boundaries of individual communes. These roads are built by contractors, often to low standards, as part of federally-subsidized projects.

In the period before the 1924-1942 management plans were written, harvesting concentrated on high-quality sawtimber trees, whether for construction, agriculture, or fuel. Presumably, this habit was because individuals wanted to minimize their effort, particularly since logs were skidded downhill by hand in the absence of good access. In the few areas where good access existed, as between Riederalp and Ried-Morel, almost all usable wood was removed. However, throughout the area there was little high-quality timber for construction. Large trees near timberline were generally severely damaged by browsing and sliding snow; those lower down typically had heartrot, resulting from damage by trees being skidded and rockfall.

For those Communes for which data are available (Betten, Bitsch, Goppisberg, Greich, Martisberg, Ried-Morel), the levels of use during the period between the 1885-1892 and 1924-1942 management plans were 5-25% higher than those recommended in the former plans. The main use of harvested timber was for firewood, accounting for about three-quarters of the total use, as in the last century. Harvested timber was predominantly used locally; sales were rare and generally small. The influence of accessibility on emphasizing the harvest of larger trees was shown by the distribution of reserves in trees of >16 cm dbh. In general, lower proportions of the total reserves were found in the largest size-class (>40 cm dbh) in forests which were relatively easily accessible, such as those of Bitsch, Goppisberg, Greich, Betten, and the Riederwald; than in those which were less easily accessible, such as the Martisberg forests and the Aletschwald.

The forests were principally composed of spruce trees, with less than 10% larches, and 1-2% pines. However, the latter species were comparatively over-represented in the larger size classes. The management plans suggest that the growth of larches should be encouraged. It is not clear whether this was because it was already realized that mixed forests provided better protection against avalanches (cf. Mayer, 1976) or that larches were assumed to have higher growth rates, so that their encouragement would result in greater future yields. The management plans also mention that grazing and browsing had resulted in inadequate regeneration; livestock had been banned from parts of many of the forests by the time the plans were written. The preferred harvesting method was selective cutting, to increase the diversity of species and age-classes; thinning was proposed in stands of poles. The production of high-quality wood was also to be encouraged by banning skidding in the summer months, when standing trees are most susceptible to damage.

The sustained yields defined in the 1924-1942 management plans were lower than the average annual harvests since the 1885-1892 plans, generally at levels slightly lower than those proposed in the earlier plans. The only exception was Betten, where the sustained yield was increased by a third, since growth had been sufficient to recover the high harvests which provided timber for rebuilding after the 1855 fire. Annual harvests for the communes of Betten, Bitsch, and Goppisberg, which have the longest periods of record, are shown in Figure 5.1. This shows the great variation in harvests which results from the interaction of biological, physical, and socio-economic factors. To provide a clearer basis for discussion by removing short-term and local factors, five-year average annual harvests for the forests of the study area from 1938 to 1987 are shown in Figure 5.2, which also indicates the number of times in each period that harvests were -->10% over the sustained yields defined in the 1924-42 plans.

Until 1947, harvests were typically higher than the sustained yield. Throughout the 1930s and 1940s, when demand was high, large harvests were made to provide wood for sale. Average harvests subsequently declined in the 1950s, although the 1953 and 1956 harvests were close to the levels of the 1940s. From 1957 onwards, there was a general decline in harvests which continued until 1970. The next decade was marked by very low harvests; in two-thirds of the communes, there were no harvests for at least half of these years. From 1982, federal support for the removal of trees damaged by bark beetles and air pollution was available, and harvests rose substantially, to levels above those of the 1940s. Most of this harvesting would have been impossible for the Communes to undertake without subsidies; deficits as large as SF 100/m^3 occurred where helicopters were used to remove diseased trees.

Bellwald and Graf (1985) found that, in the previous 30 years, only 7% of the total forest area had been managed according to the prescriptions in the 1924-1942 plans. Most of this area was in small, narrow strips within 250 m of roads and trails. However, access does not appear to have been the only factor determining harvest levels; in the late 1960s and 1970s, there were no or low harvests in many of the Communes with good access, and vice versa. Large harvests occurred after government authorities required and subsidized removal of trees damaged by insects, windthrow, sliding snow, or avalanches. Such conditions account for all of the harvests >10% over the sustained yield during this period. In nearly every Commune, such harvests were preceded and/or followed by years without harvests.

In general, therefore, it seems that the management policies proposed in the 1924-1942 plans were of little significance in determining harvesting patterns. The primary factors which decided locations and levels of harvest were available manpower and access, demand for timber for fuel and construction, and government requirements and subsidies for the harvesting of

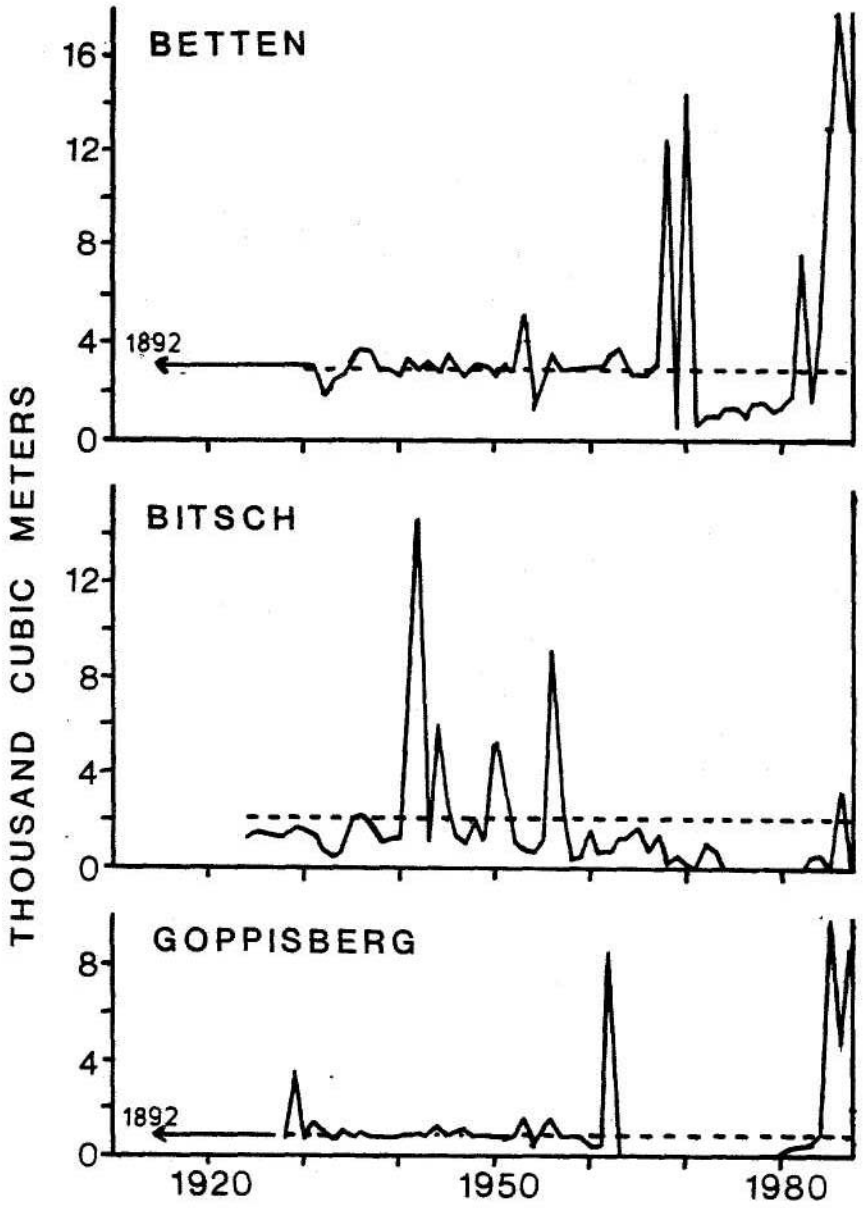

Figure 5.1: Betten, Bitsch, and Goppisberg: annual harvests 1892 - 1987

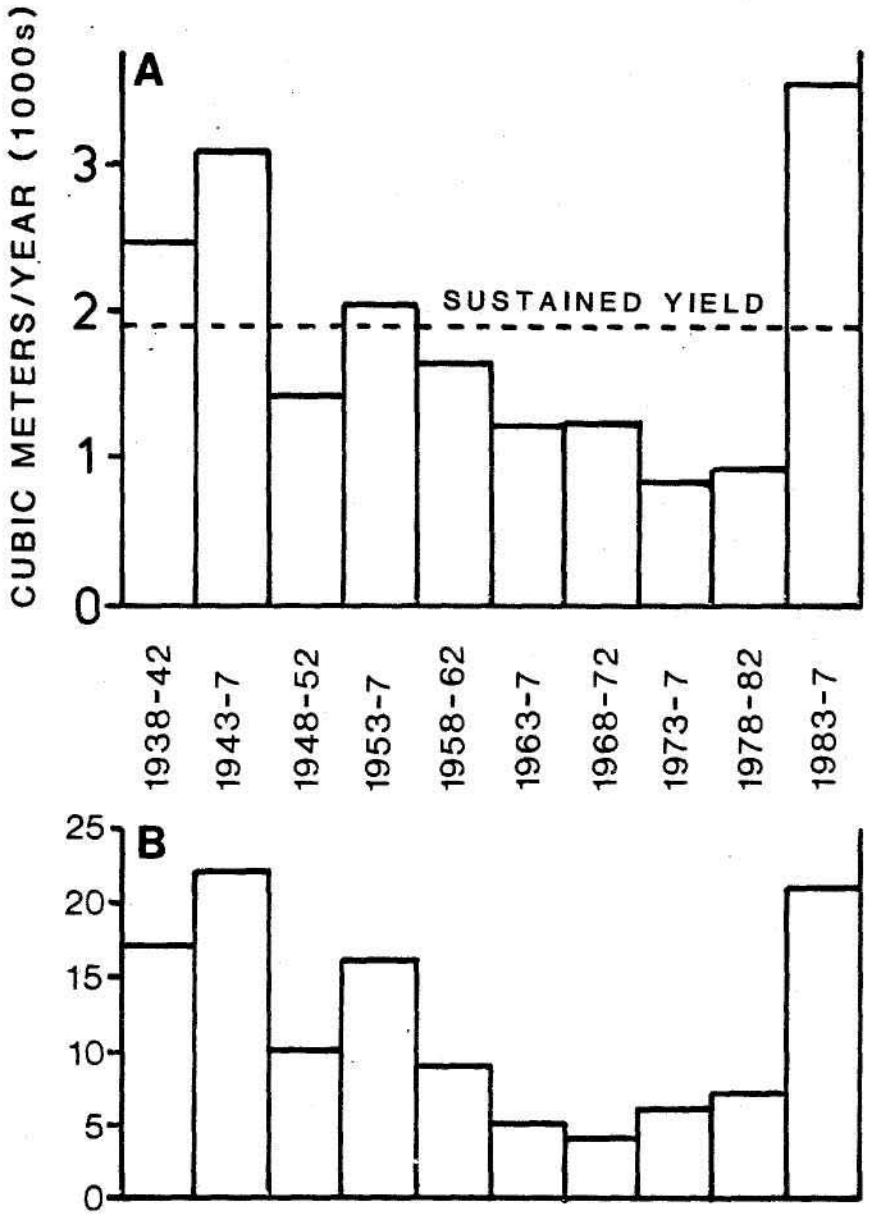

Figure 5.2: Aletsch study area, 1938 - 1987:
A: five-year average annual harvests
B: frequency of harvests >10% over sustained yield

diseased or downed trees. Thus, the decline in harvests from the mid-1950s through the 1970s may be explained by the decrease in available manpower as the primary sector declined, and the growing availability of less costly sources of fuel and timber for construction. In the latter regard, it is worth noting that many of the "Swiss" chalets at Bettmeralp were prefabricated in Finland and erected by Finnish workers (Leu, pers. comm., 1986).

During the four to six decades between the preparation of the management plans and Bellwald and Graf's (1985) study, the total forested area in the study area increased by 17%. This increase has probably all been natural, occurring as grazing pressure and harvesting decreased. While many of the management plans proposed reforestation projects, Walther (pers. comm., 1986) identified no projects in the study area. In the upper Goms area, north of the study area along the Rhone valley, the limited attempts at reforestation during this century have generally been very unsuccessful (Walther, 1964). Reasons given include unsuitable sources of plants and seed, inadequate numbers of plants, grazing pressure, landslips, and lack of supervision, maintenance, and fences. The costs of planting and maintenance are typically high, and these activities must take place during the summer. Thus, as with road building, lack of financial resources and manpower probably would have precluded planting projects if the Communes had wanted to undertake them.

Bellwald and Graf (1985) sampled the forests of the study area at 613 randomly chosen sites, in order to analyze the species distribution, size and age structure, and damage to trees. As in the 1920s and 1930s, the forests were dominated by spruces, which accounted for 78% of the volume of growing stock (numbers of trees were not recorded). This is a smaller proportion than for the Communes for which management plans are available, and may represent greater harvesting of this species, faster growth of the other species, or a greater predominance of spruce in the forests of the other communes. The second most important species was larch, with 9% of the growing stock, followed by pine (6%), arve (4%), and deciduous trees (3%).

Analysis of forest structure showed that only 3% of the area was covered in coppices or stands of saplings (<12 cm dbh), and 7% was dominated by poles (12-20 cm dbh). These stands were dominated by either spruce or deciduous trees. Small timber (21-30 cm dbh) stands covered 14% of the area; medium timber (31-40 cm dbh), 27%; large timber O41 cm dbh), 27%; and mixed stands, 22%. As in the 1920s and 1930s, larches, pines (and arves) represented a greater proportion of the larger trees than spruces. Most of the former species were in stands consisting of trees of a mixture of species and sizes. In contrast, single- or two-layer stands were dominated by medium and large spruces; such stands, often with closed canopies, covered 75% of the forest area. It is not possible to assess changes in size structure in any detail since the recent data are not comparable to those in the management plans.

The size structure described above suggests low levels of regeneration for much of this century, as is also suggested by the age structure obtained from cores and shown in Figure 5.3. This shows a clear predominance of trees 80-120 years old. The 80-90 year class is both mean and modal. About a fifth of the sampled trees were at least 150 years old. In accessible areas of forest, these are likely to have been deformed or diseased trees which were left when high-quality timber was removed. Regeneration appears to have increased in the 1970s, since the 0-10 year class had a similar frequency to those around the mean; significantly higher than those in the previous 30 years. However, regeneration was defined as inadequate over 90% of the area, principally because most of the forest canopy was closed, allowing insufficient light for germination and growth.

This conclusion was further substantiated by a separate analysis of the distribution of saplings. The majority (70%) were deciduous, primarily on avalanche slopes. A further 21% were spruce, 4% larch, and 5% other conifers. As shown in Table 5.2, the distribution of saplings was rather uneven. The lack of saplings from 1000 to 1200 m may be explained by browsing pressure, discussed below, and the spread of high bushes and grass on abandoned fields. Above 2000 m, browsing by livestock may also be a factor, together with the climatic factors which limit the survival of trees at timberline. Saplings found beneath larger trees were generally on elevated microsites.

Additional reasons for the lack of saplings are suggested by the results of a survey of small trees (<12 cm dbh). Almost half of these were damaged (37%) or dead (10%); the latter included about a quarter of the small spruce, larch, and fir trees. The distribution of damaged and dead small trees varied little with altitude, although the proportion of dead trees doubled above 2000 m. The commonest cause of damage was browsing, which affected 21% of the small trees, including 45% of the fir and 26% of the deciduous trees. Over more than a quarter of the forest area, at least 10% of small trees were damaged by browsing. The proportion of such damage was inversely related to altitude, and was predominant below 1200 m. It is worth noting that, within this zone, hunters provide winter feeding stations for deer, according to the provisions of the 1876 federal hunting law. The deer eat not only the hay provided, but also browse on and rub against the adjacent trees. Other damage was from a variety of causes, both physical (e.g., sliding snow) and biological (e.g., fungal infection); these affected 26% of the spruce, 12% of the deciduous, and 9% of the fir trees.

A survey of large trees (>12 cm dbh) found that 26% were damaged. The commonest cause of damage (39% of damaged trees) was rockfall, which can be either natural or the result of rocks being dislodged during harvesting, which was identified as the direct cause of 15% of the damage. Both of these causes mainly affected the trunks of trees, resulting in increased

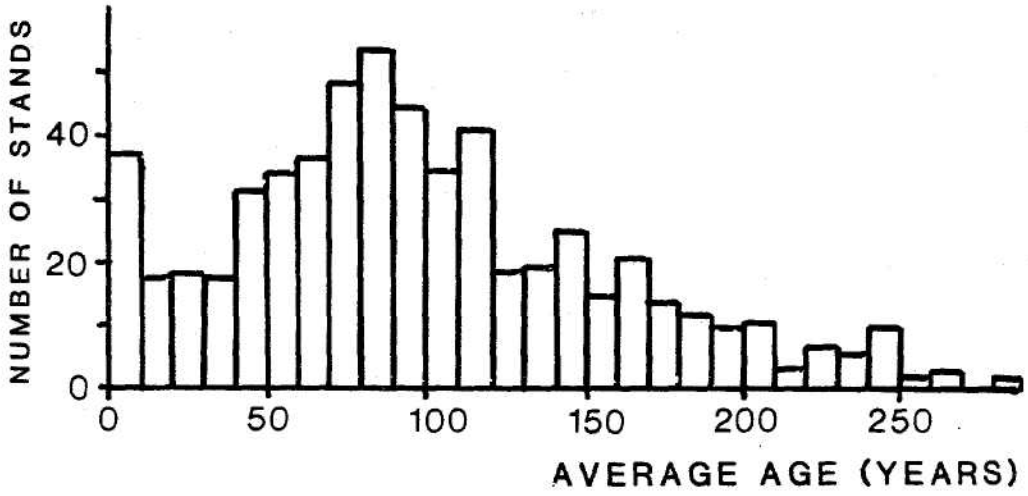

Figure 5.3: Aletsch study area: forest age structure

Source: Bellwald and Graf (1985): Page 46

TABLE 5.2

ALETSCH STUDY AREA: DISTRIBUTION OF SAPLINGS IN ALTITUDINAL ZONES

ALTITUDES (m)	PROPORTION OF SAPLINGS (%)	PROPORTION OF FOREST AREA (%)
500-1000	21	6
1000-1200	0	9
1200-1500	37	25
1500-1800	21	36
1800-2000	21	19
2000 +	0	5

Source: Bellwald and Graf (1985): Page 37

susceptibility to heart rot and other diseases. This problem, which was often mentioned in the 1924-1942 management plans, greatly decreases the value and strength of the trees and can be, at least to some extent, attributed to the practice of skidding felled trees through the forest in the absence of adequate access. The problem has been further exacerbated by the practice of paying contractors according to volumes harvested. As a result, roads are quickly built, so that the best timber can be extracted as fast as possible, with little regard to resulting damage to standing trees. Such conditions typify recent logging in the southern Communes; in the northern Communes, logging is not on a piece-work basis, and is closely supervised by the district forester. Physical factors, such as wind and snow, were the cause of 19% of the damage, mainly by breaking crowns - though trunks may also be broken. Other factors, mainly biological, accounted for the remainder of the damage. The level of damage was least in mixed-size stands (15%), higher (21%) in pole and small timber stands, and highest (27%) in stands dominated by medium and large timber trees.

A final analysis of the forests of the study area considered their ability to fulfil a variety of functions. This analysis found that 62% of the area was important or very important for protection from avalanche, rockfall, erosion, landslides, or flash floods. To assess the ability of the forest to fulfil these functions, stands were classified according to Langenegger's (1979) criteria for stability. "Stable" stands can probably fulfil their functions for the next 10 to 20 years without special measures. These covered 66% of the area, with higher than average values in stands dominated by both the smallest (<12 cm dbh) and largest (>40 cm dbh) size classes. In "unstable" stands (30% of the area), active management is needed within this time period, otherwise the stands may not be able to fulfil their functions. "Critical" stands require immediate action; these included 4% of the area, particularly in pole-sized stands and, to a lesser extent, in mixed stands and stands dominated by trees of 20-40 cm dbh. Of these critical stands, 67% consisted of trees in a single size class. In contrast, 84% of mixed-size, but only 58% of single-size, stands were stable; stability generally increased with greater variation in age and size. Together, these analyses suggest that active management is necessary in much of the area.

5.1.3 Summary

In conclusion, the structure of the forests of the study area does not appear to have been markedly affected by the implementation of stated policies, whether in legislation or management plans. The 1924-1942 management plans were based on silvicultural theory which hardly considered local conditions, particularly access and, as is still the case today, were written without any input from local people. Proposals for reforestation projects and selective cutting to produce a more diverse forest

structure were not implemented. Levels of harvest primarily depended on local needs and available manpower and access and, secondarily, on government requirements for the removal of diseased or downed timber.

In other words, economic factors were paramount. The Communes were not prepared to invest in the management of their forests to ensure the long-term provision of protective and recreational functions; even today, the citizens of the northern Communes only allow the forester to undertake activities which can break even. No sales were possible because of the low quality and inaccessibility of the timber; higher harvests resulted from the availability of government subsidies in isolated instances during the 1960s and 1970s and since 1982. Similarly, no avalanche control structures were built until government funding became available in the 1980s. The structures on the Riederhorn were built with a 92% subsidy; those above Fiesch, Fieschertal, and Lax had subsidies of 90% to 95%.

Bellwald and Graf's (1985) classification of the forests in terms of function and stability remains academic as long as resources (access, manpower, etc.) are unavailable for planning and undertaking management to make sure that the forests provide these functions. The high harvests of the 1980s have primarily been in reaction to short-term problems (with potential long-term consequences), rather than being part of any planned management policy. The cantonal forest service has classified nearly all of the forests of the study area as protective. The only forests identified as primarily productive are near the lower forest margin in the Communes of Fiesch, Fieschertal, Martisberg, and Betten; all are of low quality. In addition, recreation is identified as the primary function of the forest southeast of Bettmeralp. However, until new management plans are prepared, and unless the economic situation improves, harvests are likely to continue to be in response to short-term conditions, rather than long-term plans.

5.2 Davos study area

5.2.1 Human influences on forests before federal legislation

The history of the use of the forests of Davos has been described by Gunter (1980). As discussed in Chapter three, the Commune of Davos passed regulations concerning the use and protection of both public and private forests from the fifteenth century onwards. However, regulation was not particularly successful, and the forested area continued to decrease. Major uses of the wood, as in other parts of the Alps, were for construction, fuel, and agricultural activities. In addition, after mining began in the fourteenth century, timber was also used for this purpose, and considerable quantities were harvested for sale.

By the seventeenth century, sales of wood had decreased substantially. It is not clear whether this was because communal regulation was having some effect, or because the growing stock had become so depleted that supply was barely more than local demand. Gunter (1980: 65) estimates that, at the beginning of the nineteenth century, the minimum average annual requirement for construction was 900-1000 large (30-45 cm diameter) trees. From 1807 onwards, many areas of private forest were either purchased or leased for a 50-year period by mining companies. The forests were typically cleared in strips. When possible, adjacent strips were logged at least three years apart. Harvested wood was used by the mining industry for props, sluices, and many other purposes, and also as fuel for the zinc smelter which operated from 1816 to 1848. While no data are available for the quantities of wood harvested, logging was effectively unregulated, taking place up to the timberline.

In the 1840s, the Davosers regarded the first cantonal regulations as a great infringement of their rights, and refused to appoint a bailiff. This was although, according to the cantonal inspector's 1852 report, levels of harvesting to provide timber for sale were excessively high, and regeneration was minimal. In 1861, the Davosers accepted the second set of regulations, appointing a forester and establishing a communal forestry commission. However, the commission was disbanded, and the forester fired in 1869. Next year, there were severe floods, and in 1873, the Commune finally accepted cantonal regulation. Sparse data on timber sales are available for the early 1870s, though these generally describe numbers of permits or trees sold, rather than volumes of timber extracted, so that definite statements regarding harvesting levels cannot be made. In the late 1870s and 1880s, small plantations were developed, and some afforestation of avalanche paths was started.

More detailed data for 1894 and 1895 show that permits were only provided to those who respected the regulations and were prepared to reforest logged areas and keep domestic animals from grazing them. While the average annual permitted harvest for sale at this time was around 1400 m^3, far more wood was cut for private use

under various communal orders allowing cutting for fencing and construction. In addition, this was a period during which the tourist industry was undergoing great expansion, requiring increasing amounts of wood for construction and fuel. This first phase of tourism, from about 1870 to 1914, also increased the accessibility of the forests. One reason was that, with the increased demand for milk for the sanatorias' patients, more trails were needed to permit milk to be brought down from the Alp in the summer. A second reason was that hiking trails were built for both patients and recreational visitors.

5.2.2 Implementation and effects of forest management policies from 1902

Analysis of the implementation and effects of forest management policies until the 1980s is complicated by the predominantly private ownership of the forests of the study area. Most owners owned too small an area of forest to make the cost of inventory or planning worthwhile, and government subsidies for these purposes were unavailable. Most timber was cut for personal use, and harvested volumes were not recorded. Thus, comprehensive information on the use or structure of the forests is lacking. The following analysis is based on Giinter's (1980) study; the current management plan for the forests of the study area (Teufen, 1985); the MAB forestry study (Hefti and Buhler, 1986), which covered only the northern end of the study area, including the Dischma valley; and interviews with foresters concerned with the area (pers. comms.: Florin, 1986; Teufen, 1986, 1987) and the director of the tourist bureau (Gerber, pers. comm., 1987).

During the first two decades of this century, a primary concern of the Commune and the cantonal forest service was to protect roads, railroads, and settlements from avalanches, rockfall, and floods. The first major project started in 1903, and others began in 1907, 1909, and 1919; according to Gunter (1980: 86-7), 103 ha were planted. Most were in areas of communal forest, some of which had been privately-owned and bought or expropriated by the Commune. From 1920, the projects combined reforestation with the construction of avalanche or flood control structures, subsidized up to 80% by the federal and cantonal governments. During this period, and for the next few decades, private owners felled their own timber, or employed contractors. Winter was the main logging season; the logs were skidded out over the snow by hand or with horses. Where trails were available as a result of the development of tourism, as discussed above, these were probably used. Harvested timber was used for construction and fuelwood in roughly equal proportions into the 1930s (Teufen, pers. comm., 1987).

The first district foresters were employed in 1925. Until 1965, there were three, one for each of the districts into which the study area is divided. Each was employed for 20% of his time to manage the communal forests according to management plans, where

these existed. They were also responsible for marking trees to be cut, grading timber, and general policing, particularly to make sure that wood was not stolen. Data on annual harvests throughout this period are unavailable. Gunter (1980) divides the period from 1932 to 1964 into two periods, each characterized by different levels of harvest. From 1932 to 1945, the average annual harvest was <2 m^3 /ha in both private and communal forests, From 1946 to 1964, annual harvests in private forests decreased to >2 m^3/ha, while those in communal forests increased to >4 m^3/ha, mainly because of mandatory harvesting, as discussed below. Estimated average harvests from private and communal forests for various periods from 1932 to 1982 (Table 5.3) corroborate this difference. These average values are somewhat misleading, in view of the varying accessibility of different areas of forest; more accessible forests, such as the Rutiwald and Aebiwald, had harvests well above the average. Gunter (1980) estimates that the average annual harvest from private forests from 1937 to 1964 was 8250 m^3 (1.77 m^3/ha). Teufen (1985) estimates the average annual harvest from private and communal forests from 1924 to 1964 as 10,300 m» (1.85 m^3/ha). Since only 16% of the forest area is communal forest, the two estimates appear comparable.

Throughout this period, most harvested timber was sold; probably only 15% to 25% was used by private or communal owners. Data from the Monstein communal forest for the early part of this period (1932-1949) show that harvested timber was used equally for sawtimber and fuelwood. However, while 87% of the sawtimber was sold, 55% of the fuelwood was used by the Commune's members. The average annual harvest in this period was 54% higher than for 1912-1931. Figure 5.4 shows five-year averages of volumes of timber sold from 1940 to 1984. The values in the early to mid-19403 were higher than in the previous decade, because of the high demand for timber during the Second World War. During the late 1940s and 1950s, local demand was lower, with the stagnation of the tourist economy. However, lower-quality timber began to be sold for industrial use once transport became available. The average values shown were also increased by two unusually high mandatory harvests, particularly in the communal forests. These occurred after avalanches brought down 4000 m^3 of timber throughout the study area in the winter of 1950/51, and after a windstorm brought down 15 ha of trees at the west end of the Fluelatal in 1956. These trees were harvested in 1956 and 1957, and the area was subsequently reforested.

From the mid-1960s through the 1970s, there was a considerable decrease in harvests, linked particularly to a marked drop in the proportion of wood harvested by private forest-owners. From the mid-1940s to the early 1960s, this proportion had remained quite constant, accounting for approximately five-sixths of sales. Subsequently, the proportion has decreased, from less than two-thirds to about a half. These trends may be attributed to the interaction of a number of factors. The rapid expansion of the skiing industry meant that local people became less interested in

TABLE 5.3

DAVOS STUDY AREA:
ESTIMATED AVERAGE ANNUAL HARVESTS

PERIOD	AVERAGE ANNUAL HARVEST (m^3/ha) PRIVATE FOREST	PUBLIC FOREST	TOTAL FOREST	SOURCE
1932-45	<2	<2	<2	1
1946-64	>2	>4		1
1946-56	2.0	2.6	2.1	2
1958-69	1.4	2.2	1.5	2
1965-77	<0.6	>3		1
1972-82	1.1	1.8	1.2	2

Sources: 1: Günter (1980), Page 100

2: Hefti and Bühler (1986), Page 59

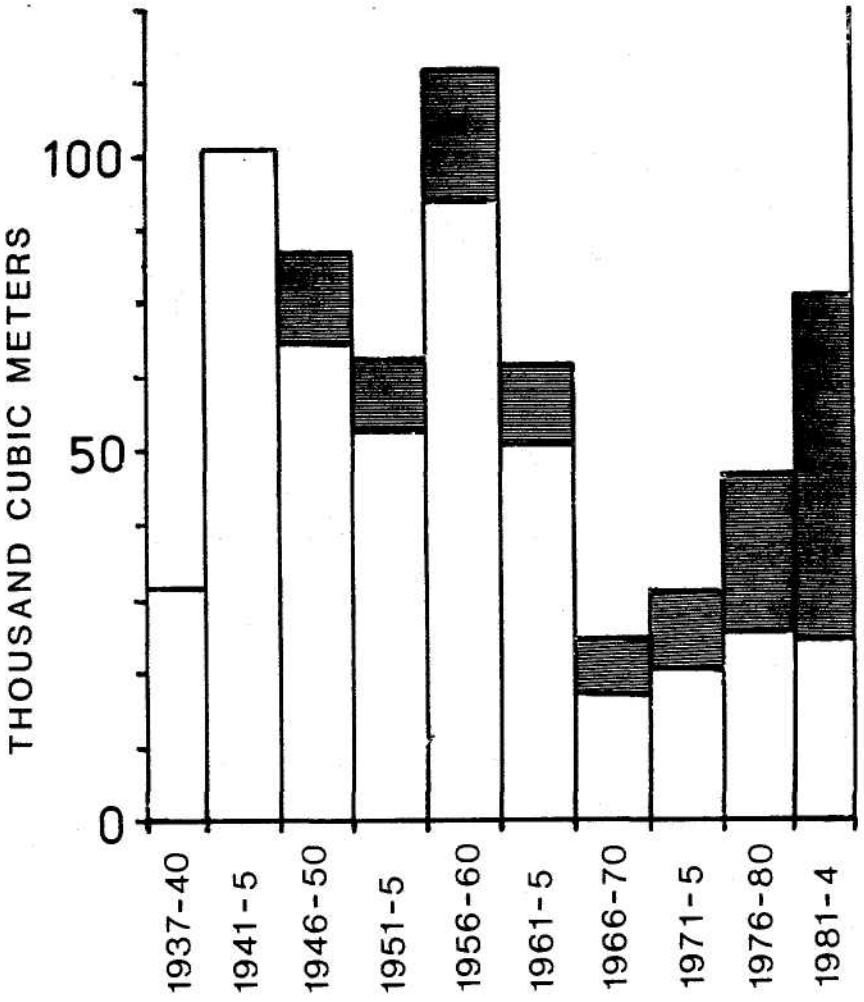

Figure 5.4: Davos study area: five-year average annual volumes of timber sold.

Unshaded = sales from private forests, shaded = sales from communal forests.

Sources: 1937-1975: Günter (1980): Page 99
1976-1984: Annual statistics for communes, Eidgenössisches Forststatistik, Bundesamt für Statistik, Bern

forestry, as opportunities for winter jobs increased. Such jobs made it possible for forest-owning farmers to work on the ski hill during the day and still look after their cattle at night. Also, as agriculture became more intensive, fewer poles were needed for fences, gates, and roofs, so that there was less thinning of the forest. The demand for fuelwood also decreased with the availability of oil as a competitive heating source; although lower-quality wood was increasingly sold for industrial use when a profit could be made. However, since the early 1960s, wood prices have changed little while labor costs have risen sharply, so that it became uneconomic for private owners to employ contractors to work in their forests. For the same reason, the Commune employed only two district foresters (each at 30%) from 1965 to 1971, and one (at 60%) from 1971 to 1980. They were increasingly unable to fulfil their responsibilities, particularly since they had no logging equipment. Finally, as the main logging season changed from winter to summer, the lack of adequate road access became increasingly critical.

In 1979, an early wet snowfall brought down approximately 120,000 trees throughout the area. To cope with the resulting need to remove this timber, much of which was of high quality, the Commune employed two district foresters, one full-time and one at 60%, in 1980. In 1984, the Commune agreed that three full-time district foresters should be employed to carry out the activities described in chapter four. The number of forest workers was also increased. Half of these now come from the Tyrol for about seven months each year. The local workers are paid year-round by the Commune, and work for the skiing industry or the tourist bureau in the winter.

Strong communal support for forestry has also extended to the construction of new roads and the purchase of cable-cranes and other equipment, to allow the development of the access system according to Taverna's (1984) plan. There are two potentially serious problems in expanding the road network. First, road construction and use can conflict with hiking. Gerber (pers. comm., 1987) estimates that up to one million people hike on the dense network of trails each year. The trails are maintained by the tourist bureau at an annual cost of c. SF 500,000; the workforce is almost as large as for forestry. Forestry activities are planned to minimize audible and visual impacts on hikers, even when this increases costs; for instance, branches from harvested trees are turned into chips, rather than being left in the forest. At the same time, the tourist bureau is trying to educate hikers about the importance of forestry.

The second problem is that some private owners refuse, for political rather than economic reasons, to allow new roads to be built across their land. This problem can be solved by expropriation in the common interest, but the process takes two years. In contrast to the existing pattern of narrow trails, passable only by small tractors, new, wider roads are being built near the base of slopes, and cable-cranes used to harvest the

timber above. New roads have been built in the south end of the study area and east of Davos. Increased accessibility has permitted harvests in the 1980s to approach the level of sustained yield (14,000 m^3/year) defined in the current management plan (Teufen, 1985). However, a large proportion of recent harvests has been to remove trees damaged in 1979; many of the damaged standing trees subsequently developed root rot.

The discussion in the previous paragraphs has concentrated on harvesting over the past six decades. This has been the principal activity, except since the mid-1980s, when roads have also been built. However, reforestation and afforestation projects have also continued. For the period 1903 to 1977, Gunter (1980) describes many projects, on both private and public land, at various levels of detail. The projects covered 175 ha, with seedling densities from 2700 to 6100/ha. All projects used a mixture of species; sometimes only spruce and larch, but often arve, pine, and alder in addition. Respective proportions of these species were 39%, 25%, 18%, 14%, and 4%. Teufen (1985) gives only the areas of projects, dividing them by purpose and ownership (Table 5.4). It is not clear to what extent the areas described by the two authors overlap. In any case, the combined area of these projects is less than 3% of the total area of forest.

Table 5.4 brings out the importance which the Commune has given to the protective function throughout the century; many of the public projects are on sites bought or expropriated from private owners because of their importance for protecting settlements, roads, or railways. In contrast, most of the private projects took place after forest cover was removed by natural agents (wind, fire, avalanche, snow pressure) or harvesting. In view of the high financial and labor inputs which are required for both planting and maintenance, it is worth noting that little of the planted forest can compare with naturally-regenerated forest in terms of growth rates, quality, and stability (Teufen, 1985). Most of these projects were undertaken only when government subsidies were available; reforestation after harvesting took place in compliance with government regulations.

While considerable detailed data are available concerning the composition of the small patches of planted forest, little is known of the structure of the forests of the study area as a whole until 1982/3, when an inventory was taken at 798 randomly chosen sites (Teufen, 1985). This showed that the forests were dominated by spruce trees, accounting for 82% of trees, and 80's of the volume of growing stock. Comparative proportions for larches were 11% and 19%; for pines, 4% and 1%; and for arves, 2% and 2%. Most larches date from the turn of the century, when there were many clear areas for regeneration and livestock grazing had been curtailed. Many of these trees are found at the margins of patches of forest, where competition from other trees is low; hence the comparatively large volume of these trees, on average 42% greater than for spruce trees. Young larch trees are

TABLE 5.4

DAVOS STUDY AREA: PURPOSE AND OWNERSHIP
OF REFORESTATION PROJECTS

	****** AREA (ha) ******		
PURPOSE	PRIVATE	PUBLIC	TOTAL
Protection	10	69	79
Post-damage reforestation	50	0	50
Post-harvest reforestation	6	3	9
Research	0	9	9
TOTAL	66	81	147

Source: Teufen (1985), Pages 19-20

now rarely found except in avalanche paths. Pines and larches are disproportionately represented in the lowest-quality stands on extreme sites, such as the Wolfgang Pass. Arves are mainly found near timberline at the south end of the study area, usually with larches.

Teufen (1985) did not survey the age-structure of the forests of the study area. However, Hefti and Bühler (1986) took cores at 196 sites in the northern part of the study area. This age structure is shown in Figure 5.5, and is probably similar for the whole area. While trees as old as 250 years were sampled, half of the sampled trees were from 40 to 100 years old, with a slightly greater proportion in the older age classes. About a fifth of the trees were over 150 years old. Trees under 40 years old, most younger than 10 years, accounted for only 8% of the sample. This structure shows that enforced regulation of harvesting and grazing around the turn of the century permitted a larger proportion of seedlings to survive than previously. While thinning continued, until the middle of this century, new trees could still become established. However, the lower levels of use in the past four decades, particularly in the private forests, have led to increased competition for light and nutrients from older trees, shrubs, and high grasses, thus decreasing establishment and survival.

Other factors are also important in the survival of young trees. Teufen (1985) found that 21% of small trees (<8 cm dbh) had been browsed or debarked by game animals. The proportion of damage was greater in open stands, where levels of regeneration are generally higher, and afforestation projects. Hefti and Bühler (1986) found that the most severely damaged species was larch, of which 12% had been damaged by rubbing (which hardly affected other species), and 35% by browsing. Browsing affected 27% of spruce, 13% of arve, and 6% of pine trees. A further 20% of the sample of small trees had been damaged by other causes, including creeping and sliding snow, frost, dessication, wind damage, rockfall, and off-piste skiing; each species showed similar levels of such damage. Less than 1% of large trees (>8 cm dbh) were damaged by game animals, and 2% had collapsed; most of the latter were larches broken by snow pressure. All of these trees were poles (<24 cm dbh). Large trees of all sizes had been damaged by rockfall (6%), and by harvesting (3%). A likely reason for the degree of harvesting damage is the vertical orientation of many parcels of private forest, from timberline to valley bottom. Traditionally, logs were skidded downhill through an owner's forest, with consequent damage to standing trees on the steep slopes. All types of damage result in greater susceptibility to various forms of root and trunk rot, which have affected increasing numbers of trees of all ages over the past decade. Because of their thinner bark, spruces are more susceptible to rockfall damage and subsequent infection than larches.

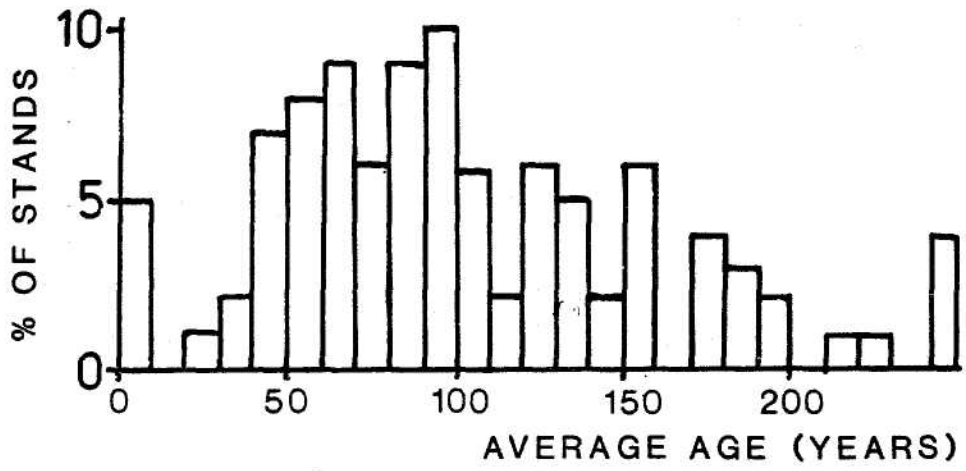

Figure 5.5: Davos MAB test area: forest age structure

Source: Hefti and Bühler (1986): Page 31

The size structure of the forest (for trees >8 cm dbh) is shown in Table 5.5. This structure, like the age structure, can be largely explained by the changing patterns of use since the middle of the last century. The causes of the low levels of regeneration, which have led to a relatively low proportion of poles (<24 cm dbh), have been discussed above. The relatively high proportion of small and medium timber trees (24-52 cm dbh) results from two main factors. The first was the introduction of restrictions on use around the turn of the century, which permitted the establishment and survival of many new trees; these trees also dominate the age structure. The second was the subsequent lower levels of use, particularly thinning over the past four decades, which resulted in slow growth. This is also the reason for the relatively small proportion of large timber trees (>52 cm dbh); according to their age, many of these trees would have had 60-70 cm dbh had the stands been thinned. These conclusions are further supported by the analysis of growth rates from cores (Teufen, 1985).

As shown in Table 5.6, 46% of the forest area is composed of stands dominated by a single size-class. Mixed stands, with a variety of size-classes, occupy 31% of the area; open stands at timberline and along avalanche paths account for 21%. The majority of the single-size stands are dominated by medium timber trees (36-52 cm dbh: 28%). Over half of these stands have closed canopies; a third have open canopies with good regeneration. Stands dominated by large timber trees (>52 cm dbh) account for 5%; over half of these have open canopies and good regeneration. Stands dominated by small timber trees (24-36 cm dbh) cover 9% of the area, and those dominated by poles and saplings (<24 cm dbh) account for 4%.

The long-term stability, i.e., ability to fulfil protective functions, of the forests of the study area was assessed in relation to stand structure by Teufen (1985). The most stable stands were those with a mixed structure. This structure typically results from long-term intensive use, and thus is more common in the communal forests. Open stands of medium and large timber trees with good regeneration were also classified as stable, since adequate numbers of small trees are available to replace the larger trees when they are harvested or die from natural causes. Thus, 43% of the area has stable stands. Stands at timberline, and those dominated by medium and large timber trees with closed canopies, were classified as moderately stable (34% of the area). In both cases, lack of regeneration is a problem. At timberline, browsing and climatic factors are paramount. In the closed stands, lack of light is a problem. Many of the trees have slow growth rates and are very susceptible to disease; thinning is the best way to improve stability.

Two types of moderately unstable stands were recognized, covering 9% of the area. Medium and large timber trees in open stands without regeneration generally have slow growth rates. The lack of regeneration can be the result of poor soil conditions,

TABLE 5.5

DAVOS STUDY AREA:
FOREST SIZE STRUCTURE

SIZE CLASS (cm)	PERCENTAGE OF TREES IN CLASS
8-16	30.2
16-24	23.4
24-36	25.1
36-52	16.1
52 +	5.2

Source: Teufen (1985), Page 43

TABLE 5.6

DAVOS STUDY AREA:
FOREST STAND STRUCTURE

PERCENTAGE OF FOREST AREA IN CLASS

SIZE CLASS	CLOSED CANOPY	****** OPEN CANOPY ******* WITH REGEN.	WITHOUT REGEN	TOTAL
<24 cm				4
24-36 cm				9
36-52 cm	17	4	2	28
>52 cm	1	1	5	7
Mixed				31
Open				21

Source: Teufen (1985), Page 49

grazing, browsing, or competition from shrubs and tall grasses. To improve stability, afforestation and the exclusion of animals are necessary. Stands of poles and saplings are very susceptible to both physical and biological damage; thinning to permit the rapid growth of the remaining trees is the best way to improve stability. The most unstable stands are those dominated by small timber, which cover 9% of the area. These densely-packed, dark stands are highly susceptible to snow pressure and wind, as shown in 1979 and 1956. However, growth rates are generally high when the trees are released by thinning, which also permits seedlings to become established.

5.2.3 Summary

In conclusion, the success of federal and cantonal policies has been influenced to a large extent by economic factors. From the early part of the century, the Commune recognized the importance of projects to protect against avalanches and floods, paying the 20% of the costs not covered by government subsidies. Until the 1960s, harvesting in the communal forests, overseen by district foresters from 1925, and in some cases guided by management plans, remained at levels which generally permitted the development of a reasonably stable forest structure. Harvesting in the private forests, however, was primarily driven by markets for timber and local demand for wood for fuel and construction. From the 1950's, a trend towards lower harvests developed, due to increasing labor costs and decreasing demand for fuelwood; this was partially offset by the development of an accessible market for industrial timber. In the 1960s and 1970s, this trend became more marked in both private and communal forests, as oil's competitiveness as a fuel source increased and alternative employment opportunities, resulting from the great expansion of the skiing industry, became available. The latter was also linked to the further intensification of agriculture, thus decreasing demand for many forest products, particularly those derived from thinning.

The heavy early snowfall in 1979, like the floods of 1870, provided dramatic evidence to the Davosers that the harvesting and maintenance of their forest resources could not be driven mainly by short-term economic motives. Recognition of these facts is shown by the employment of full-time foresters and the agreements to manage all forests under a comprehensive plan and underwrite harvesting, road-building, and maintenance costs. These developments were additionally encouraged by the regional forester's public awareness program of the forests' importance for the community's future (e.g., Teufen and Hess, 1985), which has been supported and promoted by the head of the tourist bureau. Thus, the local community now regards forestry activities less as a means for providing a short-term source of income and raw materials than as an investment in the long-term ability of their forests to fulfil both protective and recreational functions. Government subsidies are no longer relied on to ensure

these long-term functions. For the first time, the current management plan considers the area as a whole, emphasizing not only harvesting, but also maintenance to provide a greater diversity of both stand and age structure. The plan's purpose is to improve the long-term stability of all of the area's forests, both by dealing with the backlog of activities resulting from low harvests in the past decades and by encouraging regeneration.

5.3 Human activities and the forests of the Swiss study areas

The foregoing sections show a complex set of interactions between ecological and human systems in the two Swiss study areas. In general, the complexity and extent of relationships are not too clearly defined until the 1930s, from which time detailed data on harvests, sales and, for the Aletsch study area, forest structure are available. Nevertheless, it must be recognized that the policies described in Chapters three and four were developed in response to existing perceptions of the forest resource, whatever the level of information available. In addition, the connection between the protective and productive functions of forests, whether privately-or publicly owned, was recognized as by the citizens of both study areas no later than the sixteenth century.

Until the mid-nineteenth century, the forests of both study areas were used by their owners for their personal needs and, as external markets developed, to earn additional incomes. It is critical to discriminate between the effects of the very different patterns of ownership and economic development in the two areas. In the Aletsch area, where most of the forests were owned by the Communes, local citizens principally used the forests to fulfil their requirements in a primary economy which lasted until the middle of this century. The main use was for fuel; in general, a third to a quarter of the annual harvest was used for construction and agriculture. Hare exceptions occurred in times of disaster, such as destruction of Betten by fire in 1855, and when external markets for wood developed.

The sources examined in this study are not sufficient to identify the extent to which early industrialization in western Valais, in the early nineteenth century, influenced harvesting patterns in the Aletsch area. Nevertheless, in spite of the distance of the main centers of development from the study, there were definitely some effects, including the clearcutting of part of the Aletschwald and the sale of forest by the Commune of Morel (Wuilloud, 1981). Whatever the patterns of harvesting, the levels of sustained yield set in the 1885-1892 management plans were well below recent harvests. This suggests that the implementation of the early cantonal laws had not been particularly effective; from the viewpoint of contemporary foresters, these harvests had been too high for the forests to fulfil the paramount function of protection recognized in the 1876 Forest Police Law.

In the Davos area, external economies began to affect the use of the forests as early as the fourteenth century, with the introduction of mining. One of the results of widespread logging during the first mining boom, in the sixteenth century, may have been that the forests were barely able to meet local demand, thus supplying the impetus for the first communal regulation of the use of private as well as communal forests. Decreased sales of wood in the seventeenth century also suggest inadequate supplies of wood for local demand. Yet, until 1870 neither communal nor cantonal regulation appears to have been successful in persuading

private forest owners to limit harvests for available markets in addition to traditional uses. In general, the maintenance of personal and communal autonomy was more important than the maintenance of forests for protection and long-term production.

The floods of 1870 appear to have persuaded the Davosers that unplanned and unregulated use of their forests was not in their short- or long-term interest. Yet it was still three years until cantonal regulation was fully accepted. By the turn of the century, levels of harvest had probably declined from the levels of the mid-nineteenth century. However, the development of the tourist industry and rapid population growth probably acted to maintain the demand for wood at higher levels than deemed suitable by contemporary foresters. Nevertheless, the present age structure of the forests in both areas suggests that, through the restriction of harvesting and grazing, cantonal and federal regulation were beginning to permit regeneration of the forests. In the Davos area, the first reforestation projects further emphasize local awareness of the forests' protective function.

Throughout this century, access has been a primary factor influencing harvests in both study areas. Until government subsidies (and local support in the Davos area) for road construction became available in the 1980s, good access generally resulted in harvests higher than the local average, and vice versa. Local demand has been another primary factor. As long as this was high, harvesting continued in the forests of both areas, increasing when needs were high, as during the Second World War. Harvesting mainly concentrated on large (sawtimber) trees since their harvest and removal represented the most efficient use of labor; even though smaller trees would have been equally suitable for fuel, a major (if not the main) use in both areas. Thinning was also practised to provide pole-sized trees for various agricultural purposes. This pattern of harvesting was instrumental in creating the present forest structure, dominated by single-sized stands and small and medium timber trees. A third primary factor has been mandatory harvesting (Zwangsnutzunqen): the removal of trees damaged by insects or natural disasters, as required by cantonal forest services.

In coraparison to access, local demand, and mandatory harvesting, the sustained yields and forestry activities, such as thinning and road-building, defined in management plans generally appear to have been of secondary importance in influencing harvesting levels for the first half of this century. In the Aletsch area, the communes in which harvests were similar to proposed sustained yields were generally those with reasonable access. Available data for the Davos area are not sufficient to draw any conclusions, though both Gunter (1980) and Teufen (pers. comm., 1987) suggest that the use of the communal forests was more extensive than that of the private forests. For this area, the financial support of protective reforestation and construction projects, sometimes after expropriation, by the Commune shows awareness of the importance of protecting settlements, roads, and

railways. Yet it must be emphasized that, because of the early diversification of Davos' economy, it has been an exceptionally wealthy Commune for many decades. In contrast, with government subsidies for such projects never exceeding 80%, the Aletsch Communes could never have afforded the residual costs while their economies were based on primary activities.

From the late 1950s, but especially in the 1960s and 1970s, management plans had even less influence on forestry activities than previously. In addition to the factors of access and local demand, three new primary factors led to harvests, in both study areas, which were far lower than in previous decades or proposed in management plans. The first factor was the development of winter tourism, which offered less strenuous, well-paid employment to local people. This had many effects, including the loss of manpower during the winter season, and the further decline of extensive agriculture. The second factor was the decline of demand for wood. Oil substituted for wood as a fuel source, and less wood was needed for agriculture. Finally, mountain timber became less competitive, as cheaper wood for construction became available, with the improvement of transport networks, and Swiss wages in forestry rose in comparison both to wages in exporting countries and to Swiss wood prices (Affolter, 1985).

In the 1970s, there were no harvests for many years in many of the communal forests of the Aletsch area, although harvests of timber from privately-owned parcels of forest probably occurred. In both areas, occasional high harvests were mandatory, when government subsidies were made available after heavy snowfalls, insect infestations, windstorms, or avalanches. In effect, such subsidies represent the only instances of the implementation of government policies; yet they were reactive rather than proactive, solving problems in the short term rather than ensuring that the forests could fulfil the functions defined in these policies.

In the 1980s, forestry has experienced a resurgence in both areas. In the Aletsch area, this primarily results from the continued availability of government subsidies to remove trees affected by bark beetles and air pollution. In addition, the employment of a forester by the northern Communes represents a greater awareness of the importance of forest management for the long-term future of the area's economy. For the present, most of the work done in this area is heavily subsidized by the cantonal and federal governments. Moreover, the level of funding is still only adequate to cope with current problems, rather than lay the foundations for forests which will be able to fulfil the functions recognized in both federal and cantonal legislation. However, once these short-term problems have been dealt with, the new cantonal forest law and regulations potentially provide the basis for plans which can be implemented to fulfil these long-term goals. A further key factor is for the citizens of all of

the Communes to support such planning and implementation through cooperation and, where possible, financial and manpower support.

The resurgence of forestry in the Davos area results from a rather different combination of factors. As in 1870, a natural disaster in 1979 provided the impetus for political decisions which recognized the importance of planning and managing the use of the forests for the long term. These decisions also represent a further loss of autonomy for private forest owners; a loss which not all are willing to accept. Yet, in contrast to the Aletsch area, there is good cooperation within the different sectors of the community, and general acceptance of the importance of the forests in the local economy.

These factors, combined with the availability of both local and government financial resources, have led to the writing and implementation of a management plan which recognizes the multiple functions of the forests. It is likely that the recent levels of forestry activities, including road-building, will continue, so that the age and size structure of the forests will be modified to permit the forests to provide both protective and recreational functions in the long term. In addition, the development of new markets for local wood may even enable many of the costs of forestry to be covered; though this depends to a large extent or external economic factors.

In conclusion, in spite of federal and cantonal legislation and policies which identify the protective function of the forests as paramount, the implementation of these policies has primarily depended on econonic factors. As long as a market existed for wood thinning and other types of harvesting continued, permitting regeneration and encouraging radial tree growth. However, since all activities were limited by access, the areal distribution of management activities was very uneven. Many areas of forest have probably not been directly affected by human activities for decades, and the prescriptions in management plans have generally had little practical importance. With decreasing demand for wood, resulting from substitution and a changing "economy, harvests decreased to low levels. A primary result of the patterns of forest use over the past century has been the development of forests with a preponderance of stands composed of trees with a limited range of ages and sizes. Such forests are not necessarily able to fulfil the functions intended by legislation and policies and desired by local people, as shown by recent events in both study areas.

With decreasing demands for wood, economic factors remain paramount in developing and implementing policies to increase levels of forest management, so that the protective and recreational functions can be provided in the long term. In the Aletsch area, with limited levels of financial support and cooperation at the community level, funding to provide public goods of regional or national importance has mainly been provided by governments. In contrast, in the Davos area, where the Commune

has strong financial resources and cooperation is good, an increase in forest management activities is being directly supported by the community. In both areas, however, it must be stressed that increased levels of forest management were in reaction to the loss of a significant number of trees; i.e., policy changes were reactive, not proactive. It is to be hoped that future policy development and implementation, to ensure that the forests provide protection and a recreational environment in the long term, will be proactive.

5.4 Pikes Peak study area

5.4.1 Human influences on the forests of Pikes Peak before federal management

Information concerning the extent of human influences on the forests of Pikes Peak in the nineteenth century is limited and inexact; although the information for this area is more detailed than for almost anywhere else in Colorado. In the covering letter accompanying the first study of these forests (Jack, 1899), many reasons for the lack of reliable information are cited, including the changing population, absence of detailed records, and contradictory witnesses. Until the area was declared a reserve in 1892 (and for a few years afterwards), the forests were subject to two main anthropogenic influences: fire and logging. Jack (1900: 43) stated that "Of all the reserves established by the Federal Government, the [Pikes Peak reserve and the two adjacent to its north and west] have probably been the most damaged by fire and have been subject to the greatest depredations by timber cutters."

Analysis of the fire history of the area is complicated by the lack of detailed studies, the erratic course of fires, and the fact that no records of fires were kept by either city nor county authorities, as "no account [was] taken of the burning of public timber" (Jack, 1899: 9, 12). Jack's (1900) map shows at least three-quarters of Pikes Peak as either "much burned over by old or recent fires" or "badly burned". Rohrbach (1962), who does not cite sources, provides a map of the extent of six early fires, including a late eighteenth century fire in Nigger Gulch and a 170,000 acre fire in the Crystal Creek watershed in the early 1850s. This may have been part of the "Big Burn", which may have been set by Indians, who used fire for many purposes (Pyne, 1982: 71-83). The fire burnt from Cheyenne Mountain, around the east and north sides of Pikes Peak, to Divide (Somners, 1965). According to Jack (1899), the fire occurred in 1848; according to Somners (1965), in 1854. Gardner (1904) counted annual rings in 3,500 trees in the southern part of this area, and concluded that a large fire occurred between 1850 and 1853. In all probability, all three authors were writing about the same fire.

In 1880, a fire set by a homesteader burned at least 200,000 acres, from Victor up Middle Beaver Creek into the upper watershed of Boehmer Creek (Horgen, 1923). In 1887, several thousand acres burned on Cheyenne Mountain, already burned in the 1850s (Jack, 1899). The last major fires both started at sawmills: in 1896, on the west slope of Pikes Peak; and in 1897, burning the west side of the East Beaver Creek watershed. The former may have been deliberately set to provide timber for sawmills, the latter probably started in sawdust piles (Jack, 1900; Horgen, 1923) .

By the time that the 1890s mining boom began, there was little large timber remaining on Pikes Peak. However, fires continued to

be set for three purposes. First, to remove vegetation along railroad rights-of way (Jack, 1899), just as Indians had done along their major trails (Pyne, 1982: 252), such as Ute Pass. Also, accidental fires from sparks from locomotives continued to occur. Second, to clear vegetation from prospective mining areas: a practice which dates back to Roman times (Pyne, 1982: 128). Finally, to kill trees; according to existing federal legislation, green timber could not be removed from public domain lands, but dead timber could.

Lumbering began with settlement in the 1860s, to provide timber and fuelwood for local miners and homesteaders. The first sawmills were small and portable. Only the best trees were cut, utilization was poor, and slash was not disposed of: a cause of many fires, whether caused by lightning or by people. Large-scale lumbering dates from the arrival of the railroads and the first mining boom in the early 1870s. Essentially, the whole economy depended on wood, for construction, mining, railroad ties, and fuel. Wood was the principal fuel, and at least two charcoal ovens operated on Pikes Peak, supplying smelters (Horgen, 1923). After the construction of the Colorado Midland railroad, logging was intensive along Ute Pass from Manitou Springs to Divide, and to north, outside the study area; the estimated cut was 100 million board feet by the end of the century. In 1880 alone, the Woodland Park Lumber Company had a contract to supply 3 million board feet to the Colorado Fuel and Iron Company in Pueblo (Galbreath, 1942: 43).

In the early 1890s, logging mainly concentrated on the large trees on one of the few unburned areas, west of Glen Cove. Part of this area was burned in the 1896 fire; the dead trees were then cut up and shipped to Cripple Creek to be used as mining timbers. By 1898, lumbering was limited to cutting dead trees, along the route of what would soon be the Short Line, for telegraph and trolley poles and railroad ties. No sawmills were operating on the reserve, since there was almost nothing left to cut: "there [was] but a small portion of the area of this reserve sufficiently covered with trees to deserve the name of timber land" (Jack, 1900: 73).

5.4.2 Implementation and effects of forest management policies from 1898

As discussed in section 4.4, the primary activity of the first years of federal forest management on Pikes Peak was preventing the theft of timber (Galbreath, 1942). Much of this policing concerned dead trees, used for mining timbers and, particularly, firewood, as there were few living trees which would provide sawtimber. Except in the most inaccessible sites, there were hardly any ponderosa pines >1' in diameter; the remaining larger trees all had serious defects. Douglas firs were generally <8" in diameter; larger trees had defects. There were still Engelmann spruce 12-15" in diameter, but mainly on high, inaccessible sites

on the south and west sides of Pikes Peak. These stands contained perhaps a few million board feet. Limber pine was scattered throughout the area, and bristlecone pine was common near timberline. These species had been cut least, since they were of little use for any purpose except fuel. Most of the area was covered with a mixture of a few large trees, saplings and seedlings <30 years old, and aspen. The north edge of the area was almost entirely dominated by small stands of aspen and shrubs (Jack, 1900: 48-57, 68). Under natural conditions, Jack (1900; 73) estimated that, because of the lack of seed trees and poor soil conditions, it would take two to three centuries for "a scanty covering of medium-sized trees" to develop.

Given these conditions, and the recognized importance of forests for protecting the watersheds of the adjacent communities, shown by the 1913 federal law and subsequent cooperative agreements, it is not surprising that, until the mid-1920s, the primary emphasis of forestry on Pikes Peak was reforestation. Experimental projects and nurseries were both started in 1904. A survey in 1911 identified 4287 ha (10,594 ac) which needed to be reforested to protect the watersheds of the communities surrounding the area, and also to improve the landscape for recreation. Timber production was viewed as of secondary importance (Duthie, 1914; Waha, 1927). However, it was hoped that the cost of reforestation could be met from the sale of dead and downed timber; it never was.

The plantations on Pikes Peak used stock from the nursery at Monument, north of Colorado Springs. From 1907 to 1915, production was 20% douglas fir, 10% engelmann spruce, and 70% ponderosa pine. Over the next seven years, respective proportions of these species were changed to 65X, 25%, and 10% (Lynch, 1972), reflecting the comparative survival rates of these species (Stahelin, 1942: 19). While successful plantings were made from 1906, large-scale projects did not begin until 1910. In the first two years, 108 ha were planted (Fitzgerald, 1911). By 1950, 3078 ha had been planted, mostly between 1910 and 1923, and in the 1930s when Civilian Conservation Corps (CCC) crews were available (Roeser, 1952a).

The reforestation program in all of Colorado's National Forests from 1906 to 1939 was reviewed in detail by Stahelin (1942). The plantations on Pikes Peak accounted for about a fifth of the total area planted in Colorado, and were the most successful. Survival rates after five years in these plantations and those on Mount Herman (west of Monument; the second most successful projects) were >60% on 23% of the combined area; 41-60% on 45%; 21-40% on 20%; and <20% on 12%. The high rate of survival was attributed to above-average rainfall, good site conditions with little competition; good supervision; and carefully chosen stock. Much of the stock had been selected in trials at the Fremont Experiment Station on Pikes Peak, established in 1909 (Fuhlrodt, 1967). Most plantations were monocultures, with ponderosa pine

from 2280 to 3050 m, douglas fir from 2280 to 3350 m, and engelmann spruce from 2740 to 3650 m.

For the first three decades of this century, there is little detailed information concerning activities other than reforestation on Pikes Peak. In 1920, the district ranger spent six months on reforestation projects (Lipson, 1920). Fire prevention, supported by local volunteers, was also a concern. Unfortunately, data on the number of fires, and areas burned, on Pikes Peak cannot be disaggregated from summaries for the entire Pike National Forest (McCord, 1942). These show a decrease in both variables from 1910 to 1929. The only major fire of record occurred along the north edge of the study area in 1924 (Rocky Mountain News 9/26/24). There was also a severe flood in June 1921 (Carter, 1956: 39).

As described in Chapter two, recreation was important both before and after the First World War, with 200,000 visitors in 1913 (Duthie, 1914) and the construction of many summer homes on private land (often mining claims) and lots designated by the Forest Service on Crystola and Little Fountain Creeks and in North and South Cheyenne Canyons (US Forest Service, 1919b: 14). However, until the mid-1920s, Forest Service officers appear to have spent little of their time providing for, or controlling, recreational use except where fires were concerned; a few special-purpose facilities, such as shelters and fireplaces, were constructed from 1915 (Horgen, 1923). In general, visitors used existing Forest Service facilities, such as forest roads, or private facilities, such as the road and railway to the top of Pikes Peak; the Barr Trail to the top of Pikes Peak, built from 1915 to 1921 (US Forest Service, 1979); the Corley highway, following the Short Line; and the Cheyenne Mountain road, built in 1926 (Carter, 1956: 34).

The development of summer homes, and the expansion of the settlements around the area for recreation, resulted in a high demand for firewood, although these settlements had far smaller populations in winter than in summer. There was also strong demand for poles for ranching; for railroad ties for the Colorado Midland railroad; and, near Cripple Creek, for mining timbers (Miller, 1914; Shoemaker, 1917b). Statistics on harvests in the study area are available from 1930. It is important to note that these are for the Pikes Peak Working Circle. The study area formed about four-fifths of this; but the area north to Woodland Park and Monument Creek was also included. Since some of the study area is above timberline, and much was inaccessible, the proportion of harvested timber was less than four-fifths. Table 5.7 shows average annual harvests and uses of harvested timber from 1931 to 1957.

Table 5.7 shows some clear trends in harvests and uses of timber from 1931 to 1955, particularly the great decrease in harvests over this period. Fuelwood was the dominant use until 1950. The demand for ties stopped after 1935. The demand for props dropped

TABLE 5.7

PIKES PEAK STUDY AREA:
FIVE-YEAR AVERAGE ANNUAL HARVESTS
AND USE OF WOOD, 1931 - 1957

	AVERAGE HARVEST (MBF)	PERCENTAGE OF HARVEST USED FOR: SAWTIMBER	FUEL	POSTS POLES	PROPS	TIES
1931-35	994	35	38	5	18	4
1936-40	914	21	60	10	9	
1941-45	369	15	52	16	17	
1946-50	105	10	62	18	10	Free Use
1951-55	91	64	4	11	10	11
1956-57*	62	16	31	29		24

*Two-year average only

Source: Data filed with Roeser (1952a)
in Denver Federal Records Center file 742725

throughout the period, with the decline of the mining industry. From 1931 to 1950, the proportion used for sawtimber declined; in the next five years, there was an increase to the level of demand of the war years. Finally, while the demand for posts and poles generally decreased, these accounted for a growing proportion of the harvest, with continued demand from local ranchers.

From 1931 to 1936, these harvests were only about half of the permitted cut (Keithley, 1937b). This figure was presumably based on timber inventory data for El Paso and Teller counties for 1924 (Keithley, 1929) and 1931 (Stanley, 1931); however, there was no timber management plan for the study area (Roeser, 1952a). In the 1930s, the level of activities undertaken under Forest Service supervision increased, with the availability of CCC labor. CCC crews worked on thinning, recreation, and timber survey, as well as reforestation, projects. Throughout the 1930s, the dominant pattern of harvesting appears to have been in the form of small timber (<$100) and forest products sales.

In 1930, there were 110 small timber sales (Keithley, 1930). In 1936, there were 610; in 1937, 485; and in 1938-1940, about 900 a year. There were 266 and 346 forest products sales in 1936 and 1937 (US Forest Service file FRC 62597; Thompson, 1940). The products removed in these sales included Christmas trees (averaging 8,000 a year from 1936 to 1941), boughs (at least 30 tons a year from 1936 to 1941), ornamental shrubs, and kinnickinnick. The district ranger was meant to supervise all of these sales, but was evidently unable to do so; careless logging and skidding on small sales were leading to severe erosion in both unplanted stands and plantations (Spencer, 1940).

Concerns that patterns and levels of harvesting, and of recreation, in the 1930s were endangering the protective function of the forests were also expressed by officials of Manitou and Colorado Springs (Bruce, 1934; Nichols, 1937; Mosley, 1938). The Forest Supervisor's replies emphasize that watershed protection was still the paramount concern of the Forest Service (Keithley, 1934; 1937a). Harvesting concentrated on thinning young stands (e.g., for Christmas trees) and the selective cutting of small stands of "overmature and decadent" trees and younger trees infested with bark beetles. Of the 2000 ha of the Manitou Springs watershed below timberline, only 30% had merchantable timber, and half of this was inaccessible. Cutting had only occurred on 2%. The remainder was composed of plantations (14%) and immature stands of naturally-regenerated trees, which would not be cut in the foreseeable future (Keithley, 1934).

Recreation projects, such as trail construction, were also undertaken in ways that minimized erosion and pollution (Keithley, 1937a). The numbers of people reaching the top of Pikes Peak had increased substantially in the 1930s (Figure 5.6); a second road to the summit was proposed in 1939 (Denver Post 5/25/39). In 1939, 779,400 people visited the study area "primarily to enjoy the forests". However, most of these merely

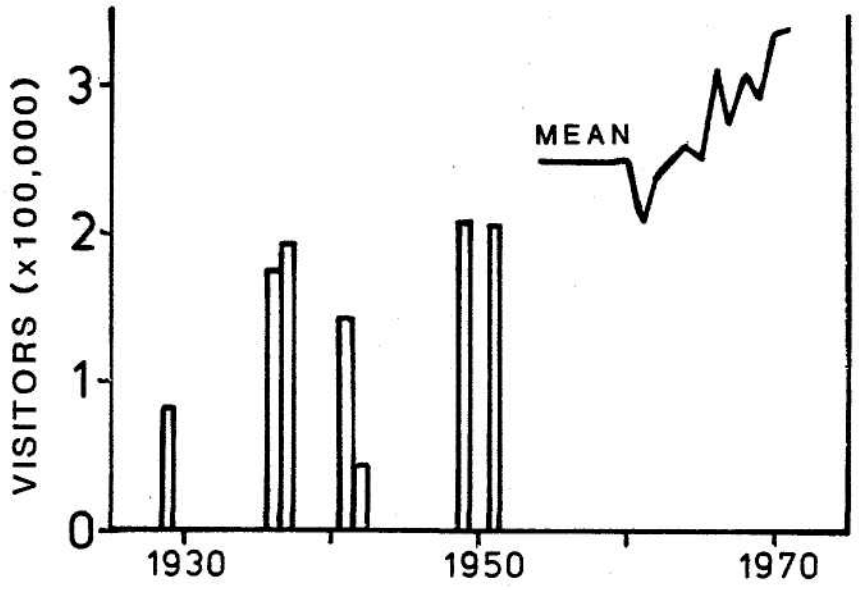

Figure 5.6: Pikes Peak study area: visitors reachin g the summit of Pikes Peak by road 1929 - 1972

Sources: 1929-1951: Newspaper reports
1954-1971: Lynch (1972)

drove through: only 12% were picnickers, and only 6% stayed overnight (Colorado Springs Gazette 12/30/39).

During the Second World War, the total harvest from the area dropped to less than half that of the previous decade. Volumes used for sawtimber and fuel dropped to about a third of the previous five years, while the volume used for posts declined by a third, and that for props by only a quarter. These decreases relate to various changes: fewer Forest Service officials were available, thinning by the CCC stopped, and many of the local people who had cut or bought small volumes of timber were in the armed forces. However, the war resulted in continued demand for strategic minerals - hence the lesser decrease for props. Pikes Peak was used for military training, which resulted in a small increase in the number of man-caused fires. Numbers of man- and lightning-caused fires from 1941 to 1983 are shown in Table 5.8. In the late 1940s, the total harvest decreased still further, to only a tenth of the level of the 1930s.

From 1952, forestry activities in the study area were guided by a timber management plan (Roeser, 1952a). This was based on surveys made by CCC crews in 1936-7; the results are shown in Table 5.9. This shows that, as at the turn of the century, aspen stands were the most frequent, covering nearly a third of the area. Stands dominated by douglas fir and engelmann spruce each covered nearly a quarter of the area; pole-sized stands were more common for the former, and intermediate timber stands in the latter. The size distribution of limber pine, the next most common species, shows marked regeneration and the continued survival of the stands identified by Jack (1900); all of these mature stands were regarded as "inoperable" (i.e., inaccessible or unsaleable). Similarly, all of the mature bristlecone pine stands were inoperable. There had also been limited regeneration of ponderosa pine, which had been the most heavily logged species in the late nineteenth century; many stands were being replaced by douglas fir (Roeser, 1952a: 8-9). The overall size-class distribution suggests that the result of about four decades of federal protection had been to permit the trees remaining from the nineteenth century to dominate the forest. However, regeneration had not been particularly successful, probably because of the lack of seed trees.

The 1952 plan primarily proposed salvage harvests, to remove mature timber for use by the Army and local ranchers. The plan also recognized the potential supply of props, posts, poles, and fuelwood as generally sufficient for local mining and ranching needs. The importance of watershed protection and recreation was recognized by prohibiting limber, bristlecone, and ponderosa pine harvests on steep slopes, and limiting salvage cuts to 50% in ponderosa pine and douglas fir stands, and 40% in engelmann spruce stands. Similarly, no more aspen stands would be planted with conifers, as aspen were regarded as satisfactory for watershed protection. However, planting was planned on various old burn areas. Sales of forest products and fuelwood were also

TABLE 5.8

PIKES PEAK STUDY AREA:
FIVE-YEAR FIRE FREQUENCIES 1940 - 1983

	MAN-CAUSED	LIGHTNING-CAUSED
1940-44	11	10
1945-49	7	6
1950-54	18	6
1955-59	11	19
1960-64	14	
1965-73	NO DATA	
1974-78	19	11
1979-83	10	

Sources: 1940-45: File 742943 in Denver Federal Records Center
1946-49: Roeser (1952a)
1947-83: Fire plan, Pikes Peak Ranger District Office

TABLE 5.9

PIKES PEAK STUDY AREA:
FOREST SIZE STRUCTURE FROM 1936/7 SURVEY

* PROPORTION OF 28,726 TIMBERED HECTARES (%)

SPECIES	Repro	Poles	Interm	Mature	Total
ASPEN	?	?	?	?	31.3
BLUE SPRUCE	-	+	+	-	0.1
BRISTLECONE PINE	0.3	+	0.1	0.7	1.1
DOUGLAS FIR	2.0	9.3	8.9	3.5	23.7
ENGELMANN SPRUCE	2.8	5.0	12.1	2.3	22.2
LIMBER PINE	4.9	1.9	1.2	5.7	13.7
PONDEROSA PINE	2.8	1.8	1.7	1.5	7.8
TOTAL	12.8	18.1	24.1	13.7	

Definitions: Reproduction = 0-50 years old
Poles = 51-100 years old
Intermediate = 101-160 years old
Mature = >160 years old
+ = <0.1% of area

Source: Roeser (1952a), Table II-A.

to be limited to minimize the potential for erosion. The limitation of Christmas tree harvests to 250 a year suggests that the levels of harvest in the 1930s, more than an order of magnitude greater, had been excessive (Roeser, 1952a: 7-20).

In the 1950s, harvests generally remained at the low levels of the late 1940s. An important change was the drop in demand for wood as a source of fuel. In contrast, there was an increase in harvests for sawtimber in the early 1950s; the Army constructed a new road into one of the few areas designated for salvage logging. A low level of demand from local ranches for posts and poles also continued. However, little of the study area was even considered for harvesting; as discussed in Chapter four, most was classified as important for watershed protection and recreation. While watershed protection remained the primary consideration of Forest Service management, recreation had become a major emphasis although, as is still the case, it mainly remained restricted to the three corridors to the summit: the cog railroad, the highway, and the Barr Trail.

By 1949, the annual number of people using the study area had surpassed pre-war levels. Winter recreation had also started in 1946, with the installation of the first ski lift. The ski area was never very successful, because the lack of reliable snow cover meant that use varied greatly from year to year; the maximum annual use was around 11,500 in the late 1970s and early 1980s. For a number of seasons, the area did not operate at all; it eventually went bankrupt in 1984. As before the Second World War, sight-seeing remained the main type of recreation, although demand for hiking was growing; the Barr trail was upgraded in 1949. Most of Roeser's (1952b) report on the area concerns recreational facilities, many of which were suffering from lack of maintenance, often due to insufficient funds. At the same time, many new developments, including campgrounds, were proposed. Many were constructed during the next two decades.

Recreational use increased during the 1950s and, by 1960, Leissler (1961) estimated that over a million and a quarter people visited the area each year. Most were still sight-seers; only 20,000 people a year were estimated to use the area for picnicking and hiking. The 1960s and 1970s were also characterized by growing use, with continued emphasis on sight-seeing. In the early 1970s, Lynch (1972) estimated that, each year, over 3,000 people hiked the full length of the Barr trail (18 km), and as many as 30,000 used the lower part. In addition to the Barr trail, a further 50 km of hiking trails were available. Many of these were poorly maintained. Later in the 1970s, Youth Conservation Corps volunteers were used to maintain and improve trails and campgrounds (Marler, pers. comm., 1988).

In the 1960s and 1970s, according to data in the Timber Atlas for the Pikes Peak Block, timber harvests were negligible; there was continued but limited demand for fuelwood (<5 MBF a year), and occasional sales of sawtimber, posts, and poles. Christmas trees

were harvested from naturally-regenerated douglas fir stands (Anderson, pers. comm., 1988). Lynch (1972) described the timber situation in the early 1970s as follows: "Any productive saw timber sites will only be found on inaccessible and rugged locations which are unsuitable for harvesting; productive and accessible sites are currently covered with trees of a size class suitable only for small product utilization." There had been no timber stand improvement of any consequence, particularly in the plantations. These exhibited stagnant growth and were regarded as susceptible to outbreaks of insects, diseases, and fire. Both mountain pine beetle and spruce budworm were active, but not at significant levels. In the mid-1970s, a mountain pine beetle outbreak occurred in ponderosa pine stands along the north edge of the area. This was controlled around private property and campgrounds by Youth Conservation Corps volunteers (Marler, pers. comm., 1988).

The trends of the 1970s have continued into the 1980s (Edson, Marler, pers. comms., 1988). Recreational use, mainly limited to the three corridors, continues to grow overall, although the increase in fuel prices in the mid-1970s led to decreased use of the highway until the early 1980s. The area around the lower part of the Barr Trail is used extensively for hiking; the trail itself is now used by 75,- 80,000 people a year. Hiking and cross-country skiing are also increasing on the west side of the area. Volunteer labor has been used extensively to maintain hiking trails and campgrounds, but a considerable backlog of work exists. In the southern part of the area, accessible from the old Corley highway, illegal off-road vehicle use is growing, leading to great potential for soil erosion. Very few fires start each year; most are man-caused, mainly spreading from abandoned campfires.

Harvesting in recent years has primarily been for firewood. Public demand for firewood has led to the imposition of a permit system in designated areas, in contrast to the free use of dead and downed wood which was allowed through the 1970s. In spite of an outbreak of spruce budworm in douglas fir stands in at least three areas, the dead trees have not been removed because of the inaccessibility of these areas. However, salvage sales will occur if outbreaks occur in accessible areas. Some aspen has been clearcut on the south side of the area, but other sales have not been successfully offered because of the inaccessibility of the sites.

Table 5.10 shows the current size structure of the forests of the study area, as recorded in the Forest Service RIS. Since the survey method and area surveyed have changed from that used in 1936-7, direct comparisons between the data in this table and those in Table 5.9 cannot be made. However, the current data suggest some trends. The most marked difference in areal distribution is for aspen. Powell (pers. comm., 1988) indicates that many stands identified as dominated by aspen are actually dominated by conifers, so that the proportion recorded in RIS is

TABLE 5.10

PIKES PEAK STUDY AREA:
)REST SIZE STRUCTURE FROM RIS

* PROPORTION OF 28,566 TIMBERED HECTARES (%)

SPECIES	Non-stocked	Seedling/ Sapling	Poles	Sawtimber	Total
ASPEN	2.2	1.9	9.9	0.5	14.5
BRISTLECONE PINE	-	-	-	5.5	5.5
DOUGLAS FIR	-	1.8	4.4	24.3	30.5
ENGELMANN SPRUCE	2.1	1.8	3.6	20.9	28.4
LIMBER PINE	0.3	0.5	0.6	11.7	13.1
PONDEROSA PINE	-	0.8	1.3	6.1	8.2
TOTAL	4.7	6.7	19.7	68.9	

Definitions:
Non-stocked = <10% of area with stock (merchantable) trees
Seedling/Sapling = stands dominated by trees with dbh <12.7 cm (5")
Poles = stands dominated by trees with dbh 12.7-22.6 cm (5-8.9")
Sawtimber = stands dominated by trees with dbh >22.9 cm (9")

Source: US Forest Service Resource Information System (RIS)

an overestimate, resulting from two causes: misinterpretation of aerial photographs, and successional change since the photographs were obtained in 1975. However, at least part of the change results from the growth of conifers which were previously in the understory. This would provide a reason for the greater areas of both douglas fir and ponderosa pine; in addition, the former continues to replace the latter (Powell, pers. comm., 1987). The area of limber pine appears to have remained similar; the great difference in bristlecone pine is likely to result from misinterpretation.

The other general trend evident from Table 5.10 is the continued growth of the forest, apparently with little regeneration. Since the size structure of aspen stands was not recorded in 1936-7, it is not possible to make any statements for the forests as a whole. However, for the conifer species, the proportion of sawtimber stands has increased, while that of smaller size-class stands has decreased. In spite of the tenuous comparability of the data, this reflects the low levels of harvests over the intervening four decades. Figure 5.7, which shows the age structure in the six types of stands which each occur over >4% of the area, also suggests a lack of recent regeneration. Together, these types account for 77% of the forested area. These data are somewhat misleading because, since most of these stands are dominated by pole and sawtimber trees, seedlings and saplings would not have been recorded. However, regeneration is limited by the high density of trees in many conifer stands.

The aspen stands were established around the turn of the century, which agrees with the historical data presented at the beginning of this chapter. The stands with the greatest range of ages are dominated by engelmann spruce; these are presumably those which escaped fire and logging. However, in these stands, as in the a really-dominant older douglas fir stands, there appears to have been little new growth this century. Nevertheless, natural regeneration of engelmann spruce and douglas fir is taking place in open ponderosa pine and aspen stands (Edson, pers. comm., 1988) .

5.4.3 Summary

Throughout this century, watershed protection has been regarded as the primary function of the forests of the study area by both the Forest Service and local people. This was probably the primary reason for the creation of the Pikes Peak reserve in 1892, and the main impetus for the many reforestation projects which started in 1904. The importance of the forests as part of the recreational landscape was also recognized around the turn of the century. However, the current approach to forest management left little time for developing or maintaining recreation facilities; and most visitors were sight-seers, restricted to the narrow corridor along the summit road and railway. In addition, much of the area, in the municipal watersheds, was closed to the

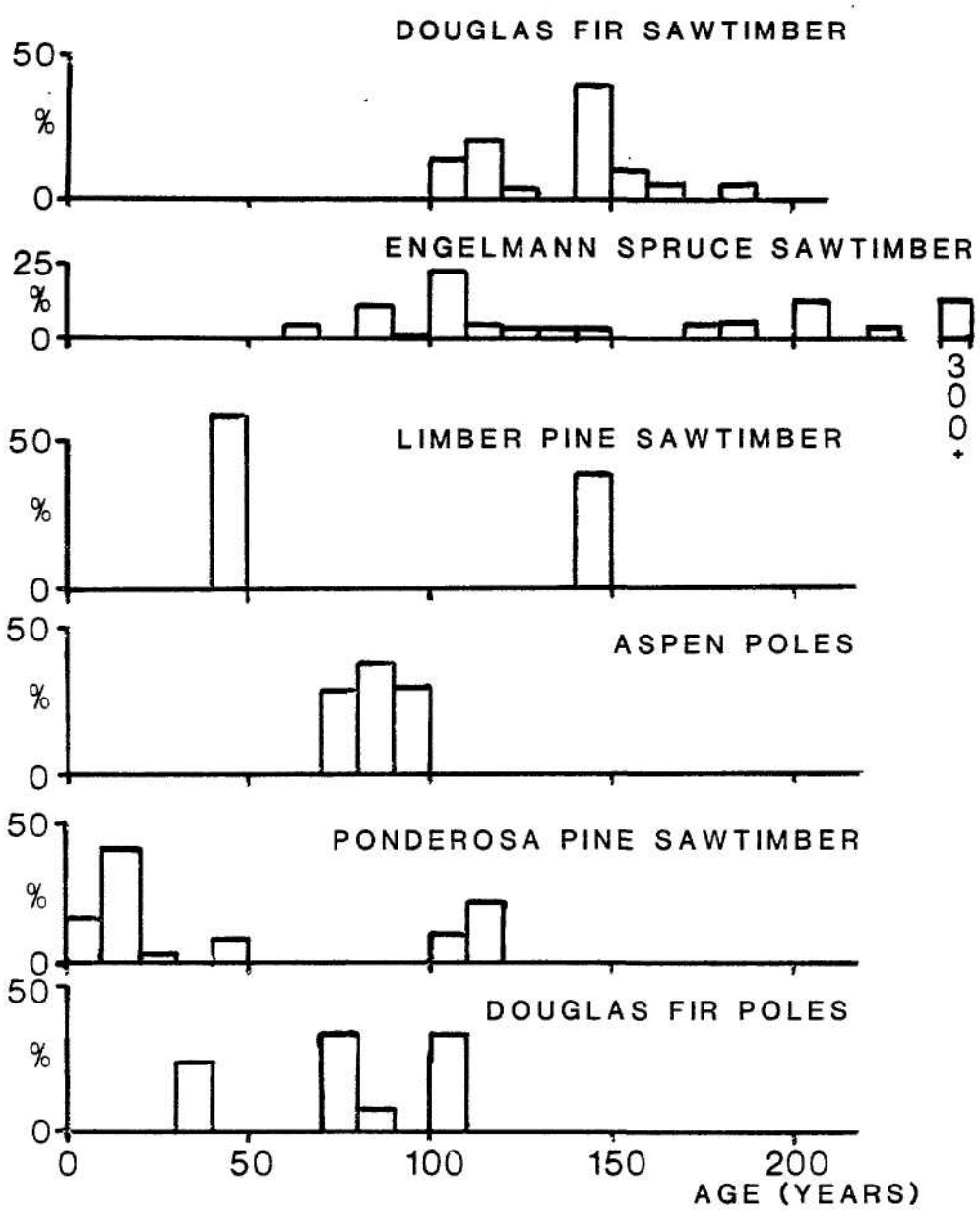

Figure 5.7: Pikes Peak study area: age structure of six most frequently-occurring stand types

Source: US Forest Service Resource Information System (RIS)

public; as it still is. The principal forest management concern with recreation was with the risk of fires from careless visitors' campfires and cigarettes; since the proportion of man-caused to lightning-caused fires has generally increased during this century, this concern has probably been justified. In any case, the development of a well-organized fire prevention and suppression program appears to have been successful in limiting fires to very small areas.

During the 1930s, the level of forestry activities in the study area was increased by the availability of CCC crews. It is not possible to say whether harvests were at a higher level than previously; but those from 1934 to 1939, when these crews were active, were the highest recorded this century. In addition, there was a high demand from local people for forest products and fuelwood, and recreational use was increasing. It seems likely that supervision of forestry activities was inadequate, and that watershed protection was not given as much attention as before. This trend stopped with the beginning of the Second World War, during which harvests decreased substantially. By the 1950s, harvests were a fraction of the pre-war levels, and have declined even further ever since.

Essentially, the forests have been left to grow, without any maintenance or thinning. In the absence of road access to much of the area, and because road construction would probably result in severe erosion of the area's friable soils, the best method for creating a greater diversity in the area's forests is prescribed burning. This method, however, has not been considered in the current management plan, or in the management plan for the forests owned by the City of Colorado Springs, adjacent to and interspersed with the National Forest lands of the study area (Farmer, 1987). Prescribed burning on the municipal watersheds would require the approval of municipal authorities. In view of the success of Forest Service education programs in emphasizing the negative impacts of forest fires, considerable re-education of the public concerning the natural importance of fire in maintaining forest ecosystems would probably be necessary before such approval could be gained. In addition, the esthetic implications of both fires *per se* (e.g. smoke pollution) and their aftermath would have to be dealt with.

5.5 Summit study area

5.5.1 Human influences on the forests before federal management

Information concerning human influences on the forests of Summit County is available from the beginning of permanent settlement. However, no detailed study of early fires or logging in the area exists; this information is derived principally from newspapers, Forest Service documents, and local histories. As Pritchard (1982: 65) points out, newspapers, letters, and statistics provide little information about landscape change in the area; the best sources, when available, are photographs. The fires described below are undoubtedly only a sampling of the total; evidence of many others is visible (US Forest Service, 1968), and there is an emphasis on fires near and visible from settlements and transportation routes.

The first recorded fire, believed to have been deliberately set, occurred during the first gold rush in 1860, burning from the confluence of French Gulch and the Blue River south to Nigger Gulch (Gilliland, 1980: 43). In 1866, readers of the New York Tribune were informed of the desolate appearance of burned forest along the Blue River four miles south of Breckenridge (Rocky Mountain News 10/19/66). However, in 1872, Breckenridge was apparently still surrounded by "vast bodies of pine timber" (Rocky Mountain News, 8/8/72). Fires burned along the Ten-Mile Range west of Breckenridge in 1874 and 1875; in both cases, discarded cigarettes were the assumed cause (Borden, 1924: 24).

During the next mining boom, considerable areas of timber were burned to permit placer mining (Kutzleb, 1947a: 4), and fires occurred in and around settlements throughout the area. Attempts to put them out were only made when they threatened private property (US Forest Service, 1968). In 1879, the forests from Kokomo to Carbonateville burned (Rocky Mountain News, 7/2/79). The next year, Breckenridge was threatened by another fire starting in French Gulch. Its progress was slowed by backfires, and it was eventually put out by rain (Rocky Mountain News, 6/15/80; 6/27/80). Many fires occurred in 1888 (Ensign, 1888a). In 1889, a forest fire, which started at a sawmill in Chihuahua Gulch, destroyed the mining camp of Chihuahua (Borden, 1924: 24). In Spring 1893, sparks from a sawmill burned thousands of acres of lodgepole pine along a five-mile stretch of the Blue River south of Breckenridge (Jack, 1899: 17); that Fall, a fire burned from the middle fork of Indiana Gulch to the Continental Divide and three miles to the south, around Boreas Pass. The next major fire, described as man-caused, started half a mile south of Breckenridge in 1896, and burned 1600 ha (4000 ac) from the Blue River to timberline. In both of the latter cases, no attempt was made to put the fires out; they burned until the snow came (Heaton, 1927).

In 1898, fires again burned all around Kokomo (Denver Times, 10/1/98), and there were many fires on Boreas Pass; at least one

was started by locomotive sparks and destroyed a snowshed (Jack, 1899). Four years later, there was another fire on Boreas Pass (Denver Times, 6/24/02), and again south of Breckenridge. The latter fire burned across a 20-mile front, including 12 along the Swan River. The Denver Times (6/25/02; 6/28/02) commented that there was no danger of the fire reaching Breckenridge as all the timber surrounding the city had been burned the previous Fall; and also that there was no valuable timber left on government land in the vicinity.

Large volumes of timber were doubtless cut in the area from the 1860s onwards, to supply the various needs of the people who arrived in the first mining boom and those who stayed after it collapsed. Photographs from the 1870s show both log and plank buildings, so that at least one sawmill must have been in operation (Pritchard, 1982: 16). However, the first mention of a sawmill in the area is from 1872, when 10,000 board feet were being cut daily to build a 15-mile long flume on the South Swan River, 12 miles from Breckenridge. The flume would require 200,000 board feet of sawed lumber (Rocky Mountain News, 8/8/72). In the early 1870s, there were over 100 miles of flumes and ditches, all wood-lined, in the area. At the beginning of the next mining boom in the early 1880s, there were two or three sawmills in the area, each cutting 8-10,000 board feet a day, and over 500 miles of flumes and ditches. Placer mining also used wood for pipes and sluice boxes (Martin, 1915: 1; Pritchard, 1982: 15, 70).

Logging increased substantially with the arrival of the railroads: "the greater part of the Ten-Mile watershed was cut over and the timber was shipped to Leadville." The larger timber was cut first for lumber, to be used locally; and smaller timber was used for fuel, for both domestic and industrial use; ties, for both local and more widespread use; and charcoal (Martin, 1915: 1-2). Charcoal kilns operated from the early 1880s, both in the Ten-Mile canyon and around Frisco, where over 50 were built. Charcoal was shipped on the Denver and Rio Grande railroad to smelters throughout Colorado. The industry died by the end of the century, when the wood ran out and cheaper coal coke began to be used for smelting (Clawson, 1986). By the late 1890s, there were two or three sawmills on Meadow Creek, near Frisco (Gilliland, 1984), and at least 29 on the West Ten-Mile Creek drainage; the two main operators shipped a total of 50 million board feet. This traffic kept the Blue River branch of the Denver and Rio Grande railroad in operation; three train loads of lumber were shipped each week to Leadville (Heaton, 1927). Sawtimber was used locally, ties were shipped elsewhere (Martin, 1915).

The early history of the forests of Summit County is summarized in the proposal for the Leadville Forest Reserve, dating from between 1900 and 1905 (Bureau of Forestry, n.d.). The firing of green forest to provide dead timber, in response to the restrictions of the Free Timber Act, was the assumed cause of most of the fires. After fires, both dead and live trees were

cut, though there was poor utilization, and no slash disposal. By 1905, since practically all of the accessible sawtimber had been cut, there were no sawmills left in the proposed reserve. The only commercially-valuable stands were in the inaccessible William's Fork Mountains.

5.5.2 Implementation and effect of forest management policies from 1905

For the first two decades that the forests of the study area were under federal jurisdiction, there is no detailed information about the implementation of Forest Service policies or their effects in the forests. Summit County was an isolated area forming the northern extension of the Leadville National Forest, with opportunities for camping, hunting, and fishing (US Forest Service, 1919a). The average annual harvest in the Dillon working circle, which comprises the southern half of the study area Cup to a line west from Ptarmigan Peak), from 1905 to 1925 was estimated at 500 MBF (Kutzleb, 1947a: 4). The only document found which specifically considers parts of the study area is the Land Classification (US Forest Service, 1915). This describes the "forest values" of a number of townships, described below from north to south.

At the north end of the study area, most of the forest was lodgepole pine, in inaccessible stands on both sides of the Blue River drainage. While any logging would be for local needs, this area was regarded as potentially valuable for timber production. In addition, the importance of watershed protection was recognized. On the southern part of the Gore Range, dead timber had been removed for mining and railroad ties where access to the Colorado and Southern railroad was good. In general, there had been good regeneration of lodgepole pine in the southern part of the study area. Around Hoosier and Boreas Passes, much of the dead timber that remained after federal reservation had been removed, all for mining timbers. There was little green timber, and none had been sold; it should be reserved for local mines. Since this area was at the headwaters of the Blue River, its importance for watershed protection was also recognized. There had been little reproduction in high-altitude stands of Engelmann spruce which had been burned.

During the 1920s, timber inventories of the Dillon working circle were taken, to provide information as to the volume available for use and transport by the Colorado and Southern railroad (Peck, 1920). The total standing volume was estimated as 327,156 MBF (Hutton, 1926). In 1924, growth estimates were made in stands clearcut between 1890 and 1904, presumably for the same purpose (Anderson, 1924). These showed rapid growth in dense stands of lodgepole pine and engelmann spruce. The first timber management plan, based on these data, was prepared in 1927. This proposed an allowable annual cut of 3,500 MBF for the Dillon working circle (Kutzleb, 1947a: 4).

From 1926 to the late 1950s, considerable information about the study area is available from the district rangers' annual reports and yearly summaries of harvests. Average harvest data from 1905 to 1987 are shown in Figure 5.8, and uses of harvested timber from 1926 to 1957 in Table 5.11. These are for the Dillon working circle; it was not possible to disaggregate harvests in the northern part of the area from the statistics for the Middle Park working circle. However, most of this area, in the Gore Range and Williams Fork Mountains, is inaccessible by road, so that little timber has been cut there during this century. In addition, most of the Gore Range was declared a Primitive Area in 1933, thus preventing subsequent cutting (Kutzleb, 1947b).

Table 5.11 shows some clear trends in patterns of use, in spite of great variations in annual harvests. In the late 1920s and early 1930s, a significant proportion of the annual cut was used for railroad ties. However, when the Colorado and Southern railroad ceased operation in 1937, this market disappeared. Two other trends are evident: an increasing proportion of the annual harvest used for sawtimber, and a decreasing proportion used for mining props. Very low proportions were used for fuel, or for posts and poles, which might seem unusual in an area where ranching was important. Wood for these uses was presumably supplied from free use, not recorded in the annual statistics, or from areas of privately-owned forest.

From the late 1920s to the beginning of the 1930s, there were substantial markets for timber. The primary user was the local mining industry, which had a strong demand for both props and sawtimber. The other main market was the Colorado and Southern railroad. However, there were problems with the quality of sawed ties (Nelson, 1929). These markets were provided by a mixture of a few large sales (between three and six a year) and up to 25 small sales to small independent contractors. During this period, a number of trails were completed along the Gore Range, over Ute and Ptarmigan Passes, and in the upper drainage of the Snake River (Heaton, 1926-1930; Lundell, 1931). On average, only one fire was recorded a year: these were all man-caused and quickly suppressed, except for a 30 ha fire above Breckenridge in 1929 (Peck, 1929). No lightning fires were recorded from 1927 to 1939. Fire frequencies from 1926 to 1960 are shown in Table 5.12.

From 1933 to 1940, harvests were, on average, only a fifth of the volme of the preceding seven years. In most years, there were no large sales; the occasional ones were to supply railroad ties. The main reasons for the sudden decrease in sales were the severe decline of the local mining industry and the closure of the Colorado and Southern railroad 1937, so that there was no market for ties or means to transport large quantities of timber. The ties from the railroad were removed and used by local people (Harlan, 1938). During the 1930s, about 2200 ha of dense lodgepole pine stands, mainly in the Keystone area, were thinned by crews working through the CCC and other New Deal programs.

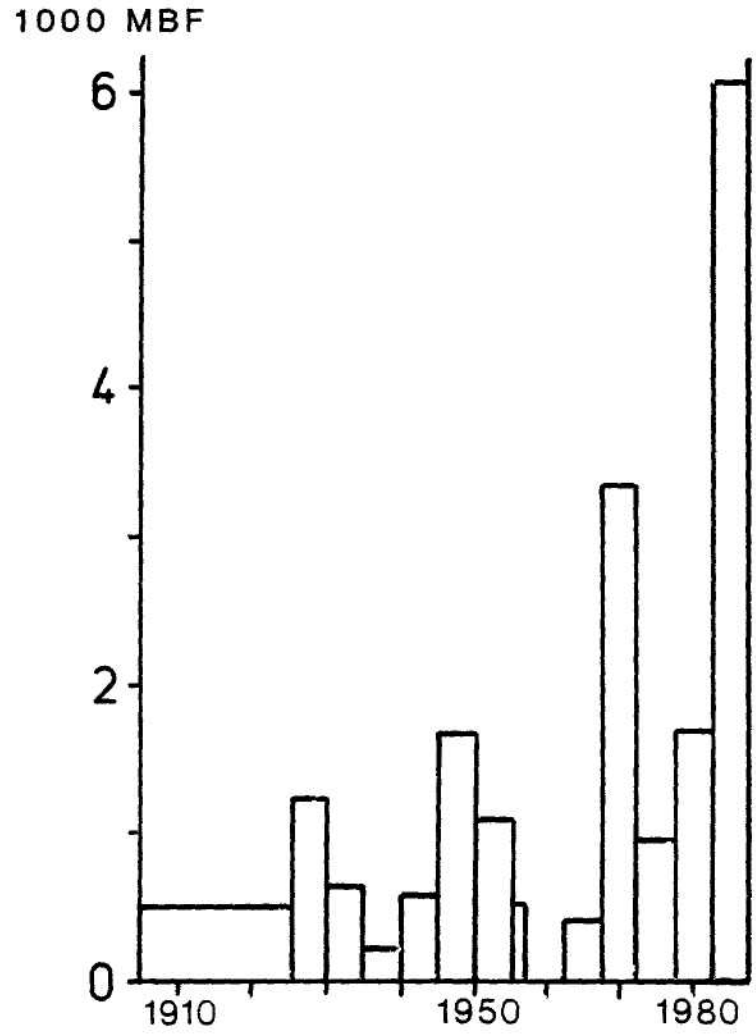

Figure 5.8: Summit study area: average annual harvests 1905-1

Sources: 1926-1957: Data filed with Kutzleb (1947a)
in Denver Federal Records Center file 742725
1963-1977: Timber Atlas, Dillon Block
in Dillon Ranger District Office
1978-1987: White River National Forest
Supervisor's Office, Glenwood Springs

TABLE 5.11

SUMMIT STUDY AREA (DILLON WORKING CIRCLE):
USES OF HARVESTED TIMBER, 1926 - 1957

	PERCENTAGE OF HARVEST USED FOR:				
	SAWTIMBER	FUEL	POSTS POLES	PROPS	TIES
1926-30	20	2	+	37	41
1931-35	25	1	+	32	42
1936-40	67	3	+	23	6
1941-45	84	1	+	14	
1946-50	86	1	3	10	
1951-55	91	+	1	8	Free Use
1956-57*	90	+	2	2	6

* Two-year average only
+ = Less than 0.5 percent of harvest

Source: Data filed with Kutzleb (1947a) in Denver Federal Records Center file 742725

TABLE 5.12

SUMMIT STUDY AREA:
FIVE-YEAR FIRE FREQUENCIES 1926 - 1960

	MAN-CAUSED	LIGHTNING-CAUSED
1926-30	6	1
1931-35	14	0
1936-40	17	1
1941-45	5	2
1946-50	10	1
1951-55	11	2
1956-60	36	9

Source: Annual chronologies in Dillon Ranger District Office

These crews were also used to build roads and campgrounds (Lundell, 1933; Brown, 1934, 1935; Harlan, 1936; US Forest Service, 1960). Summer recreational use increased during the 1930s, as a consequence of improved access. There was greater demand for campgrounds than for hotels and resorts because of the Depression (Lundell, 1932). While the railroad was operating, it was the source of small fires almost every year; during the late 1930s, more fires were started by recreationists. These were all rapidly suppressed, except for an 11 ha fire in 1939 (Harlan, 1939). In 1940, a 56 ha fire was started by a crew clearing a telephone line (Harlan, 1940).

During the Second World War, harvests increased substantially: to double the levels of the 1930s, on average. The renewed demand was primarily for sawtimber, partly from the revival of the mining industry, to provide strategic minerals, but also because prices were high. In addition, roads were constructed and improved to provide access to mines and timber (Jauch, 1943; Skinner, 1944). Not surprisingly, recreational use decreased (Figure 5.9). Near the end of the war, new estimates of the volume of timber in the Dillon working circle were made. These concluded that the 1926 estimate of 327,156 MBF had been too high; the estimate was cut to 191,000 MBF in 1944, and 120,000 MBF in 1945. However, the Forest Supervisor did not see a necessity for revising the management plan, since the annual harvest had never exceeded half of the allowable cut (and had generally been far lower), and no increase in harvests was foreseen (Heaton, 1946).

After the war ended, new timber management plans were made for the study area (Kutzleb, 1947a, b). The estimated volume of timber for the Dillon working circle plan decreased even further, to 85,866 MBF; the proposed annual allowable cut was 1,250 MBF, only 36% of the cut set in 1927. The maps in these plans show about half of the forested area as immature (<120 years old) lodgepole pine, often mixed with aspen. The only areas of mature lodgepole pine were scattered: in inaccessible stands in the Cataract and Rock Creek drainages of the Gore Range, near Ute Pass, and below Ptarmigan Peak; in Keystone Gulch; and in small stands in the southern part of the study area. A large proportion of the engelmann spruce stands were mature: these were found at and below timberline, along the Gore Range and scattered throughout the Dillon working circle, often above immature stands. In the latter area, 57% of the volume of commercial timber was engelmann spruce; 39% lodgepole pine; and 4% alpine fir. These stands occupied 5260 ha; the only large accessible stand (1030 ha) was in Keystone Gulch. There were also 2850 ha in old burns which had not regenerated, and needed planting; only 1 ha had previously been planted (Kutzleb, 1947a: 7-8, 12-13).

The tables in the management plans do not permit analysis of the age structure of the forests of the study area as a whole, since no data were recorded on the 39% of the area regarded as "inoperable". The criterion of "operability" is not defined, but

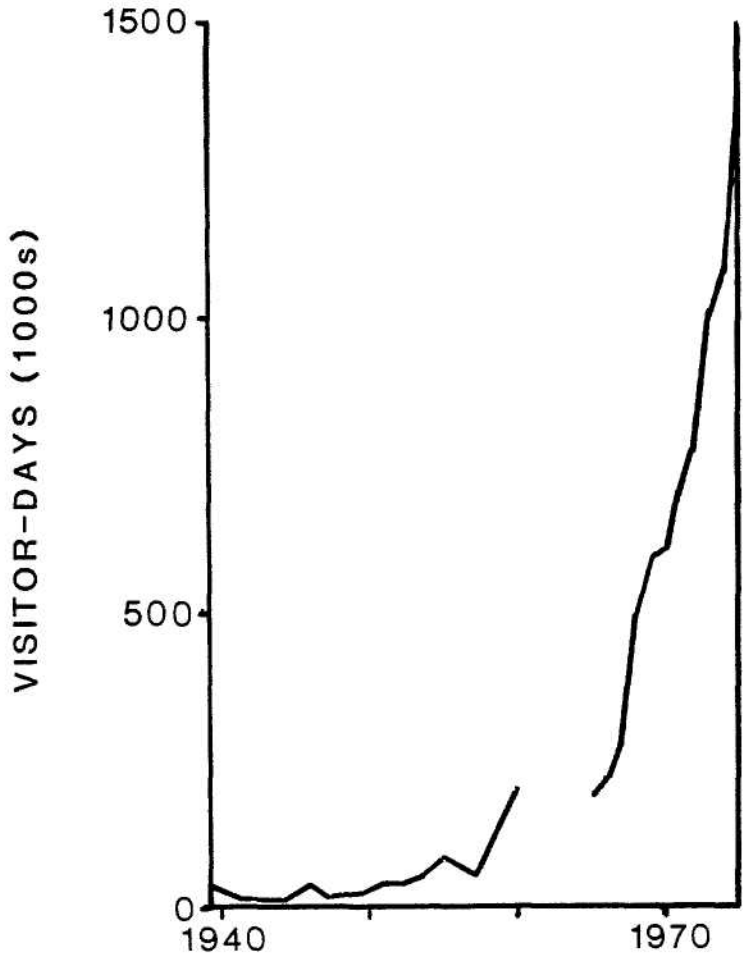

Figure 5.9: Summit study area: recreational use 1939 - 1960, 1965 - 1975

Note: Measurement method changed in 1961

Sources: 1939-1960: US Forest Service (1960)
1965-1975: Recreation Information Management files in Dillon Ranger District Office

appears to be based mainly on potential and actual access. For "operable" timber, stands on 10% of the area were 0-40 years old; 40% were 41-80 years old; 19% were 81-120 years old; 6% were 121-160 years old; and 25% were >160 years old. The high proportion in the 41-80 year class presumably represents stands which had regenerated after logging and fire. Most of the stands in the youngest age class were in the southern part of the area, particularly in the Ten-Mile drainage, which had been most extensively logged at the turn of the century. However, since these data represent only 61% of the study area, more definite conclusions on the influence of human activities on the age structure cannot be drawn.

The Dillon working circle plan (Kutzleb, 1947a) describes watershed protection as an important function of the area. Summer recreation was viewed as a growing use of the forests, and it was recognized that increased winter use would result from the development of Arapahoe Basin ski area. The main markets for timber were for sawtimber and, to a lesser extent, for props at Leadville and Fairplay. No new operators would be allowed, because of the low allowable cut. At the time, there were six sawmills operating in the area; only two were regarded as viable. Although thinning was deemed advisable over much of the area, there was no market for poles, so no projects were proposed.

In general, Kutzleb (1947a) did not anticipate the scale of the changes in the uses of the forests which occurred after the Second World War. In the post-war decade, demand for sawtimber was far higher than during the war, initially for mining, and later for construction in Denver. Demand for props, poles, and posts was also higher. Thus, from 1946 to 1954, harvests were 2.6 times higher than during the war, on average; generally greater than the allowable cut. However, as soon as prices for lumber dropped, so did harvests, although free use cutting for fuelwood, posts, and poles continued (Hauk, pers. comm., 1988). The main post-war change was the rapid growth in recreational use, shown in Figure 5.9. This was made possible by year-round road access to the cities of the Front Range and the expansion of Arapahoe Basin; most of the increase was in winter. As a result, Forest Service officers had to spend increasing amounts of time developing and maintaining recreational facilities. In addition, more time had to be spent on fire prevention and suppression, as the number of man-caused fires was rising, probably as a result of greater summer use. However, recreation was not the overwhelming concern that it subsequently became (Hauk, pers. comm., 1988).

In the 1960s, recreational use rose rapidly, with increasing demand from the cities of the Front Range and the development of Forest Service facilities, such as the Dillon Reservoir, trails, and campgrounds, and the Breckenridge ski area. Summer use grew more rapidly than winter; from 1960 to 1968, the former rose from 48,500 to 524,000, the latter from 55,200 to 266,140 (US Forest Service, 1969). It should be noted, however, that much of the

summer increase was linked to the use of Dillon Reservoir, rather than forest recreation. The development of the total lift capacity of the study area's ski areas from 1960 to 1987 is shown in Figure 5.10. With the increase in capacity came a huge increase in skier visits, averaging 21% a year in the 1960s and 19% a year in the 1970s. The average annual rate of increase has dropped to 5% in the 1980s (data from Colorado Ski Country USA).

Timber harvests in the 1960s were highly variable (Figure 5.6), depending on the availability of markets, both local and in Denver. The 1960 Land Management Plan for the Dillon working circle (US Forest Service, 1960) maintained the allowable annual cut at 1250 MBF, on the basis of "an unreliable timber management plan prepared and approved in 1933 (which) still represents the best available data." This was presumably Kutzleb's (1947a) plan; the reason for the incorrect date is unclear. The writers of the 1960 plan also appear to have been unaware of previous harvest levels. The plan identified about 16,200 ha in need of thinning, and 3250 ha in need of reforestation. Since no thinning or reforestation had been undertaken in the 1950s, these are probably the areas mentioned by Kutzleb (1947a).

In the mid-1960s, there were 47,483 ha of commercial and non-commercial timber in the Dillon working circle (Table 5.13: US Forest Service, 1968). Almost 90% of this area was in pole and sawtimber stands. Most of the sawtimber was in high-elevation engelmann spruce stands which were either inaccessible or in small blocks. Most lodgepole pine stands consisted of pole-sized timber, were becoming stagnated through lack of thinning, and were often heavily infested with dwarf mistletoe. These represented a significant hazard because of the danger of crown fires in stands with closed canopies.

The allowable cut was "about 1000 MBF", and was expected to decrease because harvesting would be precluded by higher priority uses, such as recreation. Logging was described as unimportant because of the lack of markets. However, while harvests had been very low in the early 1960s, 17,500 MBF were cut from the Deep Creek drainage, at the north end of the area, for the sawmill at Kremmling from 1967 to 1970. All but 5% of this was engelmann spruce; the rest was lodgepole pine. In general, however, the main emphasis of forest management in the 1960s was recreation, though watershed protection was also considered in multiple-use planning. The 1968 supplement (US Forest Service, 1968) also recognized "a need to maintain productivity" and that fire and insect damage (particularly from mountain pine beetle, which was currently in the area) were potential problems which could grow in severity as the demand for recreation grew.

In the 1970s and 1980s, recreation has been the most important function of the forests of the study area. Overall annual recreation use has grown every year to a current level of about 2.2 million visitor-days, fuelled by the expansion of ski area capacity, improved access from the Front Range and the rest of

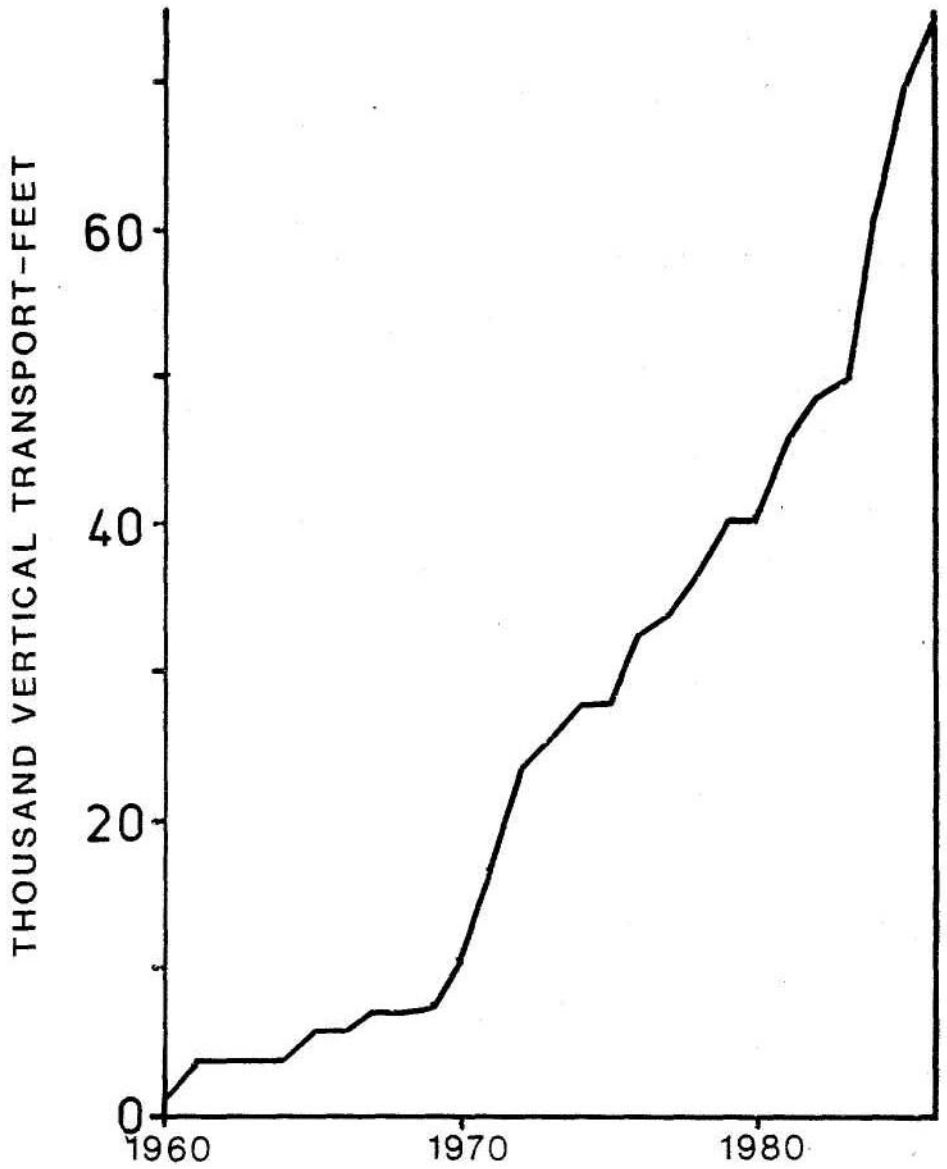

Figure 5.10: Summit study area: ski lift capacity 1960 - 1987

Source: Data in Colorado Ski Country USA office, Denver

TABLE 5.13

SUMMIT STUDY AREA: FOREST SIZE STRUCTURE
IN DILLON WORKING CIRCLE, MID-1960S

SPECIES	* PROPORTION OF 47,483 TIMBERED HECTARES (%) *				
	Non-stocked	Seedling/ Sapling	Poles	Sawtimber	Total
ASPEN	-	0.9	1.9	-	2.8
DOUGLAS FIR	-	-	+	0.3	0.3
ENGELMANN SPRUCE/ ALPINE FIR	5.2	1.8	12.9	35.1	55.0
LODGEPOLE PINE	+	3.2	26.7	11.9	41.9
TOTAL	5.2	5.9	41.6	47.3	

Definitions:
Non-stocked = <10% of area with stock (merchantable) trees
Seedling/Sapling = stands dominated by trees with dbh <12.7 cm (5")
Poles = stands dominated by trees with dbh 12.7-22.6 cm (5-8.9")
Sawtimber = stands dominated by trees with dbh >22.9 cm (9")
+ = <0.1% of area

Source: US Forest Service (1968)

the nation, and population growth in Colorado. The most marked change in recreational use came in the early 1970s, when the Eisenhower Tunnel and the Keystone and Copper Mountain ski areas opened. Table 5.14 shows the sudden increase in winter use in this period; winter is now the dominant season, with about 1.5 times the volume of summer use (Hetzler, pers. comm., 1988).

There has also been a rapid rise in new forest activities, e.g., backpacking, cross-country skiing, and mountain biking, though these still probably account for less than 3% of total use. The growth of new activities, and of recreational use in general, has considerable potential for conflicts between different types of users, particularly motorized and non-motorized, which is already becoming evident. The planning and maintenance of recreational facilities has therefore become a primary emphasis for Forest Service officers. In addition, much trail and campground maintenance is done by volunteers. This is important, especially after low maintenance levels in the 1970s, high use levels, and low budgets (Hetzler, pers. comm., 1988). Fires related to recreation are not seen as a major management concern. While almost all fires are man-caused, the generally low level of fuels, typically wet summers, and adequate access mean that fire control is unlikely to be a major problem except during a very dry year. However, there is no fire management plan; the current policy is to extinguish all fires (Sheakly, pers. comm., 1988).

The clearing of the right-of-way for Interstate Highway 70 and ski runs required the cutting of considerable amounts of timber. However, until 1971, most of this was burned on site, as markets could not be found. A total of 215 ha were cleared in 1971 at Breckenridge, Copper Mountain, and Keystone, providing sawtimber, corral poles, and firewood for sale (Lynch, 1971). Harvests in the 1970s were highly variable in terms of volumes (Figure 5.8) and types of end uses. Overall, the primary use was firewood, followed by posts and poles; sawtimber was the least frequent use. Many of the sales of poles were from thinning projects at campgrounds and viewpoints around Dillon Reservoir. These projects, like those along Interstate 70 and in the ski areas, were undertaken with aesthetic considerations in mind (Gregg, pers. comm., 1988). Since the population of mountain pine beetles had dropped to low levels, there was little interest in prophylactic cutting (US Forest Service, 1984).

In the 1980s, a severe epidemic of mountain pine beetle began in stands of lodgepole pine, as foreseen in the 1968 multiple-use plan supplement. Subsequently, a significant activity has been to bring this infestation under control by cutting and spraying. The program began in 1982, with a congressional appropriation of $1.4 million (US Forest Service, 1984) and has continued to the present (Pearson, 1986; pers. comm., 1988). Spraying projects are expensive, and thus have been limited to campgrounds and other developed sites. This is also generally true for thinning projects; 450 ha were thinned as part of the program. At times, the removal of infested trees, both in thinning and cutting

TABLE 5.14

SUMMIT STUDY AREA:
RECREATIONAL USE 1965 - 1975

	THOUSAND VISITOR -DAYS	PERCENTAGE OF USE BY CATEGORY: WINTER	CAMPING	SIGHT-SEEING	HIKING
1965	189.8				
1966	219.2	47	27	+	2.4
1967	278.8	44	35	4	2.1
1968	498.1	46	26	12	1.8
1969	587.1	30	39	11	2.0
1970	618.9	23	40	14	2.5
1971	740.7	20	33	22	0.2
1972	786.1	27	33	23	0.6
1973	1011.1	29	32	20	2.6
1974	1079.0	38	29	17	1.7
1975	1430.9	42	29	14	1.6

Source: Recreation Information Management files
in Dillon Ranger District office

projects, resulted in the blowdown of remaining trees, which then had to be removed.

From 1981 to 1987, the total volume of timber cut in the study area has been 34,801 MBF, 8% higher than the volume scheduled in the 1984 plan and significantly higher than at any time during this century. Many of these sales created local controversy, since they were adjacent to private recreational developments, in elk winter range, required roads which would increase access to previously inaccessible areas, or would modify scenic views. While cutting in the early 1980s primarily concentrated on stands infested with beetles, sales are now intended to decrease the likelihood of future epidemics, by cutting the most susceptible stands (Pearson, pers. comm., 1988). As proposed in the 1984 land and resource management plan, current and proposed sales concentrate on lodgepole pine stands, which are not only more susceptible to insects and disease, but also more accessible and profitable than engelmann spruce stands.

The current size structure of the forests of the study area, as recorded in the Forest Service RIS, is shown in Table 5.15. This can not be directly compared to the mid-1960s data (Table 5.13), which derive from only part of the area, although both show a preponderance of pole and sawtimber stands. The age structure of the seven types of stands which occur over <2% of the area is shown in Figure 5.11. The distribution of species is similar to the 1940s. Very little of the forest is composed of unstocked or regenerating stands; sawtimber, nearly half of which is engelmann spruce, predominates. Stands of lodgepole pine are distributed almost evenly between sawtimber and pole-sized stands, which provides an explanation for the occurrence of the pine beetle epidemic.

The age structure of the pole-sized conifer stands shows a clear dominance of trees which date from the five decades around the turn of the century. These include both trees which were released by logging or survived fire, and those which came in after the end of the mining boom. However, there appears to have been little regeneration in these stands since the early part of this century. This is also true for the conifer sawtimber stands, which are dominated by trees which became established in the last century. However, the lack of regeneration is at least partly an artifact of the sampling method; there is considerable regeneration of engelmann spruce and fir in these stands (Pearson, pers. comm, 1988).

Stands dominated by aspen are also dominated by trees dating from around the turn of the century; the sawtimber stands are presumably those which were logged or burned earlier. Again, there has generally been little subsequent regeneration in these stands and, since the trees in these stands are in the latter stage of their lifespans, the stands are likely to be replaced by conifers in the next 50-60 years in the absence of burning or cutting (Hotchkiss, pers. comm., 1988). In contrast, the limited

TABLE 5.15

SUMMIT STUDY AREA:
FOREST SIZE STRUCTURE FROM RIS

SPECIES	* PROPORTION OF 53,262 TIMBERED HECTARES (%) *				
	Non-stocked	Seedling/ Sapling	Poles	Sawtimber	Total
ASPEN	0.2	1.5	2.8	3.3	7.8
BRISTLECONE PINE	+	-	-	+	0.1
DOUGLAS FIR	0.2	-	0.1	0.9	1.2
ENGELMANN SPRUCE/ ALPINE FIR	1.3	1.5	5.3	32.3	40.5
LODGEPOLE PINE	0.8	2.7	23.8	23.2	50.5
TOTAL	2.5	5.7	32.0	59.8	

Definitions:
Non-stocked = <10% of area with stock (merchantable) trees
Seedling/Sapling = stands dominated by trees with dbh <12.7 cm (5"
Poles = stands dominated by trees with dbh 12.7-22.6 cm (5-8.9")
Sawtimber = stands dominated by trees with dbh >22.9 cm (9")
+ = <0.1% of area

Source: US Forest Service Resource Information System (RIS)

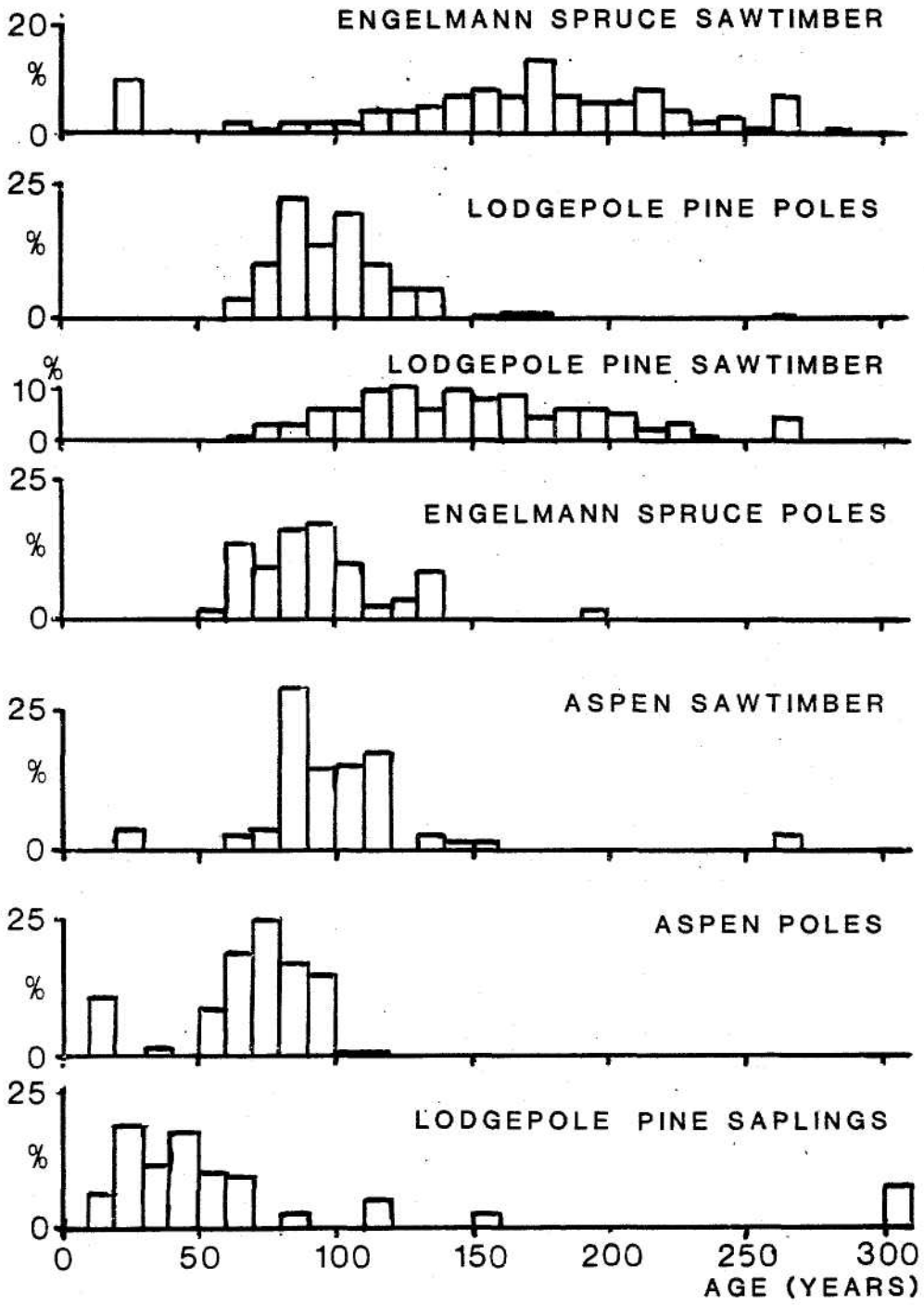

Figure 5.11: Summit study area: age structure of seven most frequently-occurring stand types

Source: US Forest Service Resource Information System (RIS)

number of stands dominated by seedlings and saplings, of all species, show regeneration for most of this century, and often include some old overstory trees. However, the dense lodgepole pine stands show little recent regeneration.

Overall, this pattern suggests that about half the forest area, i.e., sites dominated by conifer sawtimber stands, was not logged or burned during the last century. Most of these stands are in inaccessible areas near timberline and in the Gore Range and Williams Fork Mountains. On about a third of the area, seed sources were available to permit pole-sized conifer stands and aspen stands to develop after logging and/or burning during the nineteenth century. However, the effects of restricted logging and minimal thinning are shown by the large number of small-diameter trees and the lack of regeneration in these stands for most of this century.

5.5.3 Summary

Since the forests of the study area came under federal jurisdiction, the main factor influencing their use has been access. Throughout the century, watershed protection has been recognized as important, but this function was principally achieved by permitting the forests to grow and, to a certain extent, by preventing and suppressing fires. In addition, some thinning was undertaken by CCC crews. There was a paradox in Forest Service officers' pre-war perceptions of the timber resource: both the area affected by nineteenth century logging and burning and the estimate of available volumes of timber were exaggerated. The reason for the former may have been that the characteristics of the forests of the southern part of the area were extrapolated to the whole. Yet the RIS data show that many areas of forest near timberline, and much of the Gore Range and Williams Fork Mountains, were not logged or burned. Nevertheless, the demand for wood was never very high; pre-war harvests were consistently below the sustained yield defined on the basis of the more precise inventories used for the 1947 timber management plans.

Until 1937, the Colorado and Southern railroad was the principal means of access, important both for transporting and as a market for wood. The main emphasis of Forest Service management was to provide wood for local and regional consumption by the mining and railroad industries; local domestic demand for wood appears to have been limited, and generally supplied by free use. Increasing recreational demand in the 1930s, resulting mainly from improved highway access from the Front Range, generally had little effect on Forest Service activities. During the Second World War, there was increased demand for wood, particularly from a mining industry revitalized by the need for strategic minerals. The recently-completed highways, together with new local roads, enabled this demand to be met.

After the War, the highways provided a conduit for sawtimber for the rapidly-growing cities of the Front Range, as long as timber from the study area could compete with other sources. However, the principal result of improving highway access, combined with many other factors, was rapid growth in recreational demand. While the scale of this trend was initially unforeseen, the main emphasis of Forest Service management soon turned to planning and providing facilities for summer and winter recreation, and dealing with problems resulting from its growth. This trend has continued to the present.

Nearly all Forest Service activities are directed or influenced by recreation, as the provision of a landscape for recreation has become recognized as the main function of the forests. This applies not only to the development of recreational facilities, but also to silvicultural and engineering activities. Specific examples are the treatment of the recent mountain pine beetle outbreak and the construction of Interstate 70. In addition, watershed protection continues to be recognized as an important function which, however, can generally be served by implementing policies designed to ensure the long-term provision of a recreational landscape. In particular, this includes the thinning and harvesting of trees to minimize future risks of fire and insect epidemics. Such projects have led to the highest harvests this century and often receive considerable public opposition which, according to current policies, has to be considered. However, much of this opposition results from a lack of awareness of the long-term importance of these projects, the methods for implementing them, and self-interest. Consequently, public education is needed to show the reasons for management of the forests to provide recreation and watershed protection in the long term.

5.6 Human activities and the forests of the Colorado study areas

The patterns of human activities and their effects on the forests of the two study areas in the second half of the nineteenth century were very similar. The development of settlements strongly depended on wood for fuel and construction. As minerals were discovered, huge quantities of wood were needed to create a large and complex infrastructure which included mining shafts, ditches, flumes, and pipes. Since existing federal legislation did not permit green timber to be cut, large areas of forest were set alight to provide dead timber which could be used less illegally. Fires were also set to provide access to potential mining deposits.

With the introduction of the railroads, new demands for timber developed: for railroad ties, and for wood which could be sold as lumber in regional markets or turned into charcoal. Railroad engines were also the source of sparks which started many fires; and fires were set to clear rights-of-way. In addition, many fires were probably started by accident, particularly in the piles of slash left after logging operations from which only the best timber had been taken. On Pikes Peak, the largest fire may have been set, on purpose, by Indians. However, the details of this event, as of most others, are sketchy because of a lack of reliable contemporary information or subsequent studies of fire history. In addition, the perceived conditions of the state of the forests by the end of the nineteenth century was strongly influenced by how accessible they were: in the Summit area, the extent of logging and burning was probably exaggerated because the conditions around the mining camps were assumed also to apply to the rest of the area.

The result of the first decades of European settlement in both study areas was the loss of a large proportion of the pre-settlement forest cover. It is probable that the forests of about three-quarters of Pikes Peak, and half of Summit County, had been burned, logged, or both. In Summit County, these activities had concentrated on the southern part of the area, around mining camps and along the railroad lines. The forests of the Gore Range and Williams Fork Mountains, where there were few trails or roads and no settlements, and little mining took place, were least affected.

Thus, accessibility had been the primary factor influencing the extent of anthropogenic change in the forests in both areas in the late nineteenth century. The only factor of comparable importance was the flammability of the forests and the atmospheric conditions prevailing when fires started. Attempts to control fires had only been made when private property or settlements were endangered. The remaining sawtimber stands were restricted to locations which were not easily reached from trails, roads, or railroads, or were inaccessible by virtue of steep terrain. Logging was no longer an economic proposition in either study area. In general, the remainder of the forests

consisted of open stands of conifers, which had survived because of their low quality for timber or because they were too small to be worth cutting, and areas of aspen which had regenerated after fire or logging.

Since the establishment of federal jurisdiction over the forests, the policies developed and implemented in the two study areas have been very different. Much of the variation can be explained in terms of the spatial relationship of the areas to population centers and means of access. The Pikes Peak area was adjacent to the city of Colorado Springs and the Cripple Creek mining district, and was easily accessible from regional and national transportation networks. These encouraged the development of a tourist industry and the growth of small settlements along the Ute Pass highway, with visitors arriving initially by rail and, later, principally by road.

The proximity of the area to urban and tourist centers led to the identification of watershed protection as the main focus of forest management. Agreements between federal and local governments were established early in the century, and have remained in force ever since, with municipal officials reminding Forest Service officers of their responsibilities whenever other forestry activities appeared to be endangering this function. Apart from restricting access to the watersheds, the primary method of implementing watershed protection was the reforestation program, through which the majority of the area identified in the 1911 survey was planted. This represented a significant investment by the Forest Service in terms of labor and the production of trees which were well-adapted to local conditions. However, this investment was generally successful; most of the plantations became successfully established.

Apart from watershed protection, the other main aim of the plantations was aesthetic. Recreation has been important on and around Pikes Peak since the late nineteenth century. While recreation on the mountain has essentially been restricted to three corridors, it also acts as a backdrop for travellers along the surrounding transportation corridors, and for those who visit and live in Colorado Springs. Consequently, the importance of the reforestation projects has been considerable. Into the 1920s, they represented the main contribution of the Forest Service to recreation, as most recreational facilities were developed by private individuals and companies.

For the first half of this century, there was no detailed timber management plan for Pikes Peak. This is presumably because of the emphasis on watershed protection; in any case, there was little commercial timber to manage, and most of the forest area is inaccessible. Since written policy is unavailable, the success of its implementation cannot be assessed. The harvest data show that wood was principally used for fuel, and that most sales were very small. Many of these sales, at least in the 1930s, had a silvicultural purpose, aiming at removing diseased and overmature

trees. Much of this work was made possible by the availability of CCC crews, who also worked on recreation, timber inventory, and reforestation projects which had previously not been undertaken, presumably because of inadequate Forest Service manpower or budgets.

In general, harvests were below the permitted cut; although the origin and usefulness of this figure is unknown. Yet, while harvests were at quite low levels, the degree of activity in the area in the late 1930s began to endanger the primary function of watershed protection. This occurred because of the high erodibility of the area's decomposed granite soils, and is probably because Forest Service manpower was inadequate to supervise a wide range of activities which stemmed from the area's proximity to a large and growing urban center. With the loss of manpower during the Second World War, forestry activities in the area decreased markedly.

In contrast to Pikes Peak, Summit County was remote from large population centers until the late 1930s; and even then, the Loveland Pass road was not an easy access route. However, until 1937, the Colorado and Southern railroad provided both a means for transporting timber to the mines at Leadville and a market for wood. Watershed protection was a stated objective of forest management but, with the exception of fire prevention and suppression, nothing appears to have been done to specifically fulfil this objective. The 1927 timber management plan was presumably used to guide the activities of Forest Service officers who, until the late 1950s, were mainly concerned with producing timber and suppressing fires.

As in the Pikes Peak area, the demand for wood from the forests was limited by the accessible supply. The demand for wood was strongly dependent on local mining and railroad markets; local domestic use was not recorded. The timber management plan was of little relevance because of the low supply of accessible commercial timber. Consequently, the imprecision of the data used to develop the plan was of little importance in influencing forestry activities. In the late 1930s, while summer recreation increased as a result of improved highway access, it does not seem to have greatly influenced Forest Service activities.

Since the Second World War, watershed protection and recreation have remained the emphases of management in the forests of Pikes Peak. The 1952 timber management plan placed many restrictions on logging, and limited the extensive forestry activities which had characterized the late 1930s, recognizing that many of these conflicted with the forests' primary functions. However, the demand for wood for all purposes decreased to very low levels; in particular, there was minimal demand for firewood, and the demise of the mining industry removed the demand for props. Consequently, the restrictions were of limited relevance in influencing harvests. Also, neither the planting nor the stand improvement projects proposed in the 1952 plan were carried out,

probably because of budget restrictions, but also because of limited manpower. Over the past three decades, the small number of Forest Service officers have had to spend an increasing amount of their time planning, constructing, and maintaining recreational facilities and coping with problems associated with recreational and military use, such as fires and erosion from off-road vehicles.

In general, the policies for the management of the forests of Pikes Peak during this century have been successfully implemented. The reforestation projects, limited timber harvests, and fire prevention programs have permitted the re-establishment of a reasonably continuous forest cover, thus protecting the watershed and providing a visually-pleasing landscape for the millions of people who, each year, travel along the three recreation corridors and view the mountain from below. However, the forests are dominated by sawtimber stands, in many of which there has been little regeneration during this century. This situation is typically the result of lack of accessibility, or because municipal or Forest Service officials anticipated that potential logging, thinning, or prescribed burning projects would conflict with the primary functions. The stands of poles, particularly in monospecific plantations, have become stagnated in the absence of thinning. Thus, while the policies have so far been successful, the future of the forests is in question, as they are dominated by dense stands consisting mainly of poles and sawtimber trees with slow growth rates. These are susceptible to stresses such as fire and insect infestations; and there are often few young understory trees to replace them.

In Summit County, the emphases of forest management changed after the Second World War, particularly from the late 1950s. This was primarily the result of the development of good highway access from the Front Range and recreation facilities in the study area, combined with other external socio-economic factors. When the 1947 timber management plans were written, the scale of the growth of year-round recreation was not foreseen. Nevertheless, by 1960 recreation was the primary function of forest management. Timber production was also dependent on external factors, especially demand for mining timbers and for sawtimber for urban growth along the Front Range. Demand for firewood for sale was also variable; however, most firewood was probably provided from free use.

Thus, as on Pikes Peak, the principal activities of Forest Service officers from the late 1950s onwards involved planning, constructing, and maintaining recreational facilities. These are much more widespread than on Pikes Peak, including an extensive network of hiking trails, many campgrounds, and four major ski areas. In addition, Interstate 70 was built through the area, mainly on National Forest land. In this project, visual impacts were explicitly considered in both planning and implementation. Similarly, the logging and spraying projects associated with the mountain pine beetle infestation considered potential impacts on

the recreational resource. However, Forest Service employees are now beginning cutting projects in susceptible stands, rather than waiting for populations of insects to reach an epidemic level, as was the case until this decade. These projects have resulted in the highest harvests this century.

Overall, it is difficult to assess the success of the implementation of Forest Service policies in Summit County during this century. The effect of logging and fire on the forests of the watersheds of the Blue River and its tributaries were probably not as severe as perceived by foresters at the turn of the century. Eight decades of protection from fire, together with generally low harvests, have resulted in a forest cover which is well able to protect the watersheds. However, as on Pikes Peak, the structure of the forests, dominated by pole- and sawtimber-size conifers, makes them susceptible to stresses, as has been shown by the recent mountain pine beetle epidemic.

The current structure can be attributed to various factors, including the results of fire prevention which has mitigated against the regeneration, by fire, of the lodgepole pine stands which cover half of the area; inadequate road access to permit logging and thinning; and the lack of thinning in the large proportion of the forest identified for thinning in 1960. The emphases on minimizing the visual impacts of forestry activities, and considering the demands of local residents, may also be counteractive in ensuring the long-term viability of the forests, since these two factors divert resources away from the most efficient implementation of many projects aimed at this goal.

In conclusion, after the short period of substantial deforestation which occurred on Pikes Peak and in at least the southern part of Summit County at the end of the last century, these forests have primarily experienced custodial management. There have been brief periods of high harvests in limited areas when local or regional demands for wood were high but, with the exception of the current decade in Summit County, harvesting levels have never approached proposed yields. Thus, as in the Swiss study areas, forest management activities to ensure the continued provision of the protective (and more recently, recreational) function have been limited by demand and access. In addition, the primary natural agent of forest succession - fire - has been suppressed in accordance with federal policies. The result, as in the Swiss areas, is that the forests have a predominance of stands composed of trees with a limited range of ages and sizes, many of which started life around the turn of the century, when all accessible sawtimber had been burned or removed and federal jurisdiction was introduced.

The policy of protection at that time was reactive, and often there was little forest left to protect. During this century, policy developments have also generally been reactive, whether these have been in response to changing demands on the forests or potential natural disasters. Under current legislation, the

development of proactive, rather than reactive, policies is limited by the mandated requirement for public participation and the ranger districts' loss of autonomy. This will probably remain the case while a lack of public understanding of forest successional processes persists, and individuals' short-term interests, rather than long-term public benefits, and nationally-set goals can strongly influence policy definition.

6. MOUNTAIN FORESTS AS COMMON-PROPERTY RESOURCES: POLICIES AND OUTPUTS IN THE COLORADO ROCKIES AND SWISS ALPS

The first chapter of this study introduced the concept of common-property resources and presented a classification of forest outputs as private and public goods. The purpose of this chapter is to place the findings of the previous three chapters into this theoretical framework, by examining the changing communities which have used the forests of the study areas as common-property resources; the changing outputs which these forests have produced - or have been perceived to produce; how these changes have been reflected in policies for the management of these forests; and the extent to which these policies have been successful. Finally, some implications of these findings for future policy development are presented. In contrast to the summary sections in Chapter five (5.3, 5.6), which presented intra-regional comparisons, this chapter emphasizes inter-regional comparisons, particularly for the two pairs of study areas: Davos and Pikes Peak, Aletsch and Summit.

6.1 Regional analysis: pre-twentieth century

For the period up to the end of the nineteenth century, there was a significant contrast in patterns of forest ownership and regulation in the two regions. In the Swiss Alps, the pattern of ownership has not subsequently changed to any great extent, though that of regulation has. While many areas of forest have been owned by private individuals or groups as far back as records extend, the majority of the forest area is owned by civil Communes, typically including the longest-established families. These areas of private and public forest are usually interspersed. Recognition that the communal forests were common-property resources, important for providing not only wood (a private good), but also the public good of protection from natural hazards, is shown by the imposition of communal orders, such as Bannbriefe. In some areas, these were imposed from the thirteenth century or even earlier; in the two study areas, from around the turn of the sixteenth century. Subsequent orders, for instance from the seventeenth century in Davos, extended the scope of communal regulation to privately-owned forests. Davos is an unusual case, in that the proportion of the forest area in private ownership is much greater than for the region as a whole.

These orders, by limiting the number of users and types of uses, define the forests, whether in public or private ownership, as res *communes.* Up to the point when the orders were imposed, the communal forests were open-access resources *(res nullius)*, being used without any limit. As discussed in Chapter three, regulation had limited success, since population and economic pressure led to continued deforestation and, in some cases, conversion of these forests from public to private ownership. Concurrently, the use of the forests for grazing also limited their regeneration.

From the sixteenth century, a wider-scale awareness of the protective function of the forests developed, as shown by the policies made by the states of the early Swiss Confederation. In the mountains, however, these appear to have had little relevance. Regulation, whatever its success, remained at the local level and, as shown by the example of Davos past the mid-nineteenth century, communities regarded the use of their forests as a matter of local concern and did not appreciate external regulation. With respect to forest management, the main result of the short-lived Helvetic Republic was to increase the proportion of public forests, as ownership was transferred from religious orders and members of the nobility. The early nineteenth century was also marked by the introduction of scientific forestry to Switzerland by individuals trained in Germany, who realized that forests were important not only as a source of wood, but also for providing public goods such as protection from natural hazards and a landscape for recreation. In the Alps in general, the latter output was of little practical importance, since the development of tourism was limited to very few centers until the twentieth century.

The early foresters were instrumental in extending the scale of regulation from the local to the cantonal level, recognizing that both private and communal forests were common-property resources providing protection from natural hazards and, probably, a sustainable wood supply at a regional scale. The latter output would certainly have been implicit from their German training. However, cantonal regulation generally appears to have had little effect in limiting harvest levels, as long as increasing industrialization, in Switzerland and abroad, provided markets and wood remained a mainstay of life in the Alps. At the same time, grazing was still limiting the degree of regeneration. By the late 1850s, the foresters of the SFA had stated the national importance of the forests for providing wood and protection from flooding. However, such statements were not reflected in national policies until the 1868 floods provided the impetus for changing the constitution and introducing federal legislation.

The first Forest Police Law clearly aimed to ensure the continued production of public goods from mountain forests which, through the imposition of overall federal superintendence, were regarded as common-property resources for the national community. The production of timber was not specified as one of the primary objectives: these were to provide protection from natural hazards and minimize soil erosion and floods. However, this law, together with associated cantonal legislation produced before the end of the century, initially had little effect on the conditions of the mountain forests, because inadequate resources were provided for implementation. Only with the passage of the 1902 forest law, which provided federal financial support for ensuring the national-level provision of public goods, did harvesting and grazing levels begin to substantially decrease, as is shown by the structure of today's forests.

The recorded history of the use of Colorado's forests is much more brief than for Switzerland. In the four decades following European settlement, the forests in the public domain were generally regarded as open-access resources, an inexhaustible resource for the rapid development of new settlements, mining operations, and charcoal manufacture. Evidence for this comes from the extent of logging and intentional burning, which provided dead timber and access to potential mining deposits. In addition, contemporary statements from both study areas show that local residents had no interest in putting out fires in public domain forests unless private property was threatened.

The early attempts towards regulation of the forests were made by a small number of urban Coloradans, who perceived, first, that the forests were not an inexhaustible supply of timber and, second, that loss of forest cover would lead to greater variations in runoff, both affecting agriculture and increasing the danger of flooding. In other words, there was limited recognition that the forests were *res communes,* rather than res *nullius.* However, it seems unlikely that nineteenth-century Coloradans realized either the importance of fire, as the principal natural process which had created diversity in the forests, or that the end result of widespread human use of fire, followed by protection against it, would be a more homogeneous forest cover. In addition, the total extent of burning was probably overestimated, being biased by the frequency of fires around settlements.

At the national level, the institution of the General Land Office's corps of special agents represents an early recognition that the public domain forests were common-property resources. However, the main emphasis was on the forests' importance for supplying timber, rather than protection and, as in Switzerland for many centuries, these officials were unable to successfully fulfil their duties. The Creative Act made it possible for the President to declare forest reserves, but the Act's purposes are unclear, and there were still no means for limiting the uses of the forest on these reserves, as shown by the continued high levels of use in the remaining sawtimber stands on Pikes Peak. The passage of the Organic Act, six years later, can be linked to the success of conservationists and foresters, at the Colorado and national levels, in persuading federal politicians that the public domain forests were both exhaustible as a timber resource and important for protecting watersheds. They were therefore common-property resources, providing private goods, particularly timber and water, at the local or regional scale; and public goods, particularly protection from floods, at all scales from local to national.

6.2 Regional analysis: twentieth century

Thus, around the turn of the twentieth century, federal legislation implicitly recognized the forests of both the Swiss Alps and the Colorado Rockies as *res communes*. The Swiss Forest Police Law applied to all mountain forests, even though ownership remained at the local level (Communes, and private individuals and groups); while the U.S. Organic Act was extended to nearly all remaining public domain (i.e., federally-owned) forest land in Colorado by 1908. One difference between the two laws was that the Swiss law primarily emphasized the production of public goods, while the Organic Act also identified timber production as a major objective. A second difference was that implementation of the Swiss law was principally delegated to the Cantons (who in turn left much of the implementation to the Communes), while the administration of the U.S. National Forests was placed in the hands of the officers of a federal agency, who were exhorted to manage these resources "from the standpoint of the greatest good of the greatest number in the long run": a clear statement that they were to be treated as common-property resources. Nevertheless, two communities were recognized in the Organic Act: local, for timber; and regional or national, for watershed protection. Similarly, the Swiss Cantonal laws have tended to place greater emphasis on timber production than the federal law.

As discussed in Chapter four, during this century, policies for the management of the forests of both study regions have come to consider an increasing number of public goods. In addition, the scale at which these goods are to be provided has expanded. Many of these public goods, particularly recreation and landscape, are supplied to national, or even international, communities and, in the case of ecosystem and genetic diversity, to future generations. For Colorado's National Forests, this evolution developed earlier at the regional than the national level; all of the forest outputs identified in Table 1.1 are now officially considered in the development of forest management policies, as a result of the four major laws passed from 1960. Consequently, the early emphasis on timber production is no longer officially apparent. Swiss federal or cantonal forestry legislation does not yet specifically consider the pure public goods of ecosystem and genetic diversity; nor wilderness, which does not exist in Switzerland. However, all of the other outputs in Table 1.1 are considered, although the emphasis given to them varies between Cantons, appearing to depend mainly on the date of the most recent legislation.

Another major difference affecting policy development for the two regions is in the primary locus of decision-making for forest management. In Switzerland, decisions still largely reflect local economic conditions, though federal subsidies are often a key factor. In contrast, since 1960, there has been a considerable loss of autonomy for Colorado's district rangers, and also for officers at the National Forest and regional levels. Targets for outputs are strongly influenced by a wide range of computer

scenarios developed from the National Forest to national level. In addition, public interest groups now have a greater influence on decision-making which, since the passage of NEPA, can be enforced in the courts. Since a comparison of policy development in the two regions was presented in Chapter four, these regional- and national-level developments will not be discussed further. The following discussion concentrates on the development, implementation, and outcomes of policies for the management of the study areas in this century.

6.3 Local analysis: Davos and Pikes Peak

A key variable which must be taken into consideration when comparing the study areas of the two regions is their different scale, as discussed in Chapter two. In general, the smaller scale of the Swiss study areas has been reflected in intensive management, while the larger scale of the Colorado study areas has led to extensive management. However, turning first to the two areas characterized by early urban development - Davos and Pikes Peak - this generalization has not always held true. With respect to forest management, the primary concern of the residents of both areas in the early part of this century was that the forest should provide the local public good of protection from natural hazards. In the Pikes Peak area, these were primarily floods and drought; in Davos, floods, rockfall, and avalanches.

The means for providing this output was reforestation, one of the most intensive forms of forest management. Reflecting the different scales of the two areas, the total area reforested on Pikes Peak was an order of magnitude greater than in the Davos area. On Pikes Peak, reforestation was undertaken by the US Forest Service, funded by appropriations which were presumably the result of political pressure from local residents, who had been instrumental in forcing federal legislative action since the 1890s. In the Davos area, local residents invested directly in reforestation, although government subsidies were substantial. A secondary purpose of reforestation, at least on Pikes Peak, was to improve the landscape for recreation. In both areas, there was clear recognition that the forests provided this public good; tourism was a critical part of the local economy, and recreational facilities had been developed in the forests since the late nineteenth century.

For both of these study areas, there is very little information about forest management plans or activities, other than reforestation, until the 1930s; by which time the service sector dominated employment in both areas. In the Davos area, plans were generally lacking because of the predominantly private ownership; for Pikes Peak, probably because of the emphasis on reforestation and the lack of sawtimber - although lack of planning was common throughout Colorado. For both areas, available data suggest that, until the end of the 1930s, the principal local use of wood was

for fuel; wood was also cut for sawtimber, depending on supply and demand. In addition, the mining industry, defunct for nearly a century in the Davos area, still provided a market (albeit declining) for wood from Pikes Peak. During the 1930s, there was a marked increase in forestry activities on Pikes Peak, related to the Depression and the availability of government-subsidized labor. Much of this work seems not to have been planned for, and to have been counterproductive in terms of watershed protection, increasing the potential for erosion. There is likely to have been an increase in harvests in the Davos area during the 1930s, since the number of visitors was growing; in contrast to Pikes Peak, where the Depression had resulted in lower, and highly variable, recreational use.

The start of the Second World War represents the beginning of a divergence in patterns of forest use in the two areas which has lasted until the present. In the Davos area, harvests increased during the War, and post-war harvests, until the mid-1960s, were similar to pre-war levels. In contrast, harvests from Pikes Peak decreased during the War, and fell still further afterwards, to less than a tenth of pre-war levels during the late 1940s and the 1950s. These changes cannot be linked to forest management policies; they were primarily related to socio-economic factors.

In the Davos area, the War resulted in increased numbers of visitors (including wounded and refugees), causing greater demand for wood for fuel and, possibly, additional demand for sawtimber. Subsequently, wood remained important for fuel, agricultural purposes, and construction. Average harvests in the 1950s were also increased by mandatory harvests after the 1950/51 avalanches and the 1956 windstorm. These occurred in stands of pole-sized trees, which probably reflected the uneven use of the forests, resulting at least partially from their variable degree of access. In contrast, *on* Pikes Peak, the lower harvests during the War reflected the loss of manpower; subsequently, the US Forest Service (cf. Roeser, 1952a) recognized that very little could be harvested from the area. To some extent, this was because of the general lack of access; but also because timber production was regarded as of low importance, as the concept of multiple-use began to be officially accepted, and watershed protection and recreation were defined as the primary uses.

By the beginning of the 1960s, winter had become the main tourist season in Davos. As discussed in Chapter five, many socio-economic factors, many of which were linked to this trend, interacted to lead to harvest levels which were, on average, less than half of those of the preceding decade. As the main logging season changed from winter to summer, the lack of adequate road access became critical. However, after the catastrophic results of the early snowfall in 1979, harvests again began to rise, as the local citizens again realized the importance of their forests for providing local public goods: protection from natural hazards and a recreational landscape. This realization has been

exemplified by the recent: communal orders, increasing investment in forestry, and higher harvests.

To summarize the events of this century in Davos, the local people, having made initial investments in the long-term provision of public goods, in the form of reforestation projects and lower harvest and grazing levels, relied on local demand for wood to maintain their investment. When economic factors led to a decrease in this demand in the 1960s and 1970s, no attempt was made to find other approaches to maintenance. However, forests are dynamic ecosystems which require maintenance to ensure a structure which provides these public goods, as was shown by the effects of the heavy snowfall of 1979. Planned forest management played a minor role in these developments; however, the current forest plan, which recognizes interactions between different forest outputs, should ensure the long-term ability of the forests to provide the outputs required by the local people.

Since the early 1960s, harvest levels on Pikes Peak have also been very low. As in the Davos area, economic considerations have been primary; there are few roads, and wood cannot be sold at a profit when all associated costs are taken into consideration. Also, in contrast to Davos, since the local foresters are responsible for recreation, an increasing proportion of their time has been spent planning, developing, and maintaining recreational facilities; and also making the plans required by recent legislation. However, these plans have had little identifiable result; as for most of this century, the forests have remained almost entirely unmanaged. As a result, they are dominated by pole- and sawtimber-sized stands, which are often densely-packed, have low levels of regeneration, and are increasingly susceptible to insects, disease, and fire. The local people, having become involved in forest management at the beginning of this century, have not played any substantial role for decades.

While watershed protection and recreation are still regarded by both the Forest Service and local citizens as the primary outputs of the forests, the optimal method for ensuring the long-term provision of these public goods - prescribed burning - is not being used. The reasons for this are complex, but clearly include the Forest Service's public education programs which have been successful in creating the perception that any fire is bad. Since the cooperative agreements between the Forest Service and local communities still exist, it is critical for this perception, at least at the community decision-making level, to be changed. This would enable anthropogenic fire to be used productively - in contrast to its use in the last century - to provide a more diverse forest structure, crucial to fulfil the official aims of Forest Service policies for the area and to ensure that the forests provide the local public goods desired by local residents.

The marked post-war divergence in forest management activities in the two areas can be ascribed to a number of factors. Two of the most compelling are the lack of a recent disaster on Pikes Peak and the different levels of primary decision-making. In both areas, the low harvest levels of the 1960s and 1970s represented the accelerated climax of a trend of inadequate levels of forest management for much of the forest area, based on uneven access and variable demand for wood. The 1979 snowfall in Davos undoubtedly renewed the Davosers' perception that all of the forest within the communal boundaries was a common-property resource, which needed maintenance if it was to continue to supply public goods which had essentially been taken for granted. This perception, stimulated by local foresters, resulted in the 1984 and 1985 orders and subsequent investment in the resource.

In contrast, there have been no recent floods or fires on Pikes Peak; both ponderosa pine and douglas fir have suffered insect epidemics but, to date, increased fuel-loading has not resulted in fires. Decisions concerning the management of Pikes Peak's forests are not made, though they could be strongly influenced, by local people. Since no problems are apparent - particularly as much of the area is inaccessible - local people are unlikely to exert political pressure for a change in forest management, especially to a form of management which has been endorsed only quite recently by the Forest Service and runs counter to general public perceptions. Yet the traditional silvicultural approach, involving road construction and harvesting, is inappropriate and uneconomic in an area with friable soils and harvesting costs would be far greater than the potential income from selling wood. However, the data on forest structure presented in Chapter five, combined with the ecological information in Chapter two, suggest that a change to active management is necessary. It is to be hoped that a disaster is not needed to effect this change.

6.4 Local analysis: Aletsch and Summit

For most of this century, there has been a clear difference between the management of the forests of the previously-considered study areas and that of the forests of the Aletsch and Summit study areas. While watershed protection was identified, through federal and local policies, as an objective of forest management in both of these areas, no direct investment in this public good was made. Essentially, the attitude of foresters in both areas was that forest protection, based on allowable rates of harvesting, would ensure watershed protection. These rates were defined in the management plans which have been available for most of the forests of the Alestch area throughout the century, and for the Summit area since 1927.

Wood was harvested to supply the needs of the local communities (i.e., a local public good) and to supply markets (i.e., a market good). In the Aletsch area, the former use was predominant, though harvests increased to provide wood for sale when external

demands were high. This resulted in frequent harvests above sustained yield, particularly in the late 1930s and 1940s. In the Summit area, it is difficult to identify the proportion of uses, since much harvesting was unrecorded free use. However, at least until the railroad's demise, more than half of the harvest was probably for sale, to the railroad and for the mining industry. After the war, there was a substantial demand for sawtimber, both for mining and construction (at least partly along the Front Range), resulting in higher harvests than before the war. In contrast, post-war harvests from the Aletsch area were below prewar levels, probably because of a combination of emigration, declining agriculture, and competitive fuel sources.

There was a significant divergence in forest management policies and uses for the Aletsch and Summit areas from around 1960, when tourism began to become the mainstay of the local economies. In the Aletsch area, the growth of tourism led to a decrease in harvested volumes, which varied greatly from year to year, and reached zero for many years in some Communes. The occasional high harvests were mandatory, resulting from a forest structure which was the product of uneven levels of harvesting due, at least partially, to highly variable levels of access. In the 1980s, harvests have again risen, mainly because government subsidies are being provided to enable mandatory harvesting of trees affected by bark beetles and air pollution. These subsidies are to ensure that the public good of protection against natural hazards is provided; the forests protect roads, railroads, and settlements, as well as being in the upper part of a major national watershed. The main contributions of the local Communes have been part of the wages for a forester and part of the funding for avalanche control structures.

While no new plans have been prepared for the Aletsch area since 1942, the explosion of tourism in the Summit area coincided with the beginning of the US Forest Service's multiple-use and planning philosophies. Many plans for the management of the Summit area have subsequently been made, emphasizing that recreation is a primary output of the forests. This is a mixture of a private good, supplied by ski areas which are mainly on National Forest land, and an impure public good, supplied by facilities developed by the Forest Service. The provision of recreation is linked to the supply of two critical public goods: the maintenance of the landscape and watershed protection, mainly to supply water to Front Range cities.

Harvesting has continued in the area, partly to supply local sawmills and other local demands, particularly for fuelwood. However, the main impetus, as in the Aletsch area, came from an insect epidemic in the 1980s, which resulted in government appropriations to allow the harvesting of diseased trees. This program, and subsequent cutting identified in the most recent management plan, is to ensure the continued provision of the three main public goods. However, as in the Aletsch area, it became necessary because levels of forest management have been

highly variable, in both space and time, since federal protection was introduced. In the Summit area, the suppression of fire throughout the century has been an additional factor.

The divergence of forest policies and use in the two areas, since about 1960, can be attributed to the different patterns of ownership and decision-making. In the Aletsch area, only a proportion of the local people (members of the civil Commune) own the forests, which are their main assets, and have little, if any, potential for providing income to invest in forest maintenance. At the same time, members of local communities (i.e., political communes) do not derive any direct benefits from the forests, and thus have little incentive to invest in them. In addition, because of the spatial pattern of ownership, efficient forestry activities require the cooperation of a number of Communes. Since the main benefits from the forests are public goods which accrue to a far wider community than only local residents, they have left the cantonal and federal governments to make the investments necessary to ensure these benefits are provided. This pattern is probably unlikely to change unless legislation forces forest owners to increase their investment in forest management.

In contrast, the forests of the Summit area are run by the federal government, with the primary objective of providing public goods to communities which are mainly regional or national. Since about 1960, the main investments of manpower and resources have been in the development of recreational facilities and the preparation of plans. While plans from the 1960s recognized the potential for outbreaks of mountain pine beetle to disrupt the provision of these goods, nothing was done to limit this possibility until an epidemic did occur. The current plans recognize the importance of prophylactic cutting; although funds to permit this must be provided from annual federal appropriations, since the wood to be cut has a low market value. However, local people are often actively opposed to cutting because they perceive that it will decrease the quality of the landscape; which in turn may affect private property values. Thus, for the Forest Service to ensure the long-term provision of public goods, local people must be persuaded to use the public participation process to support forestry, even if this may result in short-term aesthetic, and possibly financial, losses.

6.5 Conclusion

This study considers a highly limited sample of study areas and regions. Consequently, the findings of the study cannot be assumed to be transferable to other areas within these regions or to forests in other temperate mountain regions whose ecological, political, economic, and social systems have evolved differently. Nevertheless, the study has indicated some strong parallels both within and between the Colorado Rockies and the Swiss Alps, which suggests that there may be parallels with other similar regions.

Mountain forests, by virtue of their location in the upper reaches of watersheds, are inevitably common-property resources which supply a number of public goods to downstream national or international communities, by influencing the rates at which water reaches, flows over, and infiltrates the ground surface. At the local scale, they also influence patterns of avalanches, rockfalls, landslides and other geomorphic processes which can endanger settlements, transport infrastructure, agricultural land, and human and animal life. The importance of these protective functions varies considerably in scale, from the individual to the international; but they are predominantly public goods. In the Swiss Alps, these outputs have been recognized by the introduction of regulation at least since the thirteenth century at the local level, the sixteenth century at the regional level, and the nineteenth century at the national level. Federal legislative recognition in various alpine nations and the United States came within a relatively short period: from 1860 to 1891.

In addition to the public goods described above, mountain forests also provide a variety of market goods, of which the most important is wood. The legislation of the late nineteenth century can be linked to a recognition that not only was the long-term provision of the public goods endangered, but also that supplies of wood were limited, given recent and current rates of extraction and regeneration. Consequently, when limits on harvesting and grazing were imposed by the early federal legislation, the policies introduced to manage the forests were based on the production of a sustained yield of wood. As discussed in Chapter one, the concept of sustained-yield forestry was developed under a clearly-defined set of conditions in 19th century Germany. Three of these conditions are crucial for the following discussion: that all areas of forest could be managed; that a demand for wood existed; and that there would be an adequate workforce to supply this demand. A fourth, implicit, assumption was that the optimal method of regenerating the forests was to cut trees.

The first of these conditions has never applied in any of the study areas, since access to many parts of each is limited. This is also true for the Swiss Alps as a whole (Ott, 1984); and Spinatsch (1983) has estimated that a fifth of Graubunden's forest area is inaccessible by current technological means, including helicopters. As a result, a significant proportion of the forests in each study area has not been subject to human influence in the last century. Two caveats should be made here. First, under the traditional pattern of logging in the Alps, winter was the primary logging season, rather than summer, as at present. Consequently, greater areas were accessible for harvesting, since the location of roads was a lesser constraint. Second, anthropogenic fires have influenced many otherwise inaccessible sites in the Rockies. This relates to the fourth assumption, which will be discussed further below.

The second condition was valid in the wood-based economy which existed in both regions into the 20th century. An additional demand was for railroad ties. As Olson (1971) has discussed for the United States, before the First World War these had to be replaced at least every seven years. Subsequently, new methods of cutting, preserving, and installing ties led to considerably lower demands. Other demands for local wood in both regions were decreased or removed by other types of technological change; only a few primary ones are outlined here. First, the introduction of more efficient transportation systems meant that, even when wood was needed in mountain areas (especially for construction), it could be supplied more cheaply from areas where trees grew faster and could be harvested at lower cost. Second, harvesting costs in mountain areas have been affected by mechanization to a far lesser extent than in less steep areas, further decreasing the Competitiveness of mountain wood. Third, the introduction of new fuel sources, such as fuel oil and electricity, minimized the demand for fuelwood. Fourth, the intensification of agriculture, in both lowland and mountain areas, substantially decreased the demand for posts, poles and many other products.

The third condition is linked to the second to the extent that, if there is a high enough demand for wood, prices will be high enough to pay people to harvest it. Conversely, when demands are low, the cost of employing contractors may be excessive, and harvests to provide wood for sale will decrease. This was the case in the Swiss study areas from the 1950s onwards, as tourism came to dominate the local economies, providing new employment opportunities for local people; and less locally-supplied wood was needed for fuel, construction, or agriculture. In Switzerland as a whole, wage levels in forestry have risen far faster than wood prices since 1950, and particularly since 1970; prices have decreased in the 1980s (Affolter, 1985). In addition, forestry is not perceived as a particularly desirable profession, since wages are relatively low, accident rates are high, and many positions are part-time; the number of full-time jobs decreased about 40% from the 1950s to the 1980s (BAF, 1985; Butora, 1984; Schwingruber, 1985). The number of Forest Service officers in the Colorado study areas has generally increased since 1960. Yet, in general, very little of the additional manpower has been used in forest management; recreation and planning have tended to be the areas of greatest growth, except during the mountain pine beetle epidemic in Summit County. However, most of the new employees brought in for this project have since been laid off.

The fourth assumption holds true in the Swiss Alps, where the processes which would lead to regeneration under natural conditions have been successfully mimicked by local people for centuries, permitting the supply of both wood, usually on a reliable long-term basis, and protection. However, in Colorado, where fire is the primary natural agent of succession, prescribed burning would often be a more efficient means of ensuring regeneration, particularly when the costs of cutting (including

road construction) are higher than those of burning, and both are greater than the price for which cut wood could potentially be sold. These costs are not only short-term and in terms of dollars; road construction, especially on friable soils such as those of Pikes Peak, often has long-term costs, such as increased erosion and lowered water quality.

Since many of the conditions assumed for sustained-yield forestry principally based on wood production no longer exist (and some never existed) in the study areas, policies based on this philosophy have been, and continue to be inappropriate for managing the forests of these areas. Yet, such policies officially guided forestry until the 1960s in Colorado, 1985 in the Davos area, and today in the Aletsch area. However, their prescriptions were rarely implemented to any great extent except, perhaps, in the few easily-accessible parts of the forests of each area able to provide wood for which demands existed. A primary consequence is that the forests of the four areas have a similar structure, and that this structure is neither what was intended by the policies, nor particularly suitable for fulfilling the objectives of these policies; with respect not only to wood production, but also to the provision of public goods.

The more recent policies for the Colorado areas and Davos realize, to a greater or lesser extent, that a different philosophy of forestry is necessary for managing mountain forests with the provision of public goods as a primary abjective. At a wider scale, the U.S. Forest Service's multiple-use concept and the guidelines for forest management plans in Valais also recognize this. Finally, at the federal scale in Switzerland, a new forest law has been proposed. This recognizes that protection of the forests is not sufficient to ensure that they fulfil all of the functions demanded by both local and national communities; a minimal level of maintenance is essential (Wandeler, 1986).

While this law has the potential to fulfil its desired objectives, the same cannot be said of existing federal legislation and policies for Colorado's National Forests. The legislated requirements of economic efficiency, national target-setting, and public participation, combined with the loss of local autonomy, frequently produce results which are contrary to those intended by the legislation. In particular, they tend to prevent or limit the implementation of management practices designed to increase the diversity of the age/size structure of these forests. The reform of the U.S. Forest Service and its policies is a large topic which has most recently been considered by O'Toole (1988), and will not be discussed here. Nevertheless, it may be concluded that considerable reform is necessary if these resources are to be managed for the greatest good of the greatest number in the long run.

In summary, a number of conclusions regarding policies for the management of the forests of the study regions may be drawn from

this study. The applicability of these conclusions to other mountain forests in temperate, or other, regions would have to be assessed for each individual case, and provide the opportunity for much further research. The conclusions are not presented in any particular order of significance.

First, these forests, whether owned by local or national communities, are common-property resources which provide a wide range of market and public goods. The relative importance of public goods has increased during this century as a result of changes in economic and social conditions; public goods are now the principal outputs of these forests. This evolution has been recognized in policies developed for both study regions, but has been more marked for Colorado.

Second, changes in policy have rarely been proactive; they have generally been in reaction to events affecting the structure or use of the forests. Such events have often endangered the long-term ability of the forests to fulfil the functions provided by human communities. Many of these events have been largely anthropogenic in origin.

Third, the concept of sustained-yield forestry is not sufficient as a basis for management policies for the forests of the study regions. This is because many of the key assumptions of this concept are, and in many cases always have been, inapplicable to these forests.

Fourth, the management of temperate mountain forests must involve the support of, and participation from, members of local communities, and should not be based on short-term economic factors or nationally-set goals for the production of forest outputs. Such participation must be based on public understanding that these forests provide a wide range of public goods and that policies for their management must recognize that, when their structure has been strongly influenced by human activities, continued human intervention in natural ecological processes is essential for the forests to provide the functions desired by human communities.

Taken together, these conclusions suggest that future legislation and policies for the management of temperate mountain forests must recognize that public goods are their most important outputs. This requires new approaches to mountain forestry, which should not be based principally on sustained yields of timber. Finally, members of mountain communities should play an increasing role in the management of mountain forests. However, this involvement must be informed. Consequently, members of forest management agencies must increase public awareness that close interactions exist between ecological processes and human actions in these forests, and that they are essential for the long-term future of mountain communities.

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