AN ABSTRACT OF THE THESIS OF

Abdelhai Andaloussi Ibnattya for the degree of Doctor of Philosophy in Rangeland Resources presented on October 8, 1984

Title: Effects of Cork Oak (Quercus suber L.) Canopy Cover on Seasonal Herbage Production, Foliar Cover, and Nutritive Quality in the Mamora National Forest of Morocco

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Abstract approved: ______________________
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This research was conducted in the Mamora National Forest of Morocco to: (1) Evaluate the effect of cork oak (Quercus suber L.) crown cover on seasonal herbage production, nutritive quality, and foliar cover on two distinctive sites in each of two years (1982, 1983) and to (2) assess the effects of one and two growing seasons' protection from grazing on herbage production and foliar cover. Sites differed in the dominance (81% cover) of a 1.5-3m tall legume-shrub (Genista linifolia L.) on one (G) and the near absence of this layer on the other (NG). Understory herbage yields on G were over twice as much as the NG regardless of oak cover, plant phenology or years. On the G yields were similar from 25% to full oak canopy cover and declined approximately one-third at less than 25%. Yields on the NG were essentially the same regardless of canopy cover. Yields peaked at the pre-reproductive phase and then declined by approximately one-third by maturity. Herbage under canopied stands

contained more crude protein, fat and water but less crude fiber than in the open. Nutritive quality of herbage from the G site was approximately three times greater than that from the NG.

Living vegetation ground cover was 70% at canopy cover of 25% or less but was 85% above 25% canopy. Annual grasses decreased in cover from 57% to 30% as crown cover decreased. Annual forbs were less under the densest canopy but were approximately 30% as canopy declined. Perennials tended to be similar (13%) under all canopy treatments. Foliar cover was higher on the G site. Vegetation and soil characteristics showed G having higher production potential.

The amount of rest from grazing had pronounced effects. Average herbage yields were 30% more protected two growing seasons as compared to one. Percent cover of annual grasses, perennial grasses and oak seedlings was higher when contrasting two to one seasons' protection.

Results suggest that both tree canopy cover and site characteristics such as intermediate shrub layer were major determinants in affecting herbage yields, quality, cover and composition. Rest from grazing also had important effects. Such information will be helpful in developing future Mamora management plan.

Effects of Cork Oak (*Quercus suber* L.) Canopy Cover on Seasonal Herbage Production, Foliar Cover, and Nutritive Quality in the Mamora National Forest of Morocco

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of
Doctor of Philosophy

Completed October 8, 1984

Commencement June 1985

APPROVED

Redacted for privacy

Professor of Rangeland Resources in charge of major

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Date thesis is presented October 8, 1984

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DEDICATIONS

I would like to dedicate this dissertation to:

Fatiha, my wife, for her patience, moral support and constant helpfulness towards the realization of my potential.

Narjisse, my lovely daughter, that this thesis serve as an example of a continual perseverance in her life.

Haj Jaafar and Hajja Aicha, my dear parents, for their loneliness and suffering during my absence.

THESE DEDIEE A

Fatiha, mon epouse, pour sa patience, support moral et continuelle aide dans la realisation de ce travail.

Narjisse, ma fille adoree, pour qui cette these servira de modele de perseverence dans sa vie future.

Haj Jaafar et Hajja Aicha, mes tres chers parents, pour leur solitude et leur souffrance durant mon absence.

ACKNOWLEDGEMENTS

I wish to thank those people who care about humanity and each other. This work which is on paper now, was not possible at all without the help of so many people. Among those people a few deserve to be recognized. First, I wish to express my gratitude to Dr. Thomas Bedell for his guidance, assistance and encouragement throughout the course of this investigation. His invaluable amount of help at Oregon State University as well as in Morocco, support, direction, patience and constructive criticism during the preparation of this manuscript are highly appreciated.

My gratitude is extended to Dr. Steve Sharrow for his constant support, assistance on the experimental design, analysis of this study, critical review of different sections of the manuscript and friendship.

Appreciation is expressed to Drs. William Krueger, Rangeland Resources Department Head, for his understanding and warm support and to John Buckhouse for his outstanding human relations.

Appreciation is extended to Drs. Dale Weber, William McGuire, and Philip Jackson for serving on my graduate committee.

A recognition to my friends and staff members, especially to: Mike McInnis, Iraj Motazedian and Beverly Clark for their kindness and encouragement.

A special recognition to Mrs. Frances Causbie, an active member of the International Crossroad for her love and appreciated care.

A sincere thanks to the U.S.A.I.D. and to the Institut Agronomique et Vétérinaire Hassan II of Morocco for providing the financial support.

I would like to thank my devoted wife, Fatiha, and my lovely daughter, Narjisse, who tolerated this critical period of our life.

Last, but not least, to all those responsible for making this dissertation a reality, my heartfelt thanks are expressed.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Effects of Cork Oak (*Quercus suber* L.) Canopy Cover on Seasonal Herbage Production, Foliar Cover, and Nutritive Quality in the Mamora National Forest of Morocco

CHAPTER I

Introduction

Discussion of the Problem

Traditionally foresters and range managers have been at odds over the value of forest grazing. Concern over animal damage to tree reproduction for timber species has been the primary reason for this struggle. In addition, foresters have held that timber production alone provided sufficient economic use of the land resource. This point of view has been widely discussed and criticized. The forest environment has been found to be capable of producing more than just wood fiber. Forage, water, wildlife, recreation, aesthetics, aromatic and industrial plants, fruits, shade, minerals and cork are other important tangible and intangible products of forest ecosystems. The importance of these products and values is more or less accepted by forest managers, depending upon their effect on timber growth and production, and on pertinent management legislation.

The dictum of European and North African forestry that grazing and timber production are incompatible is at variance with forest management policies in some United States forest situations. In the administration of the United States' national forests, a school of thought has evolved which acknowledges that, contrary to experience on these two continents, grazing and forestry may take place without endangering the latter. Sharrow and Leininger (1983) reported that when proper season and degree of use are observed, growth of the tree crop may be enhanced by grazing. Krueger (1983) added that grazing can reduce competitive impacts of understory vegetation to the benefit of the forest plantation. These ideas should appeal to forest administrators, in Morocco, where most of the permittees are graziers on whom the Forest Service must depend for cooperation on a daily basis.

In Morocco, the relationship of grazing to forest production presents a problem which is just beginning to be appreciated by Moroccan foresters. The problem is virtually unheard of by the public. Until recently, it has been regarded as a local matter, peculiar to some restricted national forests. But, as more information becomes available either from various administrative provinces lodging forest users' complaints and/or from forest districts pointing out the trend in local forest conditions, it becomes quite evident that this is a condition of widespread occurrence. Moroccan forest policy makers and managers should review their policy in regard to forest grazing and assign this practice the place it deserves in timber management programs. They need to recognize that the success of any forest management plan will be strongly affected by their approach to grazing use and management and that success cannot be achieved if this factor is ignored.

Almost all Moroccan forest lands are concerned with this situation. However, this study deals exclusively with the timbered areas of the Mamora cork oak forest for the following reasons:

1. Mamora, one of the largest (133,000 hectares) and most beautiful forests in North Africa, has always played an important economic role for the entire nation as well as for the people living within and around it.
2. Compared to other national forests, Mamora has been the subject of more research and studies which have resulted in more available information. The greater availability of scientific facilities motivates the researcher to continue the important work that has already been initiated.
3. The ecological study done in Mamora by Sauvage (1961) emphasized the descriptive rather than quantitative aspects of the understory vegetation. Considering the apparent forest trend, Sauvage's study should be updated.
4. Range improvement trials conducted in Mamora (Maignan and Ibnattya, 1973) essentially focused on the adaptation aspects of some forage species in the cork oak environment. The evaluation of native vegetation has as well as the economic aspects of prospective management actions and the eventual impacts on forest users have more or less been overlooked.

5. The twenty year management plan for Mamora (1973-1992) which is being intensively applied by the local Forest Service is subject to criticism. This plan points out the financial desirability of converting some open cork oak stands (those having less than 100 stumps/hectare and/or a basal perimeter of less than 80 or 40 linear meters, depending on the site) into exotic plantations (primarily *Eucalyptus* species) with little consideration given to other forest components. This management approach would certainly complement the local economy in that wood products could supply the Sidi Yahia paper mill, especially since more than 50% of the total forest area will be affected. However, no mention was made of the management of the grazing resource. A simple evaluation of the stocking rate shows that it exceeds by far the carrying capacity of the cork oak lands. This situation would be worsened if an extensive conversion into exotic plantations takes place. In addition, no effort was made to assess the economic value of the forage in relation to stand density or canopy cover before stating the conversion threshold. Finally, no investigation has been made to determine how to insure an appropriate combination of timber production and livestock utilization.
6. Some observers indicated the need of shrub removal (*Genista linifolia* L.) in the more opened stands, and

the need for introduction of other forage species as an approach to rational land use. However, little attempt has been made to evaluate the existing vegetation as a resource at any productivity level of this forest community prior to making management planning decisions.

7. Most studies concluded that grazing in Mamora was detrimental to cork oak regeneration and timber production, and grazing regulations were established accordingly. No attempts have been made to determine the seasonal forage production nor the proportions that may be removed by grazing animals without jeopardizing cork and timber production before developing forest grazing recommendations.

8. No studies have been done to evaluate understory succession and production in relation to site characteristics before assessing appropriate grazing systems.

All the above reasons and constraints have been influential in the initiation and completion of this study. A systems approach to range management research in the Mamora Forest appears important for three main reasons: first it would include and integrate several sub-concepts which provide useful guides for future research. This integration immediately would identify areas where knowledge and understanding are both missing and vital. Second, the systems approach would provide a sound basis or framework for critical evaluation of the impact of the actual management plan and practices.

And, finally, this approach would provide an opportunity to check the very important interactions of major independent variables and respond to the major objectives of the study outlined below.

Objectives of the Study

The major objectives of this study were to:

1. Determine the seasonal production and nutritive quality of herbage understory, as related to tree canopy cover and site characteristics, in a portion of the mature Mamora cork oak forest.
2. Evaluate the seasonal herbaceous foliar cover, as related to tree canopy cover and site characteristics, in a portion of the mature Mamora cork oak forest.
3. Evaluate the effects of one and two growing seasons' protection from grazing on seasonal herbage production and foliar cover.

Literature Review

Understory herbage production and botanical composition are directly affected by kind and amount of overstory. Managers of forest-range resources must be cognizant of overstory-understory relationships. Young, et al. (1965) noted that without an estimate of this relationship, it is difficult to gauge the transitory grazing potential of the successional vegetation on any manipulated ecosystem. Timber management practices in any forest, while primarily designed to increase timber production or quality, exert a strong influence on the potential food supply for grazing animals. However, Hedrick, et al. (1968) suggested that coordinated forest, range and livestock management can enhance forage production without increasing understory competition to timber production. Therefore, close cooperation between forest and range managers in planning the manipulation of any timbered rangelands is desirable, indeed necessary. The importance of this cooperation has been strongly stressed by Garrison and Rummel (1951) and Pase (1958) who stated that carefully designed timber or range management plans cannot be entirely effective if the interaction of one on the other is not fully considered. In many countries, it is common practice for managers of forested ranges to consider factors such as timber stand density or canopy cover in adjusting their livestock stocking rates (Harris, 1954). Young et al. (1967) noted that these adjustments are necessary because of scant forage produced under dense overstory canopies and the difficulty in obtaining proper livestock utilization of heavily timbered rangelands. Most studies have shown that as the crown closure increases, forage production decreases and botanical structure changes. Nevertheless, the most important feature of overstory-understory relationships is that there is no set response to all conditions (Krueger, 1981). He added that by defining the community type, management tools should become more predictable.

Ecology of the Mediterranean Annual-Type Rangelands

The "Mediterranean" climate is typified by mild, wet winters and hot dry summers (Trewartha, 1954; Rossiter, 1966; Flohn, 1969). In the Mediterranean Basin, where olive (*Olea europaea* L.) and the evergreen oak (*Quercus coccifera* L.) are generally accepted as the indicator plants of the true Mediterranean environment, the total annual rainfall varies from 200 mm. (8 inches) to 1,000 mm. (40 inches) (Anonymous, 1951). The Mediterranean climate occurs in at least five widely scattered regions of the world: the Mediterranean region itself between Europe and Africa; the Pacific Coast of North America from Oregon to Northern Baja California; the Cape Region of South Africa; certain coastal portions of South and West Australia; and the central Chilean coast (Whyte, 1949; Shmida and Barbour, 1981). As summarized well by Raven (1971), "Plant associations of the five regions are extremely similar both in their physiognomy and in the morphology and physiology of the constituent plants".

Before the advent of clearing, fire, cropping, and grazing, trees and perennial shrubs together with perennial grasses were the dominant components of the vegetation in Mediterranean areas. Today, the rangeland communities are characterized by either resistant shrubs (e.g. Q. coccifera L.) or numerous Mediterranean annual plants (Rossiter, 1966). These annuals thrive best on moderately deep soils (Litav et al., 1963). They are almost invariably long-day plants (Knight and Hollowell, 1958). Genera among the dominant annuals is restricted mostly to Bromus, Vulpia, Hordeum, Trifolium, Medicago, and Erodium (Rossiter, 1966). Rangelands comprised essentially of these winter-growing annuals have been designated as "annual type" by early California workers (Talbot et al., 1939). This term will be applied also to define pastures consisting of winter-growing annuals, in which perennial species are either absent or else play a minor and insignificant role agronomically. Indeed, it may be argued that the occurrence and extent of Mediterranean annual-type rangelands may be taken to indicate the limits of the Mediterranean environment (Rossiter, 1966).

As a rule, Mediterranean annuals are principally self fertilized, Lolium rigidum Gaud. being a notable exception (Fryxell, 1957). Stebbins (1957), in a discussion on reasons for the origin of self fertilization, remarked on the fertility insurance conferred on self-fertilized plants subjected to the periodic droughts and annual fluctuations in a Mediterranean-type climate. But, particular attention was drawn to a notion concerning long distance dispersal.

Stebbins added that "Accidental long distance dispersal of a single propagule can lead to establishment of a colony only in a species capable of self fertilization. If the type thus established is well adapted to its newly found ecological niche, it can spread throughout the area where these conditions are found, even though its capacity for genetic variation is much reduced".

Rossiter (1966) and Shoenemberger (1970) supported the hypothesis that many species, and probably strains also, have migrated from the Mediterranean Basin to each of the other four main areas with Mediterranean climates. But no obvious migration patterns have emerged, perhaps because of effects of chance over the comparatively short period of migration. LeHouerou (1969) agrees with Rossiter (1966) and Shoenemberger (1970) and added that the ecotypes of some forage species, e.g. subclover (*Trifolium subterraneum* L.), which are now intensively cultivated in some Australian pastures are originally from the Mediterranean Basin. What is not clear is whether new species have arisen on any significant scale since migration, thus adding a further component to the broad differences in floristic patterns (Rossiter, 1966).

Influence of Site

Studies done on annual grassland in California showed that a wide variety of soils support grasses, but the typical and most productive grassland soils are those occurring under an intermediate amount of rainfall. Where high rainfall occurs, soils support trees while shrub deserts occupy areas with low effective rainfall (Sampson et al., 1951). They added that the best grassland soils are dark in color, of medium to heavy texture and consequently of fairly high water-holding capacity. They are granular in structure, friable, and contain a moderate amount of organic material. These grass supporting soils vary in reaction from slightly acid to those of the rendzina type which are calcareous throughout. Also, much of the variability in California annual grasslands is related to differences in soils. Soil series are numerous; a dozen or more may appear in two and a half square kilometers (one square mile). Plots less than 30 meters apart on Montezuma clay showed tenfold differences in relative botanical composition for individual plant species (Biswell, 1956). Other site characteristics, such as topography, also affect grassy vegetation (Heady and Pitt, 1979). Bentley and Talbot (1951) classified different topographic types of rangelands as an aid in determining grazing capacity. These types, in increasing order of herbage production, were steep rocky bluffs, steep slopes, rocky brushland, rolling slopes, open rolling slopes, gentle slopes, and swales.

Influence of Season

Ratliff and Heady (1962) studied the effect of phenological development of annual species on herbage productivity. From their study they concluded that:

1. Some species start their most rapid growth earlier than others, and some deteriorated earlier than others.
2. ←Once the peak weight is reached for an annual species, there is a period during which weight remains reasonably constant, but it is not the same length for different species.
3. The initial losses in herbage weights are usually the most rapid; later losses occur more gradually.
4. The period of constant weight for a community will vary in length and starting date depending upon species composition.
5. The total loss in weight for a community will depend mainly upon its species composition.
6. Sampling for herbage weight must be carefully coordinated with species composition and with stage of growth and so designed that normal seasonal weight losses are not confounded with forage eaten by livestock.
7. The sequence of maturity was consistent and predictable from one year to the next.

In a study at the University of California Hopland Field Station in the interior coastal foothills of Mendicino County, Heady (1958) determined that in virtually all cases, a reduction occurred in total plant numbers as the growing season unfolded. Most of this reduction appeared early in the growing season between December and February.

Heady also found that different patterns of loss in plant numbers occurred between plant species and groups of plant species. Soft chess (Bromus mollis L.) and ripgut (Bromus rigidus Roth), comprised more of the vegetation in June than in December on all three study sites, while filaree (Erodium cicutarium L'Her.) maintained approximately the same proportion at all four sampling dates. Legumes were least abundant in June and most abundant in April, although this generalization was not consistent from one year to the next.

The combined effects of microsite and phenological development of annual vegetation produced important seasonal variations in plant maturity as vegetation on deep, moist soils in swales remained green longer than vegetation on hillsides where soils are often shallow (Bentley and Talbot, 1951; Heady, 1961; Pitt, 1975).

Influence of Weather Patterns

Weather patterns play an important role in annual grasslands. Fluctuations in herbage productivity and relative botanical composition exceeding 100 percent from one year to the next are the direct result of both temperature and precipitation patterns (Talbot et al., 1939; Bentley and Talbot, 1951; Heady, 1956; Heady, 1958; Naveh, 1967; McNaughton, 1968; Hooper and Heady, 1970; Murphy, 1970; Duncan and Woodmansee, 1975; Pitt and Heady, 1978).

In the northern hemisphere precipitation typically begins in October or November and ends in April or early May, with approximately two-thirds occurring from December through March. Average rainfall varies in amount from 150 mm (6 inches) to 2000 mm (80 inches). From approximately May to September there is little or no precipitation (Biswell, 1956). Differences in total precipitation from one year to the next varied by as much as 500 mm (20 inches) to 760 mm (30 inches), depending upon the particular locale (Bentley and Talbot, 1948). Temperatures below freezing may occur any time between November and March, but temperatures below -18°C. are exceedingly rare (Heady, 1956).

In California annual-type rangelands Bentley and Talbot (1948), Biswell (1956), and Heady (1956) stated that there are three major growth periods as determined by the prevailing climate. The first period usually begins in October when seeds of the annual plants germinate following the first rains of 13 mm (0.5 inch) to 25 mm (1 inch), enough to initiate germination over much of the annual grassland. During this autumn period, however, plant growth is often curtailed by insufficient soil moisture, unfavorable temperature, or both. Although plants grow intermittently during short rainy periods or occasional periods of mild weather, cold dry weather (temperatures 10oC (50oF) with frosts is frequent enough to limit or halt growth as winter approaches.

The second growth period begins in late winter or early spring. The exact calendar date throughout the annual rangeland depends upon the particular locale. During this rapid growth period, mean temperatures are near 10°C or above, frosts are infrequent, and plant growth accelerates. Later in the spring, typically April, temperatures rise rapidly and plant growth surges. Sometime in middle May, on the average, most of the plants mature and dry.

This drying of the winter annuals marks the beginning of the third, or summer period of plant growth. Summer-growing annual species or occasional perennial bunchgrasses provide scattered green herbage. This situation remains until the fall rains once again begin the cycle anew.

Weather patterns also play a very significant role in annual grasslands, both within and between years (Heady, 1956; Heady, 1958; Pitt and Heady; 1978).

Bentley and Talbot (1951) analyzed maximum herbage productivity at the San Joaquin Experimental Range, Madera County, in the central California foothills, in terms of these weather patterns. They qualitatively concluded that standing crop was approximately average in 4 of 6 seasons when total precipitation exceeded 510 mm (20 inches). Shallow-rooted annuals could not take advantage of excess rain which fell largely during the winter months before air temperatures became favorable for plant growth. Greater than average yields occurred during a year receiving 823 mm (23 inches) of rain which fell predominantly during the warm spring months. A year receiving 737 mm (29 inches) of rain occurring throughout the fall and spring months produced exceptional herbage yields. Bentley and Talbot (1951) also concluded that winter temperatures may have affected herbage yields more than was readily apparent because effects of temperature were closely correlated with effects of precipitation.

For a "natural" pasture at Adelaide, South Australia, Trumble and Cornish (1936) concluded that rain at critical periods, rather than total annual rainfall, determined total pasture yield. The correlation ($r = .95$) was strongest for the April-June period inclusive, coinciding with the early stages of pasture growth. In addition, November rainfall, which was negatively correlated with April-June rainfall, showed a high negative correlation with total yield. The possibility of using deep-rooted perennials to utilize late spring rains was suggested. Also, Hooper and Heady (1970) pointed out the importance of a second period for plant growth that occurs later in the growing season during the spring months. Warm temperatures combined with plentiful moisture during this period greatly enhanced total standing crop. Duncan and Woodmansee (1975), working at the San Joaquin Experimental Range, also concluded that precipitation must be adequately distributed throughout the growing season to ensure abundant forage yield.

Murphy (1970) studied the effect of fall precipitation on herbage productivity at the University of California Hopland Field station and found a correlation of .70 ($P < .01$) between observed low, medium and high forage production and the amount of rain received before the third week in November. He noted that this correlation reflected the interaction of temperature and precipitation at the time of germination and plant growth immediately following germination. If germination occurs early in the fall, when temperatures are still high, total standing crop increases relative to standing crop produced in a year when germination occurs later in the fall when temperatures are colder and less favorable for plant growth. In South Australia, where climate and vegetation are similar to conditions and sites producing the California annual type, initiation of growth early in the year also added to the absolute length of the growing season, encouraging greater total herbage productivity (Trumble and Cornish, 1936).

Annual weather patterns also influence relative botanical composition of the annual-type within each growing season (Pitt and Heady, 1978). Talbot and Biswell (1942) recognized especially the importance of date of "opening" rains (i.e., commencement date for growing season) in relation to botanical composition. They found that softchess and broadleafed filaree (Erodium botrys L'Her.), in annual rangelands, were likely to be abundant with early effective rains, while late rains favored a greater range of species including legumes. Heady (1958) concluded that the relative proportion of plants by species for the entire growing season was determined prior to December of each year in annual rangelands. Workers in the California annual-type generally agree that early fall rains followed by drought in late fall and early winter favor a vegetative cover relatively high in Erodium spp. which possesses a deep taproot that supplies water to the aboveground portions of the plant during times of drought. In contrast to Erodium ssp. the more shallow rooted annual grasses depend upon a continual supply of moisture for optimal growth (Pitt and Heady, 1978). However, Duncan and Woodmansee (1975) concluded that yield of annual grasses, legumes, and forbs other than legumes in the grasslands of Central California only poorly correlated with precipitation during any particular month of the growing season. These correlations were improved by using the best 2- or 3 months precipitation with multiple regression analysis.

Influence of Grazing

In California, complete exclusion of grazing animals from an annual-type rangeland leads quickly to grass dominance, especially ripgut brome (*Bromus rigidus* L.) dominance, with associated loss of clovers, bur medic and *Erodium* spp. (Talbot et al., 1939; Talbot and Biswell, 1942; Jones and Evans, 1960; Rossiter, 1966). These effects of continued protection probably apply, in general, in southern Australia also. Rossiter (1966) observed over a 7-year period that a capeweed-subterraneum clover pasture was dominated by ripgut brome after protection for 3 to 4 years; but eventually this grass was largely replaced by annual veldgrass (*Ehrharta longiflora*). Biswell (1956) has stated that the time trend for dominants in Californian rangelands, following protection, is as follows: forbs ⟶ soft chess ⟶ slender oats ⟶ ripgut brome.

A great deal of emphasis has been placed on grazing management, quite apart from stocking rate *per se*, by Californian workers. The loss of resident perennial grasses under a system of close continuous grazing (Cooper, 1960; Love, 1961) has led to an emphasis on deferred-rotation systems which will promote "desirable" species and inhibit "undesirable" ones.

Despite past emphasis on the desirability of rotation systems in annual rangelands, an experiment at Hopland Field Station, comparing set-stocking and deferred-rotational grazing, has shown no clear treatment differences in species composition (Heady, 1961). Indeed, Heady states: "Year-long grazing at reasonable stocking rates, is the best way to manage annual-type rangelands."

In studies at the San Joaquin Experimental Range, Talbot and Biswell (1942) and Bentley and Talbot (1951) noted no pronounced, long-term effects in total yield as a result of grazing ranging from close to light, a range about two-fold in stocking rate. Love (1961) suggested that since grazing animals have always been a part of virtually all grassland communities, grazing intensities within a "normal" range should not produce significant, permanent alterations in total "normal" productivity.

Hormay (1960) suggested that moderate stocking provided the best grazing technique in the California annual-type. He pointed out that old vegetation left on the ground at the end of each grazing season would enhance fertility, provide progressively improved range condition, and promote high livestock weight gains. Grazing either greater or less than this moderate level likely produces changes in both total herbage productivity and relative botanical composition. Heady (1958) postulated that grazing occurs first on taller plants, thereby increasing the relative proportion of shorter plant species. Alternatively, complete elimination of grazing animals encourages taller annual plants relative to short plant species (Pitt and Heady, 1979). Numerous grazing experiments were conducted between 1920 and 1950 to test the value of grazing systems and much experience was gained in the application of rotated rest and grazing on rangeland (Heady, 1961). He reported that part of the experimentation showed that continuous grazing gave more animal production than various rotational systems and the conflicting results were briefly reviewed.

Heady (1961) compared two 20 hectare pastures at the University of California Hopland Field Station, to test the relative effects of continuous and rotational grazing in the annual-type. He found no differences in species composition, plant density, or total herbage productivity between the two types of grazing.

The experiments which indicate either no advantage in livestock gains with specialized grazing systems or more gains with continuous grazing also report no significant differences in the vegetation under the various systems (Heady, 1961). For example, Moore et al. (1946) in Australia found that sheep in different rotations did not change the composition of harding grass (Phalaris tuberosa Hack.) and subclover (Trifolium subterraneum L.) pastures.

Studies at the San Joaquin Experimental Range showed a consistent advantage of yearlong, continuous grazing over seasonal grazing in breeding cow performance, calf weaning weights, and quality of available forage in terms of relative botanical composition (Pitt, 1975). Similar results were obtained with sheep at Hopland where the average weaning weight of lambs was consistently higher under continuous grazing as opposed to seasonal grazing (Heady, 1961).

Heady (1961) after reviewing all the studies done on grazing systems stated that yearlong grazing at reasonable rates, is the best way to manage annual-type rangelands because it pays primary attention to the day by day animal needs and because yearlong grazing amounts to a partial deferment every year. Enough forage must remain at the end of the forage growth period so that the animals have ample feed to last them until the new crop is produced several months later. This amounts to a very light grazing on all the range during the growing season every year. At the same time, it should be realized that animals must be congregated occasionally for purposes of protecting new range developments and for certain animal husbandry practices. These do not destroy the hypothesis that continuous grazing should be practiced on the annual-type rangelands.

Hormay (1944) concluded that because of the variations in productivity and range condition in different localities, each rancher must work out for his own range the degree of stocking that will result in moderate grazing and thus produce the maximum of livestock products and the highest income possible.

Importance of Natural Mulch

Hooper and Heady (1970) suggested that natural mulch is one of the most important determinants of forage production in the

California annual-type grassland. Even in the absence of grazing, removal of all mulch by clipping before the first rain in the fall: (1) reduces the proportion of desirable forage species in the stand, (2) lowers forage quality, and (3) reduces subsequent forage production as compared to areas where mulch has not been removed.

Several investigators, recognizing the importance of mulch in the annual-type rangelands, have made the recommendation that under correct utilization five centimeters (2 inches) of stubble should be on the ground when new growth starts in the fall (Hormay and Fawsett, 1942; Bentley and Talbot, 1951; Hormay, 1960). Heady (1956) in discussing the importance of mulch did not make a recommendation, but estimated the relation between forage production and mulch in kg/hectare to be $Y = 1214 + 0.354X$ where Y = forage production in the spring and X = forage residue or mulch left the preceding fall.

Biswell (1956) postulated that much of the variation in species composition in the annual grassland resulted from variable mulch accumulation. Biswell remarked that on sites producing large volumes of forage and mulch, ripgut, a tall, shade-tolerant grass, dominated the plant cover. Biswell further hypothesized that the impact of grazing on the annual-type operated primarily through its influence on the mulch layer.

Heady (1958) supported Biswell's contentions and also added that mulch accumulation favors taller annual plants to the relative disadvantage of smaller annuals. Heady (1961) studied the effect of mulch on botanical composition and demonstrated that mulch exceeding

700 kg per hectare encouraged taller grasses such as soft chess and ripgut, in annual grasslands. With no mulch accumulation small, unpalatable forbs such as goldfields (Baeria chrysostoma), smooth cat's ear (Hypochoeris glabra) and owl's clover (Orthocarpus erianthus) proliferated. With small amounts of mulch, diminutive, low-forage-value grasses such as little quaking grass (Briza minor) and silver hairgrass (Aira caryophyllea) abounded. Annual fescues (Vulpia Spp.) and nitgrass (Gastridium ventricosum) peaked in percent botanical composition with intermediate amounts of mulch, while filaree was not significantly influenced by varying amounts of mulch.

Heady (1956a) studied manipulation of mulch in a California annual-type over a 4-year period. He indicated that both total amount and position of mulch may have large effects on subsequent botanical composition and plant growth rate. He also found a significant linear association (r = .73) between the amount of mulch and subsequent spring production. No clear explanation of such effects has been advanced, and the possibility that mulch influences mineral nutrient availability should be recognized (Rossiter, 1966).

Therefore, the precise pathway(s) by which mulch affects herbage productivity and relative botanical composition is not completely understood. Rossiter (1966) postulated that plant residue on the soil surface influences evaporation, soil temperature, activity of soil micro-organisms, infiltration, soil structure, and soil nutrient status. Heady (1965) in the annual-type, detected no significant difference in nitrogen content eight centimeters below the soil surface after 8 years of mulch removal. Similarly, phosphorus, bulk density, and pH remained unchanged by mulch removal. Organic matter in the top eight centimeters of soil, however, declined significantly during the study. The most striking change after 8 years of mulch removal was that the soil structure in the uppermost three centimeters of soil became progressively more dense with decreasing amounts of protective mulch on the soil surface.

Effects of Fertilizers

Little information exists concerning the role of cycling of essential elements within annual grasslands and even less regarding the role of these grasslands in the elemental budgets of the atmosphere, streams; and ground water. Most recent reviews of nutrient cycling in range and pasture lands have virtually ignored Mediterranean annual grasslands (Whitehead, 1970; Porter, 1975; Paul, 1976; Charley, 1977). Katznelson (1977) collected information from numerous studies to develop a phosphorus budget for the annual grasslands of Israel. Woodmansee and Duncan (1980) have prepared a general review of nitrogen, phosphorus and sulfur cycling.

Two elements of principal interest in annual grasslands are nitrogen and phosphorus. Nitrogen is nearly always deficient and limiting to plant production in these ecosystems. Phosphorus is frequently deficient in some of the annual grassland soils (Woodmansee and Duncan, 1980).

The use of nitrogen fertilizers on California annual rangelands, at rates of up to almost 80 kg N per hectare has resulted in total yield increases of more than three-fold (Jones and Evans, 1960). Nitrogen fertilization also advanced the date of grazing readiness and reduced annual fluctuation in forage yield by reducing drought and frost damage. At high levels, nitrogen stimulated the growth of grasses and decreased the proportion of legumes (Jones, 1963).

Concentrations of nutrients in the available forage is important when considering meeting the nutrient requirements of grazing animals. Early research on the San Joaquin Experimental Range Station, investigating seasonal changes in the chemical composition of plant species, identified nitrogen and phosphorus as primary limiting nutrients for livestock performance on annual ranges during much of the year (Clawson and Duncan, 1979). Data from this study followed known patterns where nitrogen and phosphorus concentrations during the season when plants were green (late fall after germination to early May) appeared adequate for domestic livestock production.

Little is actually known in regard to the interactions between nitrogen availability and other environmental factors. Jones et al. (1963) determined that when mean winter temperatures dipped below $7^{o}C.$, forage growth slowed regardless of nitrogen fertilization. Grasses fertilized with nitrogen responded most when temperatures ranged from $8^{o}C.$ to $13^{o}C.$ When mean temperatures rose above $13^{o}C.$, the difference between unfertilized and fertilized grass productivity decreased dramatically.

The widespread use of subterranean clover in Mediterranean pastures has been dependent in large measure on the associated use of superphosphate, and the "sub and super" story has been frequently recounted. But even on "natural" pastures, superphosphate has had profound effects not only on total yield and, of course, animal production, but also on botanical composition (Rossiter, 1966). He reported that on a pasture at the Waite Agricultural Research Institute, Adelaide, Australia, dominated initially by perennials superphosphate applied at 185 kg per hectare per year gave mean increases of about 50 percent in herbage production. Similar results have been obtained in Mamora Forest by applying superphosphate at 120 Kg per hectare per year (Maignan and Ibnattya, 1975). The effects of phosphate supply *per se* on floristic changes are difficult to disentangle in the field, because of the concomitant changes in nitrogen supply associated with the legumes (Rossiter, 1966; Maignan and Ibnattya, 1975).

Effects of Woody Plant Removal

A technique commonly employed to achieve multiple objectives on rangeland is the conversion of predominantly woody cover to predominantly herbaceous cover. Grassy vegetation provides better forage for grazing animals and typically releases greater quantities of water than does woody vegetation (Heady and Pitt, 1979).

Oak trees grow in dense stands on many California foothill range areas and substantially reduce the quantity and quality of forage growing beneath. Murphy and Berry (1973) over a 17-year period at the Hopland Field Station studied the vegetative composition of an area which was changed from a predominant stand of trees to one of herbaceous forage plants. They found a 4 to 5 fold increase over that produced under trees.

Heady and Pitt (1979) studied the changes in standing crop, cover, and percent botanical composition of annual vegetation as influenced by site and type conversion, on watershed II at the Hopland Field Station. The major sites were characterized as open, semi-dense, and dense prior to type conversion. Before type conversion, herbaceous vegetation was virtually non existent on the dense sites and relatively scattered on the semi-dense sites. Brush conversion trebled total standing crop on the watershed, with much of this increase occurring on the formerly dense and semi-dense sites. However, standing crop remained the same on historically grassland sites characterized as open before conversion. Also, they found that the elimination of woody plants produced increases in percent botanical composition of those vegetative groups most able to colonize the dense sites following brush removal. These plant species included wild oats, perennial grasses and grasslike plants, vetches, and to a lesser degree, filaree. Alternatively, conversion produced declines in percent botanical composition of those plant species (silverhair-grass and nitgrass) not able to successfully colonize the newly available dense sites.

However, before a vegetational cover-type conversion project is undertaken, its purpose and potential benefits must be carefully assessed (Bentley, 1967). This process necessarily includes the impact of the change in vegetative cover on all management objectives. Failure to evaluate these impacts effectively has produced inconsistent results and considerable controversy over the suitability of type conversion to increase forage production in California. Much of the controversy arises because the responses to type conversion have not been carefully separated from the concomitant influences of site, grazing intensity and annual variability in forage production.

Effects of Overstory Vegetation on Herbage Production

Range scientists, ecologists, foresters and others recognize that trees making up the overstory on forested rangelands largely govern the plant community and the growth of understory vegetation. Hence, timber stand statistics often provide a practical means of predicting forage yields, which in turn indicate carrying capacity for livestock and game (Halls and Schuster, 1965).

In many foothill areas in central California, the difference in amount and kind of herbaceous vegetation under the canopy of oaks, especially blue oak (*Quercus douglasii*), is readily apparent especially in the winter and early spring. The canopy effect of the various oaks varies regionally, and definitely is influenced by the density of the trees (Duncan and Clawson, 1980).

Krueger (1981) hypothesized that trees exercise the control of understory vegetation by modifying the complex interaction of light, temperature, litter accumulation, nutrients, and moisture. He noted that these environmental factors usually react within a continually changing ecosystem further influenced by fluctuations in weather, periodic logging, and grazing by livestock and wildlife.

Within a community type, development or management of the overstory influences production, composition, and forage value of the understory in a predictable fashion. But, initial knowledge of the community type is necessary if actual predictions of response are to be made (Krueger, 1981).

Effects of Canopy Cover on Herbage Production

Responses of understory to light. The tree overstory has a direct influence on light received by understory vegetation. Some species thrive well in open plant communities while others require some shading for their growth and development.

Light is required for the growth of most plants and is characterized by four attributes: quality, direction, intensity and duration (Weaver and Clements, 1929). When a forest overstory is present it may alter one or more attributes of the light that penetrates into lower portions of the tree crowns, to the understory plants, and to the forest floor (Lemmon, 1965).

Murphy and Crampton (1964) noted under blue oak grassland at Hopland Field Station, that understory production was reduced or prevented partly because of less light intensity but apparently more because the light spectrum essential for photosynthesis was absorbed or reradiated by the canopy of tree leaves.

Krueger (1981) postulated that deciduous tree canopy reduces the relative proportion of red and blue light rays, which are the most photosynthetically active rays. Light penetrating the canopy has proportional enrichment of orange, yellow, green and infra-red. Yellow and orange light are related to cell elongation, which partially explains elongation often seen in shaded plants. Infra-red interacts with red to control plant hormones and subsequent induction of morphological changes such as flowering. A coniferous tree canopy affects light quality similarly to a deciduous tree canopy but filters less of the red light. Consequently, light quality under the coniferous canopy is quite similar to that received in the open on a cloudy day.

The specific ecological role of light quality on herbage production is not well understood and is frequently considered of little or no importance. The change in quality resulting from shading probably has little influence on presence or absence of most plant species but may well influence physiological and morphological characteristics of understory plants, and therefore their nutritional value (Krueger, 1981).

Light intensity is considered ecologically important. Shirley (1945) pointed out that understory vegetation develops poorly under light intensities of less than 4% of full sunlight, and if no other factors are limiting, photosynthesis is directly proportional to an increase in light from 1% to 15%. Krueger (1981) noted that the rate of photosynthesis depends on intensity of light until the plant is saturated. For cool-season plants, which usually dominate the understory of a forest, this saturation occurs at about 20% of full sunlight for plants adapted to growth in open areas and about 10% of full sunlight for those adapted to shaded environments.

Other studies have shown that at low light intensities leaf development takes place at the expense of root development (Shirley, 1945). Those findings were developed later by Blackman and Wilson (1951) who found experimentally that decreasing light depresses the amount of root and increases the ratio of leaf area to plant weight. They proposed that these changes influence the net assimilation rate which they found linearly related to the logarithm of light intensity in foot candles. Donald (1963) explained that competition for light is not immediately one of competition between species or even plants but could be competition between leaves.

Light conditions beneath a forest canopy have frequently been investigated with little concern for measures of understory responses (Anderson et al., 1969). Most of these studies, done particularly in the U.S. southern pine belt, indicated that forage production tends to level off under the more dense canopies (Gaines et al., 1954; Halls,1955). Campbell and Cassady (1949) and Cassady (1951) estimated herbage production to be 2 to 10 times greater under very open savannah-like longleaf pine than in well stocked plantations or second growth stands. Smith et al. (1955) noted that maximum yields obtained in Mississippi longleaf pine averaged 850,450, and 400 kilograms of air-dry grass per hectare in open, moderate, and dense canopies, respectively. Read (1951) found, in the Arkansas Ozarks, that the "poor" hardwood stands on south and western exposures produced 53 percent more herbage than the "good" hardwoods on the better north exposures. More recently, Young et al. (1967) demonstrated experimentally that forage production varies with shade classes within forest types and found a highly significant negative association between tree crown and both herbage cover and yield.

Anderson et al. (1969) conducted one of the few studies concerning the environmental factors that control understory growth response to canopy opening. Working in northern Wisconsin _Pinus resinosa_ and _Pinus strobus_ stands, they found that the understory response to canopy opening correlated better with throughfall and random drip precipitation than with light intensity in the understory. Witler (1975) noted that these authors reasoned that the droughty subsoil and high tree basal area in their study plots make moisture availability critical and that the moisture content of the lower litter layer and upper soil layer, where most northern understory herbs are rooted, is strongly influenced by variations in throughfall and random drip as determined by canopy opening. The amount of light coming through the canopy is less critical because it is generally above threshold level for the shade-adapted species studied. In contrast, Emmingham (1972) found that the occurrence of many of the understory species under mixed-conifer stands in the Siskiyou Mountains of southwestern Oregon largely depends on the amount of light in the understory.

Responses of understory to throughfall precipitation and temperature. Understory production can be limited by reduced availability of moisture in two ways: 1) The canopy and surface litter intercept precipitation, causing a reduction in the total amount of water which reaches the forest floor, and 2) the dominant overstory species of the forest community may largely compete with the understory for moisture which does penetrate to the forest floor. This effect has been stressed by many authors (Toumey, 1929; Anderson et al., 1969; Emmingham, 1972). Toumey (1929), by examining soil moisture of a denuded area in the open, and of trenched and untrenched plots under a forest canopy, found that moisture supplies became lower on the trenched plots as the season progressed due to interception of precipitation by the forest canopy and litter layer. In Eastern Oregon, Krueger (1981) noted that moisture or competition for moisture appears to be the most dominant force governing total yield of vegetation under typical forest-range canopies. But, during seasons when moisture is abundant, light and temperature may be the controlling factors. It also has been indicated by Darrow and McCully (1959) that chemical removal of oak species in Texas increased growth of grasses and herbaceous cover. This was due particularly to soil moisture and nutrients released from tree competition.

Temperature and its interactions with moisture affect plant growth and development. As temperature increases, evapotranspiration increases and moisture availability for plant needs is reduced. In addition, Krueger (1981) noted that in full light the ambient temperature is higher than in the shade. As a result, plants in the open are about 10^{o} C. warmer in the day and about 10^{o}C. cooler at night than those in moderately shaded areas. The optimum temperature range for photosynthesis of plants commonly found in the understory of eastern Oregon forests is about 21-35^{o}C. So, as ambient temperatures in open and shaded areas fluctuate about this range, productivity would also fluctuate (Krueger, 1981).

Effects of Tree Basal Area on Herbage Production

Several authors (Young et al., 1967; Hedrick et al., 1968) suggested that canopy cover rather than basal area accounted for more variation in herbage yield. However, Pase and Hurd (1958) noted that the air-dry herbage produced under ponderosa pine stands in the Black Hills of South Dakota increased from 22 to 1,660 kilograms per hectare when basal area decreased from 22 square meters per hectare to 0 on the clear cut samples. In another study done on longleaf pine (*Pinus palustris*) stands in southern Alabama, Gaines et al. (1954) found that herbage production increased as basal area and litter weight decreased. Halls and Schuster (1965) obtained a curvilinear relationship between herbage yield and tree basal area in Texas *Pinus echinata-Pinus taedra*-hardwood stands while Cooper

(1960), in a study conducted in a northern Arizona Pinus ponderosa stands, obtained a negative linear relationship between grass dry weight and percent of tree crown cover.

Effects of Stand Density on Herbage Production

An increase in tree density up to a certain level appears to have a negative impact on herbage production. Trees compete with the understory for space, moisture, rooting zone and soil nutrients. Cassady (1951) reported forage production in the piney-woods ranges of east Texas and Louisiana to be 1,500 to 2,000 kg/ha of air-dry forage in open, savannah-like stands of scrub oak. In moderately heavy stands, forage production varied from 500 to 1,000 kg/ha. In well stocked, pole-size stands of longleaf pine, variations were from 400 to 900 kg/ha. Cassady and Campbell (1951) stated that scrub oak ranges of Louisiana may be expected to produce 680 kg/ha of forage where approximately 400 trees/ha occur. On cut-over longleaf-pine ranges, according to Hopkins (1952), 1,500 to 3,000 kg/ha of native forage can be produced. However, in fully stocked pole stands, herbaceous vegetation is greatly reduced and less than 100 kg/ha of forage may be produced. In Arkansas, Read (1951) found that forest stands with only 100 trees/ha supported 6 times as much herbage as dense stands with more than 750 trees/ha. In most cases, forage production was related inversely to the amount of woodland vegetation present.

Effects of Overstory on Understory Botanical Composition

Tree overstory also directly influences the understory botanical composition. Ehrenreich and Crosby (1960) noted that the increase in grass production in the Missouri Ozarks was small per unit reduction in crown cover from 80 to 50 percent, but with successive decreases from 50 percent crown cover to none there were relatively large increases in grass production. In addition, increases in forb production with decreases in crown cover were small and constant from the dense hardwood canopies to cleared areas. Species responded differently to changes in hardwood crown cover. Little bluestem (Andropogon scoparius), broomsedge (Andropogon virginicus), switchgrass (Panicum virgatum L.), and Indiangrass (Sorghastrum nutans) were scarce in stands of dense crown canopy and persisted only as spindly, low-vigor plants. But as hardwood crown cover decreased they increased greatly in both number and vigor. Yield of most forbs, such as fireweed (Epilobium angustifolium) and sunflower (Helianthus annuus), increased as crown cover decreased.

Pase (1958) noted a decline of Kentucky bluegrass (Poa pratensis) from 191 kg/ha in an open Pinus ponderosa canopy to only one kg/ha in a closed canopy. He also noted in his experiment done in the Black Hills of southwestern Dakota that Kentucky bluegrass, the heaviest producer under open stands and in clearcut areas, decreased both in weight and in relative importance as pine crown cover increased.

Cooper (1960) found only small numbers of grass species under canopies greater than 75 percent. Forbs dominated understory production where a _Pinus ponderosa_ canopy was greater than 45 percent while grasses were dominant under a canopy less than 45 percent (McConnel and Smith, 1965). For shrubs, Young et al. (1967) stated that current annual growth peaked at crown covers between 20 and 35 percent.

At the University of California Hopland Field Station Murphy and Crampton (1964) found that removal of blue oak resulted in species composition changes. Four annual grasses exhibited the greatest changes. Soft chess and wild oats (_Avena barbata_) increased and ripgut and mouse barley (_Hordeum leporinum_) decreased with tree removal. They also noted that shade-loving forbs were eliminated, but other forbs showed no consistent change due to tree removal.

Pase (1958) stated that grasses, forbs and shrubs all increased as tree basal area decreased. However, grasses showed the greatest increase in Kg/ha. They averaged 13 Kg/ha under dense Ponderosa pine stands and 1,330 Kg/ha on clear-cut areas. Under similar conditions, forbs increased from 2 to 210 Kg/ha and shrubs from 7 to 117 Kg/ha.

The most important feature of overstory/understory relation is that there is not set response to all conditions (Krueger, 1981). Holland (1973, 1976) working on the San Joaquin Experimental Range (in Madera County, California), noted that herbaceous vegetation production was 40 to 100 percent greater under blue oaks than in open grasslands. Also, in a severe drought year on the Experimental Range considerably more herbage was noted under blue oak canopies than in open areas (Duncan and Reppert, 1960). This was confirmed over a period of seven years, and herbage growth was observed to begin earlier, and plants to stay green longer, underneath blue oaks (Duncan, 1967).

Effects of Overstory on Herbage Nutritive Quality

Various factors such as species of plants, stage of growth, type of soil and rainfall affect the chemical composition of range forage plants. Other factors such as grazing intensity and shade exert some influence on herbage yield and nutritive value but in a rather undefined direction and extent (Vallentine and Young, 1959). Crude protein content of four major southwestern forage grasses was greater under open conditions than under forested (Clary and Larson, 1971). These results contrast with those of Witler (1975), who studied the crude protein content of herbage under longleaf and slash pine and found greater crude protein values under a forest canopy than in the open. McEwen and Dietz (1965), in a study on Kentucky bluegrass and associated species in the Black Hills of South Dakota, found greater crude protein, crude fiber, calcium and phosphorus levels, but a lower nitrogen free extract level, under a forest canopy than in the open.

Changes in quantity and quality of light received by forage plants under a tree canopy influence the annual growth cycle (Krueger, 1981). Shaded plants tend to flower later in the growing season than those in the open. In fact, some shaded plants do not flower at all. Because of this later development, nutritional quality of shaded plants is higher in protein, digestible energy and probably phosphorus. Earlier in the season, plants in the open should be better sources of digestible energy and perhaps phosphorus than shaded plants; probably no differences would exist in protein levels.

Holland and Morton (1980) and Duncan and Clawson (1980), working in central California, reported similar observations as Krueger's. Nevertheless they explained that the higher yield and nutrient content of forage under blue oak is in response to a complex of microhabitat conditions created by the trees. Blue oak trees accumulate nutrients from deep in the soil and redistribute them on the surface largely beneath the canopy, primarily through litter fall. Litter from the trees (as well as the herbaceous plants) falls to the soil surface, is mixed into the mineral soil via animal activity, decomposes and releases nutrients into the soil. This results in a higher level of nutrients (including nitrogen, phosphorus, and potassium), organic matter, and cation exchange capacity in soil under trees compared to open grassland (Holland, 1973).

Because soil nutrients are more readily available under trees, forage nutrient uptake is higher than that of open grassland. Other factors such as greater soil water-holding capacity, moderate soil temperature and more favorable physical soil features under trees also play a significant role (Holland and Morton, 1980).

Effects of Overstory on Animal Distribution

Large herbivores usually show a higher preference for forage established in forest openings than for vegetation growing beneath a dense tree overstory. Elk prefer open ponderosa pine stands with higher herbage yields and lower tree basal area levels than closed ponderosa pine stands (Clary and Larson, 1971). Julander and Jeffery (1964) and Hedrick et al. (1968) noted that cattle use within dense overstory canopies or thick brush areas is usually limited. Obtaining uniform grazing use in these areas is difficult. Hedrick et al. (1968) reported problems achieving even use by cattle on available forage in forested and non forested communities. Animals preferred sites with low density of tree canopy while light or no use occurred on heavily shaded areas. McEwen and Dietz (1965) attributed heavier grazing on meadow vegetation, in comparison to available forage on Black Hills forested sites, to the lower palatability of shaded forage. Shaded plants, as compared to plants in sunlight have a lower percentage of nitrogen-free extract, lower forage production, higher percentage lignin and higher percentage of protein, during a longer period of the year (Vallentine and Young, 1959; Halls and Epps, 1969). Hedrick et al. (1968), found that cattle preferred open areas to the edges of stands of timber. Areas with dense canopies were least preferred.

Many of the problems of livestock distribution can be related to management (Julander, 1955). Knowledge of the community structure and the seasonal values of range types can be used to determine resource management (Pickford and Reid, 1942).

Livestock Utilization of
Oak Trees and Their Products

There is a vast body of literature dealing with the importance of oaks and their role played since early civilizations. In early European culture, oak was considered a symbol of manhood (Alfano, 1980).

Besides their importance in providing timber, cork, recreation, more water than coniferous forests, and suitable wildlife habitats, oaks are an important source of range forage for domestic livestock.

Oaks and livestock affect each other's welfare in many ways. For example the trees may serve as a source of browse, mast, acorns and shade during hot weather, while animals may provide organic matter and distribute it over the oak woodland.

It is difficult to estimate the value of the oak species as browse. Sampson and Jespersen (1963) pointed to the difficulty of identifying the oak species of primary browse importance because grazing animals in different situations vary in their choice of species. Duncan and Clawson (1980) reported that among oak species grown in U.S.A. interior live oak (*Quercus wislizenii*), California scrub oak (*Q. dumosa*) and black oak (*Q. coccinea*) were seen as being the most palatable. Listed as secondary are the Oregon white oak (*Q.*

garryana), canyon live oak (Q. chrysolepsis) and huckleberry oak (Q. vaccinifolia). The food value of coast live oak (Q. agrifolia) and valley white oak (Q. lobata) is probably mainly in the acorns.

An estimated 1 to 2 percent of the forage utilized by domestic livestock year after year was obtained from all browse plants on the San Joaquin Experimental Range (near Fresno, California) (Hutchison and Kotok, 1942). These species provide some green material as a source of protein, phosphorus, and possibly vitamin A during the summer when herbaceous forage is dry (Duncan and Clawson, 1980).

At the University of California Hopland Field Station, studies with sheep and cattle during July, August, and September indicated that more than 5 percent of the field-harvested forage in late summer was fallen leaves and acorns of Quercus species (Van Dyne and Heady, 1965). These materials occurred in 60 percent or more of the animal diets and comprised 4 to 12 percent of the diet by weight. Sheep diets in the late summer frequently contained newly-fallen acorns, and field observations indicated that both cattle and sheep browsed on the low-hanging branches and on fallen twigs and leaves.

Also reporting on work at the Hopland Station, Longhurst et al. (1979) presented findings on the use of oak mast and leaves by the range herbivores, on mast production, and the effect of the grazing animals on oak regeneration. In general, they found deer consumed more acorns and relied more on browse than sheep. In addition Barrett (1978) lists acorn as the most important food item of feral hogs inhabiting oak woodland in the Sierra foothills.

Browsing of young trees by livestock has often been cited as the cause of poor oak regeneration. However, Duncan and Clawson (1980) noted that exclusion of cattle in several instances for a rather long period did not bring about oak regeneration. A considerable increase in digger pine (Pinus sabiana) and buckbrush (Ceanothus cuneatus) was noted in the Natural Area at the San Joaquin Experimental Range, which has been protected from grazing and fire for many years, but no increase in oaks was reported.

In discussing the lack of the blue oak seedlings and young trees in Kern County California, Duncan and Clawson (1980) felt that poor oak reproduction was probably a combination of drought, livestock browsing and rodents, and the inability of young seedlings to compete with introduced annual plants. They suggested that a prolonged drought might be the most significant of the above factors.

Consumption of acorns by domestic animals and wildlife as well as by man greatly reduces the number of acorns that might possibly become trees and ensure oak regeneration (Derby, 1980). Reporting on acorn-feeding trials at the San Joaquin Experimental Range, Wagnon et al (1942) noted that acorn consumption by cattle increased during summer to as much as 17 kilograms per day for one cow. Duncan and Clawson (1980) also discussed the importance of acorns in quail and squirrel diets.

Herbage Production Following Tree Removal and Thinning

Most studies on the effects of logging and partial cuttings describe only the growth response of the trees. Relatively few have investigated the understory vegetation. Yet, the understory response may affect growth of advanced regeneration as well as growth of the overstory trees. The changes in cover and species composition will affect nutrient cycling and water usage by the forest. The changes will also determine the amount of forage available for wildlife and livestock. In addition, understory species can serve as indicators of site growing potential (Witler, 1975).

Most studies on understory response to tree removal or thinning have shown that as crown cover or basal area decreases, the amount of understory increases. In northern California, Johnson et al (1959), and Murphy and Crampton (1964) have demonstrated that herbaceous forage production can be increased at least four-fold by removing the overstory of blue oak. The improved forage yields have been shown to exceed those of adjacent grasslands. The increases are explained as resulting from the improved availability of light, moisture, temperature, and soil nutrients.

Kay and Leonard (1980), working in the north Sierra foothills of California, found that herbaceous forage production beneath blue oak trees increased when the trees were killed. Forage yields were greater in 11 of the 13 years following treatment, averaging 66 percent more if the roots were killed and 45 percent more if only the tops were killed. Yields when trees and roots were killed > tops only removed > naturally occurring grassland > under live trees. However, Holland and Morton (1980) found at both San Joaquin Experimental

Range and at Hastings Reservation (Monterey County), California, that forage production was significantly higher under both living and dead trees compared to open grassland. Highest forage yields extended to the edge of the canopy (6 meters) of living trees and then decreased significantly and abruptly outside the canopy in open grassland. Holland (1980) added that even after a tree has been dead for thirty years or more, little change in species composition occurs. These same results were reported by Murphy and Crampton (1964) who wrote, "There is no clear trend as to whether removal of oak favors desirable forage grasses, soft chess and slender wild oats, nor completely removes the less desirable ripgut and mouse barley".

Bailey's (1966) study in the southern Oregon Coast Range demonstrated that understory response to stand opening depends on the original plant communities. Bailey identified five plant associations in a 190-year-old Pseudosuga menziesii stand and described the differences in understory vegetation in lightspots and under the canopy in each association. In four of the associations, herbaceous and woody vegetation coverage was greater in the lightspots than in the dense forest. In many cases, the lightspot vegetation, some of which was rarely found in the dense stand, was more useful in differentiating between the plant associations than was the vegetation under the canopy. The lightspot trend from mesic to xeric associations was an increase in large, deeply-rooted shrubs and a decrease in small shrubs and herbs. In Bailey's fifth association, however, the vegetation did not show this lightspot response though tree regeneration was better in the lightspots.

Becking (1954), and Spilsbury and Smith (1947) found understory composition in natural stands to be correlated with quality of growing site for <u>Pseudotsuga</u> <u>menzesii</u>. Not all understory species respond to the same site factors as the overstory trees, and some may respond mainly to the presence of the overstory itself. Yet, many species or species groups are associated with particular growing sites. The response of some species or species groups to logging or thinning, then, may roughly indicate what the response of the overstory will be.

Each range and watershed with commercial timber stands is subjected to loss of vegetation and soil disturbance every time timber on the area is harvested. Early results of a Pacific Northwest study showed that first-year reduction in density or cover of understory vegetation as a result of logging varied with the amount of disturbance and depth of root crown or rhizomes possessed by various species (Garrison, 1960). However, by the seventh year after logging, grasses and shrubs approached their original amounts and the less desirable forbs were abundant and disproportionately represented in comparison with their original status. Total understory cover was 11 percent greater than before logging. This kind and degree of range restoration may in some opinions be satisfactory as to grazing values (Garrison, 1960).

Hormay (1940) has made some observations on a tractor-logged Jeffrey and ponderosa pine area in northeastern California. He found that skidding and slash accumulations disturbed more than one-third of the area. Of the range plants present, the desirable grasses seemed to be most readily removed by logging.

Weidman (1936) warned that masses of slash left following logging in the Pacific Northwest reduce available livestock forage for some years and cause concentrations of grazing animals in openings, with resultant overgrazing.

The decision to remove, or thin, or leave trees undisturbed depends on the objectives of the landowner or manager, and the particular combination of ecological and economical aspects (Duncan and Clawson, 1980).

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CHAPTER 2

Description and Administration of the Mamora National Forest of Morocco

Geographical and Administrative Situation

Mamora National Forest is located near Rabat in northwestern Morocco (Appendix A). State ownership forest boundaries were officially defined in 1917. Mamora Forest covers approximately 133,000 ha (Eaux et Forets, 1973). This forest is under the sponsorship of the Forest Districts attached to the Rabat Wilaya (region) and to two other Provinces: Kenitra and Khemisset.

Geology and Topography

The Mamora Forest substratum is composed of Tortonian (Miocene) grey marls and clays. However, in the eastern part of forest and far into the interior this substratum is mainly dominated by Plaisancian and Astian (Pliocene) sand and sandstone (Lepoutre, 1965). The latter appear mostly in the valleys.

During the Quarternary Period, marine advances and recessions caused the formation of dune bars parallel to the Atlantic coast. In the Villafranchian subperiod, and under a subtropical climatic type, a terresterial accumulation termed "Red Mamora sandy clay", occasionally reaching 20 m high, was laid down on these dune bars. Finally, the Villafranchian genesis was supplemented by other "Mamora sand" layers, originally from the off-shore (F.A.O., 1977).

Mamora forest shows a prominent plateau slightly inclined to the northwest with a gentle slope (0.6 to 0.8%). The altitude varies from 300 m (southeastern) to 7 m (northwestern) (Boudy, 1952).

Soils

According to Lepoutre (1965) three distinctive soil types appear in the Mamora Forest:

1. "Sand lying on clay" soil type

This type comprises beige-colored sandy layers of variable depths. They lie either on red sandy horizons or directly on red clay or sandy clay horizons. The nature, relative depths and proximity of the waterproof layers led Lepoutre to the following classification:

a. Subtype 1 - Sandy, beige-colored, slightly deep, and lying on a clay horizon.

b. Subtype 2 - Sandy, beige-colored, deep, and lying on a clay horizon.

c. Subtype 3 - Sandy, red and beige-colored, very deep, and lying on a clay horizon.

The subtype 1 soil is mainly found in the SE of Mamora where erosion has reduced the depth of the sandy horizon. This subtype is particularly moist during the winter.

The subtype 2 soil is mostly located in the northern part of the forest. It occasionally shows a deep sandy horizon reaching more than 7 m thick. This subtype is characterized by an accentuated summer drought which limits vegetation development.

The subtype 3 soil has a thick red-colored sandy layer over clay horizons. The sandy horizons, having a high clay content, possess a high water holding capacity and therefore favor vegetation establishment and growth.

2. "Hydromorphic" soil type

This type occurs throughout Mamora Forest. The soils are poorly drained because an impermeable clay layer (approximately 30 cm from the surface).

The wintry hydromorphic phenomenon related mostly to the topographic conditions (depressions) is characterized by the occurrence of "pseudogley" spots right on the soil profile.

3. "Red Mediterranean" soil type

Two subtypes of red Mediterranean soils are present in the Mamora Forest:

a. Modal red-colored Mediterranean soils: Generally deep, having built up on calcareous sandstone that has not been hidden by other accumulations or that the depositions have been moved away by the erosion process.

b. Red-colored Mediterranean soils: These are fairly deep, lying on consolidated calcareous dunes. Additionally these soils are eroded, arid, and very flinty (Lepoutre, 1965).

Climate

The climate is of the Mediterranean type characterized by mild wet winters and hot, dry and long summers (Bidault and Debrach, 1948; Bidault, 1953; Trewartha, 1954; Emberger, 1955; Sauvage, 1961; UNESCO-F.A.O., 1963; Rossiter, 1966; Flohn, 1969) (Figs. 2-1).

The Mamora forest climatological record is based on data collected from five stations: Rabat and Kenitra along the Atlantic fringe, Tiflet in the southern, Sidi Slimane in the northeastern, and Sidi Kacem in the eastern part of the forest. Mean annual precipitation ranges from roughly 441 mm (Sidi Slimane) to 617 mm (Kenitra) (Table 2-1). More than 90% of this precipitation falls between October and May with an apparent peak in December. However, the seasonal distribution, the date of the first rains, the length of dry period, and the amount of rainfall fluctuate widely. The latter might increase or decrease four times from one year to another and within the same area (Sauvage, 1961). Two severe and continuous dry years have occurred in Morocco (1980 and 1981).

Coastal stations (Rabat and Kenitra) show higher minimum and lower maximum temperatures than interior stations. Mean annual minimum temperatures are 12.8^{o}C. in Kenitra and 10.7^{o}C. in Sidi Slimane; while the mean annual maximum temperatures are 22.3^{o}C. in Kenitra and 27.3^{o}C. in Sidi Slimane.

Winds, originating from the ocean, are directed from the NW during the summer and from the SW during the winter. The Sirocco

Table 2-1.

Long Term Climatological Data of Five Weather Stations
Surrounding Mamora National Forest (F.A.O. 1977)

a. Mean monthly precipitation (mm)

Station	Period	Total Number of Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Totals (mm)
Rabat-Sale	1948-71	24	88.7	72.3	65.8	61.7	19.5	8.4	0.6	1.0	8.1	36.0	96.2	103.9	562.2
Kenitra	1951-76	26	87.1	82.0	72.3	54.1	27.8	5.5	0.2	1.0	9.4	52.9	100.6	123.9	616.9
Tiflet	1946-70	24	82.2	63.3	70.8	43.3	27.6	5.0	1.6	0.7	7.0	32.9	67.8	97.0	499.6
Sidi Slimane	1935-55														
	1961-70	25	72.8	52.0	51.2	45.2	21.5	7.4	0.1	1.4	7.8	41.4	60.2	80.4	441.3
Sidi Kacem	1945-70	26	76.3	60.8	61.0	44.1	23.7	7.9	0.3	1.3	9.9	33.6	93.5	83.8	496.2

b. Mean monthly minima and maxima temperatures (^{o}C)

Station	Period	Total Number of Years	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Mean (^{o}C)
Rabat-Sale	1948-71	24	8.2	8.4	9.8	10.6	13.1	15.6	17.5	17.7	16.5	14.2	11.3	8.8	12.6
			17.1	18.0	19.7	20.5	22.9	24.7	26.8	27.3	26.2	24.2	20.6	17.5	22.1
Kenitra	1951-76	26	7.6	8.2	9.7	11.0	13.8	16.5	8.5	18.7	16.0	13.7	10.6	8.0	12.8
			17.1	18.4	19.5	20.6	23.2	25.1	27.3	27.5	26.2	24.8	20.8	17.7	22.3
Tiflet	1946-70	24	5.7	6.1	7.4	8.4	10.9	13.8	15.8	15.2	14.3	12.0	9.6	6.5	10.3
			16.9	18.2	21.0	22.1	26.8	30.9	35.5	34.8	32.0	27.4	22.0	17.9	25.7
Sidi Slimane	1937-61	25	4.5	5.1	6.8	8.8	11.1	14.5	16.8	17.2	15.7	12.1	8.5	5.5	10.7
			18.6	19.9	23.0	25.2	28.4	32.8	36.5	36.4	33.3	28.4	23.2	19.5	27.3
Sidi Kacem	1958-70	26	7.8	8.2	9.9	10.7	13.8	16.2	17.7	18.4	17.1	14.0	10.7	8.5	12.8
			10.8	19.9	22.2	24.3	29.5	32.6	37.0	37.1	33.8	28.3	22.4	18.6	27.0

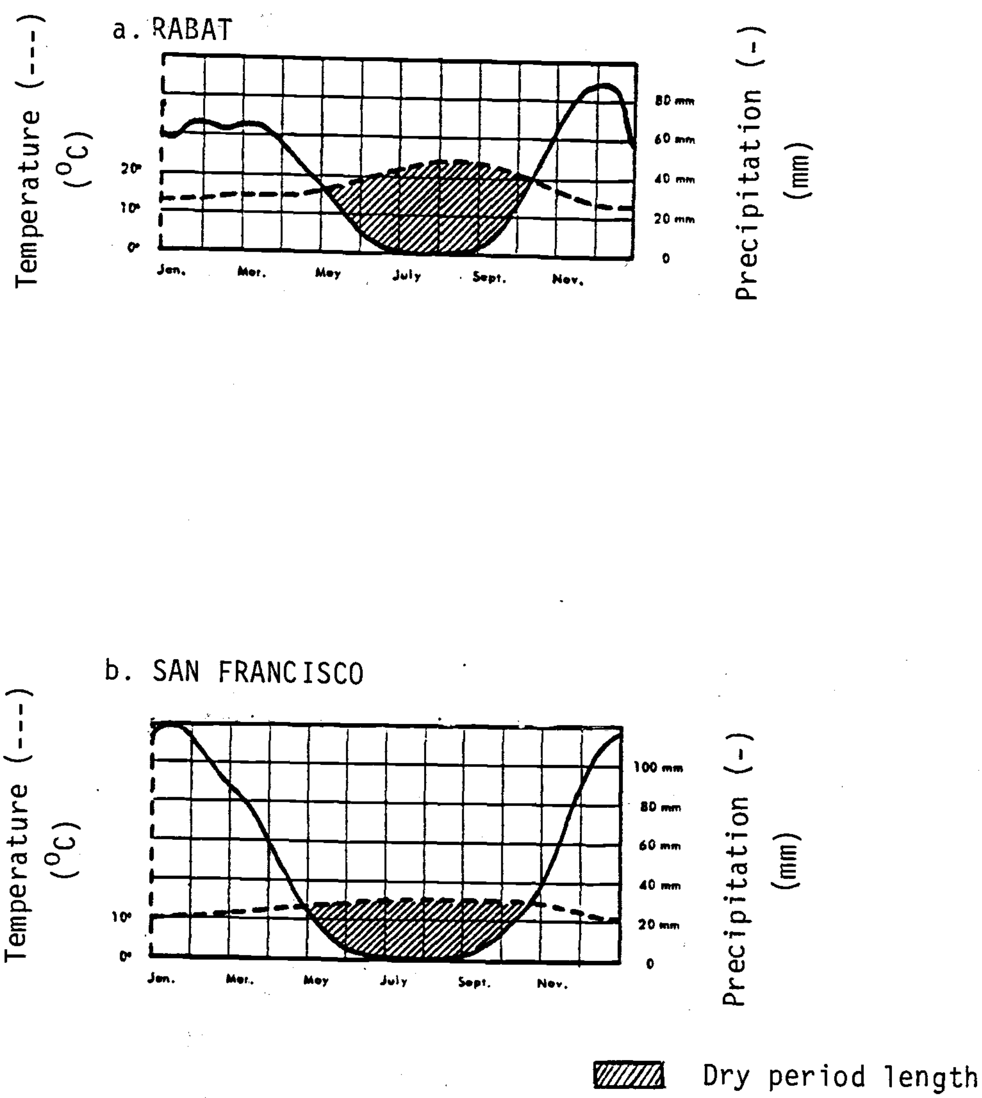


Figure 2-1. Comparison of annual precipitation and temperatures of Rabat (a) and San Francisco (b) (Emberger, 1955).

(hot winds), coming from the eastern part of the country, are exceptional. Under this type of wind, temperatures may occasionally reach $50^{0}C$. while relative humidity may decrease to 10%.

In general, relative humidity remains high throughout the year. In the western part of the forest, mean humidity values of 85% during the winter and 75% during the summer have been recorded. Additionally, fogs originating from the Atlantic ocean may contribute up to 50 mm of precipitation annually, and may reach as far as 80 km inland (Debrach, 1948).

Emberger (1955) classified the coastal fringe forest as subhumid. It is characterized by temperate winters (Kenitra) or warm winters (Rabat). He further classified the forest interior as semi-arid with temperate winters (Tiflet, Sidi Slimane, and Sidi Kacem) (Fig. 2-2).

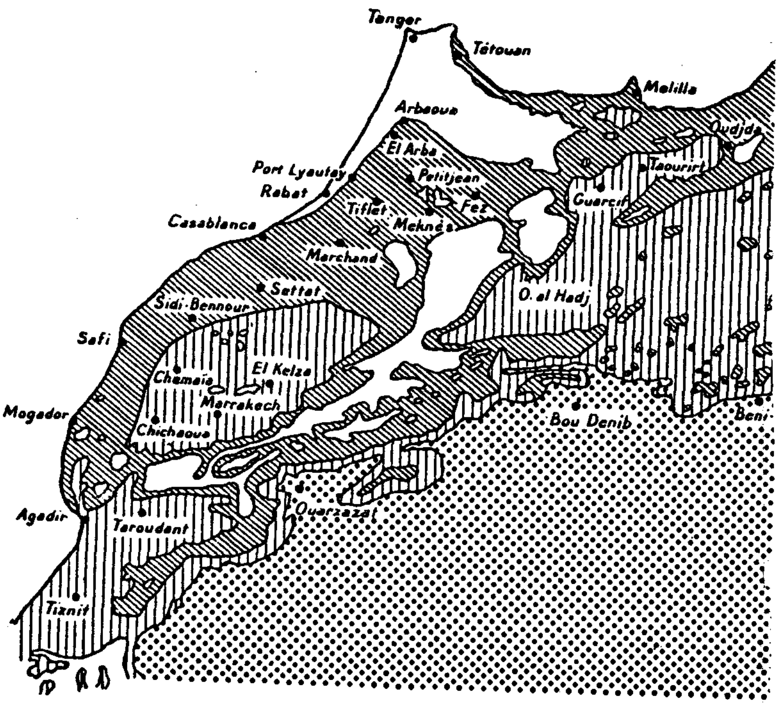
Light and Solar Radiation

Solar radiation intensity is high during every season. However, the maximum solar radiation occurs from March to May (Table 2-2).

The proportion of the day during which the sun shines (F value of insolation) shows two different cycles:

- From October to April, F is around 60%. Mornings are clear and maximum radiation occurs between 9 am and 11 am.

- From May to September, F is more than 75% between 8 am and 5 pm. It may reach 90% during July and August (Debrach, 1938).



Saharian Mediterranean stage

Arid Mediterranean stage

Semi-arid Mediterranean stage

Humid and subhumid Mediterranean stages

Figure 2-2. Geographical distribution of bioclimatical vegetational stages of Morocco (Emberger, 1955).

Table 2-2

Solar Radiation for Three Weather Stations in Morocco (Debrach, 1938)

Station	Altitude -m-	Latitude (degrees)	Solar Radiation (Gram. Cal./ cm^2/min.)
Casablanca - Rabat	40	33^{o} 36'	1.56 ly
Ifrane (Middle Atlas)	1,650	33^{o} 31'	1.69 ly
Toubkal (High Atlas)	3,600	31^{o} 03'	1.66 ly

Vegetation

Three major plant associations dominate the Mamora Forest ecosystem:

1. Quercus suber association. Considered the most important association in Mamora Forest. It thrives well on more or less deep sandy soils in the absence of limestone substratum. The tree layer is composed almost exclusively of cork oak (Quercus suber L.). There are few exceptions where this species is associated with Mamora pear (Pirus mamorensis Trabut var. eu-mamorensis Maire) trees. The understory is principally composed of a legume shrub, Genista linifolia L. var. angustifolia Webb, in the western part of the forest and Halimium halimifolium Willk. ssp. lepidotum Maire var. planifolium Maire. in the eastern part. Both species occasionally form dense stands similar in appearance to California chapparal. In some sites where the shrub overstory cover begins to decrease, other species such as Cistus salviifolius L., Lavandula stoechas L. ssp. Linneana Roz. and Cytisus arboreus DC. ssp. eu-arboreus Maire var. transiens Sauv. et Vindt dominate. In some other situations annual herbaceous take over. These occur either alone or in association with other therophytes such as Urginea maritima Baker, Asphodelus microcarpus Salzm. et Viv. and Asphodelus aestivus Brot. var. gracilis Maire (Sauvage, 1961).

According to Sauvage (1961) and Lepoutre (1965) depths of the clay and sandy horizons have a direct effect on tree density and distribution of various vegetaton associations. When the clay layer is close to the upper soil surface an accumulation of water favors the growth of Thymelea lythroides Barr. et Murb. association and retards the regeneration of cork oak. Further, when the sandy horizon is greater than 2 m the cork oak overstory becomes sparse and is replaced by another association of Ormenis mixta Dumort. ssp. multicaulis Maire, Corynephorus articulatus P. Beauv. ssp. fasciculatus Husnot, Loephlingia hispanica L. ssp. baetica Maire, Anthyllis hamosa Desf., and Halimium libanotis Lange.

2. Juniperus phoenicea L. association. This is located exclusively along the coast. It appears to be the most dominant association on calcareous dunes. However, on mobile sand, this species appears to be associated with another shrub (Retama monosperma Boiss. ssp. eu-monosperma Maire var. Webbii Maire).

3. Oleo-lentiscus association. In the extreme eastern part of the Mamora forest, cork oak gives up one's seat to Oleo-lentiscus association. This latter comprises: Olea europaea L. var. silvestris Brot, Pistacia lentiscus L., Phillyrea angustifolia L., Genista linifolia L., Lavandula stoechas L. ssp. Linneana Roz., Cytisus arboreus DC. ssp. eu-arboreus Maire var. transiens Sauv. et Vindt, Cistus salviifolius L., and Chamaerops humilis L.

Society

Historical Development

After the French Protectorate treaty was approved (1912) more than 80% of the Mamora Forest land area was incorporated to the pastoral zones of the Berberian Zemmour's tribe. The rest of the forest land was assigned to three Arab tribes: Sehouls and Ouled Sbita tribes using the southwestern portion of the territory while Beni Ahsen occupied the northwestern forest fringes (Lesne, 1959).

Economics of the Zemmour's tribe was based essentially on livestock production under a semi-nomadism system: nine months grazing in the forest and the rest of the year (summer) on the aftermath of cereal crops. A similar life mode was followed by the Arab tribes except that some of the individuals were involved in extra agricultural activities such as cereal cropping, honey-bee production, etc.

In 1917 an official administrative forest delimitation was pronounced. This latter operation allowed the two main tribes, Zemmour's and Beni Ahsen's, to share the use of the forest. The Beni Ahsens picked the northern portion of the forest (upper part of the central fire-break trench) while the Zemmours took the southern portion (Appendix A). At this time, the central portion of the forest land was still very dense but the forest edges, especially in the western side, started to be cleared (Boudy, 1958). This situation was due to overuse damage such as barking, fire, and clearings.

Forest Conditions After Settlement

Between 1917 and 1921 several judicial rules were established in order to organize the use of the Mamora Forest lands. Grazing fees paid for forest use were established in 1930. These fees accomplished two major objectives: (1) Allowed the use of forest grazing lands only to people belonging to the community, (2) favored the control of the stocking rate over the forest.

In 1950, the grazing capacity of the forest was estimated, and the stocking rate was fixed at 0.4 AU/ha (Eaux et Forets, 1973). Additionally, the Forest Service requested the complete elimination of goats because of alleged damage caused by these animals. However, this restriction did not help much since the forest users replaced goats with sheep and cattle. In 1958, the local Forest Service felt the actual stocking rate by far exceeded the legal one and that overgrazing had become more and more apparent. The Forest Service believed that this abuse resulted from profiteers, residents essentially, who ignored the well being of the forest and put all their resources into increasing their herd sizes. Therefore the local users, seeking more and more prestige within their community, were encouraged to increase their individual herd size. Indeed, in 1972, a range survey conducted by the Danish mission (Eaux et Forets, 1972) revealed a total of 75,000 cattle and 160,000 sheep over 133,000 ha. This was equivalent to 107,000 AU or 0.8 AU/ha; twice the legal carrying capacity. Additionally, the animal distribution over the territory was unequal. The stocking rate, in some areas close to Rabat and to some other cities, was estimated at 2 AU/ha (Ibnattya et al., 1972). However, the stocking rate increase followed the same trend as the human population increase. In fact, in 10 years (1960-1971), this population increased from 165,000 to 230,000; an annual growth rate of 3.07% (F.A.O., 1977).

Past Mamora National Forest Management Plans

Several management plans were developed in Mamora since 1951. However, most of these projects were aimed toward financial profit from wood products and ignored the social-economical standpoint of livestock owners. A review of these plans reveals that the undesirable grazing situation and the poor range condition probably resulted from the conversion of grazing lands to exotic forest plantations. Such plantations have a low grazing potential because of limited forage production. Consequently, grazing intensity on the remaining forested rangeland increased to undesirable levels. Vidal (Eaux et Forets, 1951) implemented a management plan aimed at increasing plantations of Eucalyptus, Pinus and Acacias species. These plantations were excluded from grazing use during a certain number of years depending on the rate of growth of each species. Further, when highly dense plantations are advanced in growth the grazing value appears too low.

A general figure of the total area planted in Mamora Forest during Vidal's plan (1954-1972) is shown in Table 2-3.

Additionally, grazing in some cork oak areas is prohibited in order to prevent damage to young sprouts and seedlings. Therefore, a total of 50% of the forest is not usable by livestock (Eaux et Forets, 1973).

Table 2-3

Area Planted by Exotic Species (1954-1972)
(Eaux et Forets, 1973)

Year	Total Area Planted (ha)	% of the Total Forest Area
1954	9,000	07
1961	30,000	22
1972	44,000	33

The revised forest management plan (1973-1992), currently being applied, aims to convert more than 30,000 hectares of cork oak lands into introduced species. Thus, by 1992 the total forest grazing land would be reduced to 50,000 ha, i.e. 38% of the total forest area. The reason for the conversion was essentially based on financial gain from wood products. All cork oak lands having a low timber density (less than 100 stumps/ha and/or a basal perimeter less than 80 or 40 linear meters, depending on the site) are proposed for conversion to exotic species. The threshold considered in this substitution seems to have been arbitrarily picked regardless of the grazing management and forage production goals.

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CHAPTER 3

Seasonal Understory Herbage Production and Nutritive Quality as Related to Tree Canopy Cover and Site Characteristics in a Portion of the Mature Mamora Cork Oak (*Quercus suber* L.) National Forest of Morocco[1]

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[1]This study was funded by the U.S.A.I.D. under the convention between the International Agricultural Programs of the University of Minnesota and the Institut Agronomique et Veterinaire Hassan II of Morocco.

Seasonal Understory Herbage Production and Nutritive Quality as Related to Tree Canopy Cover and Site Characteristics in a Portion of the Mature Mamora Cork Oak (*Quercus suber* L.) National Forest of Morocco

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Abstract

Understory herbage production and nutritive quality, in relation to cork oak (*Quercus suber* L.) crown cover, were seasonally evaluated over two years on two distinctive sites of the Mamora Forest of Morocco. Sites differed in the dominance (81% cover) of a legume-shrub (*Genista linifolia* L.) in one (G) and a near absence (4% cover) of this layer in the other (NG). Five oak canopy cover classes (75-100%, 50-75%, 25-50%, 0-25%, openings) and three vegetation phenological phases (juvenile, vegetative, reproductive) were studied.

Herbage yields varied ($P < .10$) among tree canopy cover classes, times during the growing season, between sites and between years. Herbage production tended to be similar from 25% to the most dense canopy cover, then declined as cover declined. A similar trend was found on G when sites were analyzed separately. However, on the non shrubby site herbage yields tended to be similar under all canopy cover classes. Herbage yields were two-fold higher on the shrubby as compared to non-shrubby site. These different responses appeared due to the higher moisture and nutrient status of the shrubby site.

Seasonal phenological phases also affected ($P < .01$) herbage production. Similar trends were found whether considering the shrubby and non-shrubby site together or separately. The Season x Site was highly significant ($P < .01$). Herbage yields were much higher on the shrubby site than on the non shrubby, especially at the vegetative phase. The Seasons x oak Canopy Cover treatment interaction was not evident for two year average yields. But a meaningful ($P < .05$) interaction occurred on the shrubby site. In this latter case, as tree cover declined to 50%, herbage production increased in a curvilinear fashion as the season advanced.

Yields also varied ($P < .05$) between the two years of the experiment. Herbage production in 1983 was much higher than in 1982. Weather patterns between the two years and within the years appeared to be the most influencing factors.

Most components of the herbage nutritive quality varied significantly ($P < .01$) among oak canopy cover classes, between sites and between seasons. Herbage produced under tree canopies contained more crude protein, fat, and water but less crude fiber than herbage under open conditions. The presence or absence of canopy had no apparent effects upon the ash or the N.F.E. content though these components were approximately 14 percent greater on the open stands.

Sites had a highly significant ($P < .01$) effect on the amount of most herbage nutrients sampled. Crude protein, fat, ash, and water were higher on the shrubby than the non-shrubby site; while crude fiber and N.F.E. showed the opposite relationship. In both sites, however, crude protein, ash, fat and moisture declined as season advanced, whereas crude fiber and N.F.E. increased. A Season x Site interaction was evident for all herbage nutrients, except for crude fiber. However, crude fiber was approximately 10 percent greater on the shrubby than on the non shrubby site.

The results of this study suggest that although oak canopy cover or tree density does strongly influence understory herbage production and nutritive quality, site characteristics such as intermediate shrub layers also are major determinants, especially in annual rangeland types.

Introduction

Understory herbage production is directly affected by kind and amount of overstory. Several studies (Cassady, 1951; Cassady and Campbell, 1951; Read, 1951; Hopkins, 1952; Pase, 1958; Halls and Schuster, 1965; Jameson, 1967) have shown that as crown closure increases, forage production decreases. Other studies (McCreary, 1927; Vallentine and Young, 1959) reported that shading maintains a higher level of protein, fat and ash in the plants while Campbell et al. (1954) were unable to find any significant differences between the nutrient content of grass grown on open and that on canopied stands.

Because of competition for light, water, nutrients, and possibly antagonistic chemical effects, a negative relationship between overstory and understory in terms of herbage production and chemical quality may occur. However, Krueger (1981) pointed out that the most important feature of overstory-understory relationships is that there is no set response to all conditions. Further, by defining the plant community type, management responses should become more predictable.

In the Mamora cork oak (*Quercus suber* L.) National Forest of Morocco, several management plans have been applied since 1951. A review of these plans reveals that the currently apparent undesirable grazing situation and poor forage condition probably resulted from the conversion of grazing lands to exotic forest plantations (*Eucalyptus*, *Pinus*, and *Acacia* species). Such plantations have a low grazing potential because of scant forage production. All cork oak stands with a low tree density (less than 100 stumps/ha and/or a basal perimeter of less than 80 or 40 linear meters, depending on the site) are proposed for conversion to exotic species. The threshold considered in this criteria appears to be arbitrarily selected regardless of the grazing management and forage production. Research to integrate forest management and grazing use is desirable. Krueger (1983) noted that demands for both food and fiber increase and hence land uses for multiple use productivity need to be coordinated. Sharrow and Leininger (1983) added that forest and grazing must go hand in hand and that grazing may be successfully employed as a silvicultural tool for forest well-being.

The objective of this study was to determine the seasonal herbage production and nutritive quality of understory vegetation as related to cork oak tree canopy cover and site characteristics in a portion of the mature Mamora National Forest of Morocco.

Study Area

The study was conducted during 1982 and 1983 on two different sites located in the central southwestern part of the Mamora Forest. They are roughly 2 km apart, approximately 20 km east of Rabat (Appendix B). The sites differ ecologically in vegetation structure: one was dominated (81% cover) by a legume-shrub layer (*Genista linifolia* L.) while on the other the shrub layer was nearly absent (4% cover) (Appendix C).

The experimental area was selected because: (1) It is located in the middle part of the most representative portion of the forest community and close to the oak forest sections most likely to be converted into exotic species, (2) according to the Danish forest stratification diagrams (Eaux et Forets, 1973) all the tree density classes needed for this study were present in these two sites (Appendix D).

Both sites are a part of a mature cork oak stand. The topography is gently rolling with a westerly exposure. Elevation is approximately 40 m. Average annual precipitation is 475 mm, most of which falls between November and April. The mean annual maximum and minimum temperatures are 22°C. and 12°C., respectively. The hottest month of the year is August with a mean temperature of 27°C. and the coldest is January with a mean temperature of 6°C (Appendix E). Upland sites with sandy soils predominate. Surface soils are mostly loose sands, low in organic matter content with inherent low fertility. Subsoils range from very friable to very dense clays or sandy clays, derived chiefly from unconsolidated beds of non-calcareous clays and sands of the Plaisancian and Astian (Pliocene) era (Lepoutre, 1965). These subsoils are somewhat massive when wet but become hard and brittle upon drying. However, the nutrients leach easily and this affects herbage growth and development.

Cork oak and a few individual trees of Mamora pear (Pirus mamorensis Trabut) dominate the tree overstory of the mature community. Principal shrub understory species are Genista linifolia L., Lavandula stoechas L., and Thymelaea lythroides Barr. et Murb. The herbaceous layer consists largely of mixed annual grasses and forbs such as sweet vernal grass (Anthoxanthum odoratum Trabut), soft chess (Bromus mollis L.), pearl grass (Briza maxima L.), spotted rockcist (Helianthemum guttatum L.) and buck's horn (Plantago coronopus Pilger).

The area was under heavy continuous grazing use over 9 months (October through June) of the year since 1912. During the remainder of the year the main users, Oulad Malik and Foui commons, move their livestock, essentially composed of cattle (63%) and sheep (37%) of local breeds onto crop aftermath (Hudowicz, 1970). The two commons share and cultivate about 90 State-owned hectares, located mostly on forest edges.

Oulad Malik and Foui commons, composed of 660 inhabitants with an annual population growth rate of 3.3%, live under a traditional life mode. They lodge under huts adjoined to a variable-sized paddock. The F.A.O. (1977) estimates 90% of the population to be between 15 and 60 years of age. Besides livestock activity, the two commons complement their modest incomes by practicing other extra activities such as cropping, honey-bee production, temporary forest jobs, gathering (acorns, mushrooms, truffles, flowers, etc....) and hunting.

Materials and Methods

Two 100 x 500 m exclosures were built, in January 1982, and two appended ones, in 1983, to protect the experimental plots (NG = Non-Genista plot; G = Genista plot) from grazing animals.

Each individual plot was divided into 42 subplots, of 1,200 m^2 (100 x 12 m) each, and number of standing oak tree stumps per subplot (or density) was recorded. Ten subplots, corresponding to five different tree density classes with two replications, were selected as follows:

Classes	Density (Stumps/ha)
DI	More than 300
DII	200-300
DIII	100-200
DIV	0-100
DV	Openings

A second stratification assessing oak tree canopy cover (CC) of each D subplot was also undertaken. In Temara cork oak forest, Benessalah (1978) found a high correlation (r^2 = .78) between the two tree attributes. Two separate techniques - vertical crown projection and the spherical Model A-densiometer (Lemmon, 1965) - were tested for crown measurements. Both techniques led to a very strong (r^2 = .89 and .92, respectively) correlation between CC and D (Appendix F).

In the study, the five canopy cover classes considered were:

Canopy Cover Classes	% Crown Cover
CCI	75-100
CCII	50-75
CCIII	25-50
CCIV	0-25
CV	Openings

Because high variations in weather patterns have occurred during the past few years, no calendar sampling dates were predetermined. Herbage production data were collected three times per year, coinciding with the most apparent vegetation phenological phases (juvenile, vegetative, and reproductive). Yet, these three phases occurred, respectively, around the end of February-beginning March, end April-beginning May, and mid-June.

Direct clipping (Pieper, 1978), at ground level and through the use of randomly located transects, was used to determine the standing crop within each subplot. Areas previously clipped were avoided.

The number of samples considered as well as the size and shape of quadrats varied from one plot to the other. Preliminary trials for determining the optimum number of sampling units as well as the most efficient quadrat size and shape were undertaken in each individual plot. Using the standing crop-area curve approach (plotting) (Hopkins, 1955) 40 and 20 samples per subplot and of unequal sizes were found sufficient in sampling G and NG plots, respectively. In the NG plot, a circular 1 m^2 quadrat appeared to be the most efficient in sampling vegetation of this particular site. This 1m^2 quadrat not only has the advantage of ease of conversion from grams/m^2 to kg/ha but also exhibits a lower boundary error than any other shape. The G plot, being characterized by a high dominant shrub, limited the ease of access and manipulation. Thus, a 3 sided rectangular (.40 x .60 m) quadrat was well suited in sampling herbaceous vegetation. Pieper (1978) reported that it is generally conceded that rectangular quadrats are more efficient than circular or square quadrats in areas of sparse or scattered vegetation.

The herbaceous vegetation, taken as a single sample late in the morning of clear sky days was clipped at ground level, weighed, stored in bags and then put, within the same day, in a forced air oven to be dried, at 105^{o} C. Three subsamples of mixed vegetation, originating from each subplot, were sent to EL Koudia Animal Research Station Temara, Morocco for chemical analysis purposes. Water, fat, crude fiber, crude protein, ash and nitrogen-free extract contents were determined using AOAC (1970) official methods of analysis. Also, from 3 randomly selected sample points, originating from each subplot, soil samples were collected from depths of 0-10, 10-20, and 20-25 cm. They were sent to the National Forest Research Station for determinations of moisture, organic matter, N, P, K, C:N, exchangeable Ca, Mg and Na, and pH. Soil chemical evaluations were done according to the usual European soil analysis procedures.

Herbage production and nutritive quality data were evaluated using analysis of variance techniques. Data were analyzed as a split, split, split plot design with sites (presence or absence of Genista linifolia L. shrub) as main plots and years, seasons, and oak canopy cover as sub-plots in a completely randomized design. Where appropriate, means were separated with Tukey's w-procedure (Steel and Torrie, 1980). Significant treatment effects were partitioned into orthogonal polynomial components and response surfaces were fitted by least squares regression procedures (Neter and Wasserman, 1974). Understory nutritive quality data, however, concerned only 1983 results and a partial analysis of 1982.

Results and Discussion

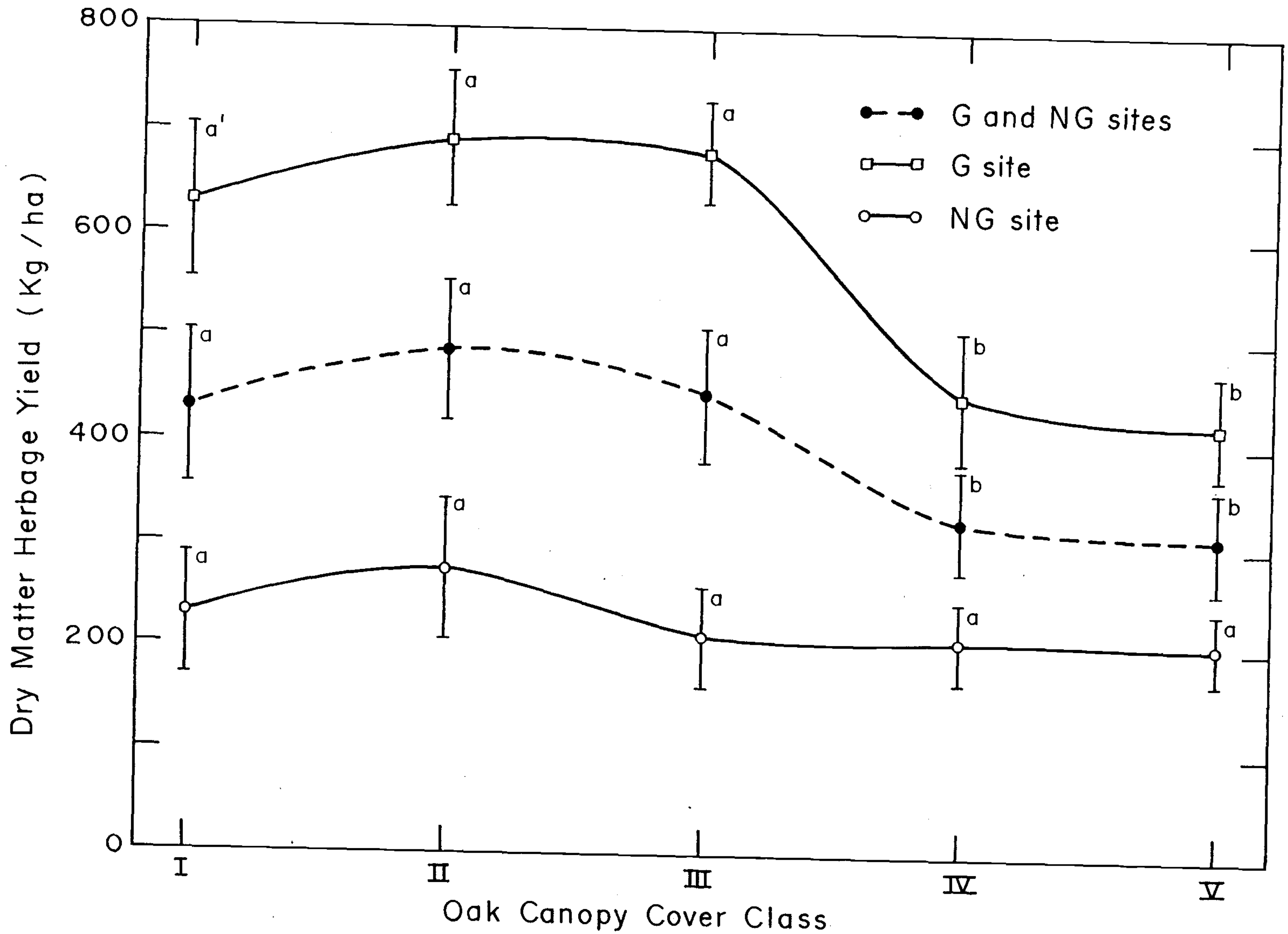
Understory Herbage Production

Average dry matter herbage yields (DMHYs) varied ($P < .05$) among oak canopy cover classes (CC) (Appendix G). Over all CC treatments, on both sites (G and NG) and over two years (1982, 1983), averaged DMHYs were: 431, 487, 446, 325 and 313 kg/ha for cover classes I, II, III, IV and V, respectively. Results depicted in Figure 3-1 show that the most rapid and significant ($P < .10$) shift occurred with 25% canopy cover or less. Also, these results suggest that herbage production tended to be similar from 25% to the most dense canopy cover, then declined as cover declined.

Herbage yields from the shrubby site (G) exceeded ($P < .05$) those from the non-shrubby (NG) for every canopy class (Fig. 3-1). In G site, averaged DMHYs were 630, 689, 681, 443 and 420 Kg/ha for CCI to CCV, respectively. On this particular site trends in DMHYs, under CC treatments, appeared to be analogous to those having occurred when both sites were considered all together. However, on NG site and over all canopy treatments DMHYs were two-fold lower than on G and averaged 231, 274, 211, 207 and 206 kg/ha for CCI through CCV, respectively. In addition, the trend observed herein showed that under all canopy cover classes herbage production tended to be similar.

Yields could have been different for a number of possible reasons. Biswell (1956) reported that much of the variability in annual

Figure 3-1. Effects of oak canopy cover on dry matter herbage yields for both and individual sites (G, NG). 1982, 1983.



'Means in each curve followed by different letters differ (P < 0.10)

Figure 3-1

grasslands is related to differences in soils. He added that soil series are numerous in annual rangeland types and a dozen or more may appear in two and a half square kilometers. This may be true in Mamora Forest where a high variability in herbage yields was noted even within the 1,200 m^2 subplots. Intrinsic and extrinsic factors inherent to the shrubby and non-shrubby sites suggest some possibilities. Though the soil physical characteristics were similar in both sites, soil chemical properties varied from one site to the other (Appendix H). The G site was dominated by a legume-shrub species (*Genista linifolia* L.), reaching up to 3 m height in the middle of the growing season and becoming somewhat spiny. This shrub favored the understory vegetation growth and development in five ways: (1) Being a legume, this shrub is capable of fixing atmospheric nitrogen into the soil, through the symbiotic process, and hence enhances soil fertility. (2) Litter accumulation from the shrub shattering leaves improves soil structure by increasing the soil organic matter content; this allows a higher soil water holding capacity. (3) Effective soil moisture also exerts a very positive control upon the accumulation of organic matter and nitrogen in soil. Ordinarily, under comparable conditions, the nitrogen and organic matter increase as the effective moisture becomes greater (Brady, 1974). (4) The extra shading provided by shrub overstory reduces the ground temperature and hence lowers the rate of organic matter decomposition and favors soil microorganisms development. (5) Damages on species composition and herbage production, caused by previous grazing uses, were less discernable on G than on NG site. This was due to the tangling shrub lowering accessibility of G site.

Additionally, most of the exchangeable bases (K, Ca, and Mg) as well as the pH were higher in the shrubby soils than in the non-shrubby. This accounts in part for a weak nitrification in NG acid soils and the sensitiveness of the organisms to a low pH. Also a low pH in the NG topsoils favors phosphate fixation and its unavailability for plant growth (Brady, 1974).

Phenological phases or seasons (S) also affected ($P < .01$) herbage production. Two-year average DMHYs over the three distinctive phases (juvenile, vegetative, and reproductive) were 229,585 and 381 kg/ha, respectively. A similar trend appeared when each site was separately considered (Table 3-1).

The Season x Site interaction was highly significant ($P < .01$) and herbage production was found much higher on G than on NG site, especially at the vegetative stage. At this particular phenological phase, favorable moisture and temperatures coupled with the apparent potential superiority of G over NG site not only stimulate a rapid growth and development of annual species therein, but also allows more abundant perennials. In addition, and because of the G richness superiority, the drying of the winter annuals marking the beginning of the reproductive phase appeared to be initiated later on G than on NG site. Beyond the vegetative phase, losses in herbage weights were more rapid on G than on the NG site. This probably reflected the differences in species composition between the two sites. Rattliff

Table 3-1.

Averaged Dry Matter Herbage Yields Under Three Phenological Phases on the Two Sites (G and NG) 1982 and 1983 Data are mean ± standard error.

	Dry Matter Herbage Yield -kg/ha-	
Phenological Phases	Shrubby site(G)	Non-shrubby site (NG)
Juvenile	326.7 ± 29.4 a[1]	131.1 ± 19.2a
Vegetative	877.5 ± 53.7b	292.0 ± 34.6b
Reproductive	514.5 ± 37.9c	248.1 ± 27.8b

[1]Means in each column followed by different letters differ ($P < .10$).

and Heady (1962) noted that the seasonal loss in herbage production, for an annual grassland, will depend mainly upon its species composition; some species start their most rapid growth earlier than others, and some deteriorated earlier than others.

The Season x oak Canopy Cover treatment interaction was not significant ($P < .10$) for two year average DMHYs. This reflected a lack of S x CC interaction on NG site ($P < .10$) due, probably, to the impacts of the past grazing abuse and possibly other factors resulting in less equilibrium on NG than on G environment. A significant ($P < .05$) interaction did occur on G site, however.

The response surface model for the shrubby site over the two years (Fig. 3-2) has up to quadratic terms for both CC and S treatments and their linear interaction term. The lowest and highest points of this surface correspond with treatments Openings-Juvenile (low) and 50% Canopy Cover-Vegetative (high), respectively. Herbage production, up to CCII, i.e. a canopy cover class between 50 and 75%, increased in a curvilinear fashion as S advanced to the vegetative stage but started declining beyond that phase.

A linear component of CC, plus a quadratic element of S were independent variables in the nonshrubby model. The response surface, therefore, consisted of parallel straight lines for CC and power curves for S treatments (Fig. 3-3). The two tails of the S curve indicate rapid responses of herbage to initiating growth, over the juvenile stage, and maturity, over the reproductive phase. The middle portion of the S curve reflects the time lapse where

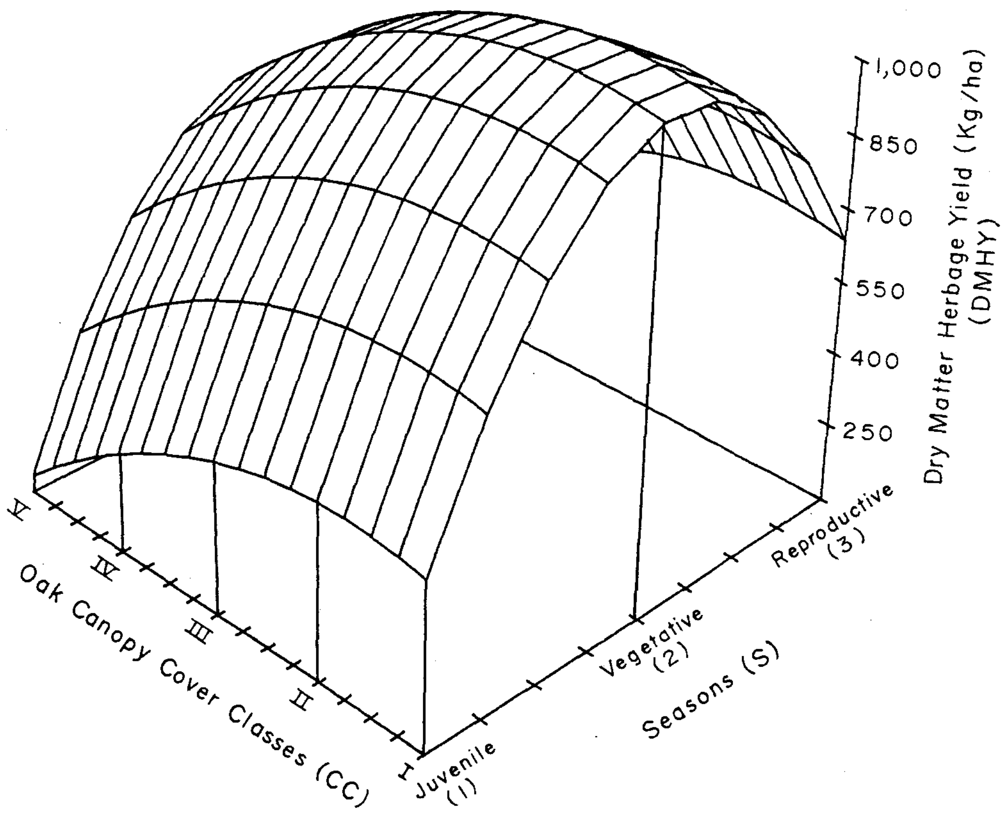


Figure 3-2. Effects of oak canopy cover classes and plant phenology on shrubby site herbage yields. 1982,1983.

$$DMHY\ (r^2 = .47) = -1115 + 1911\ (S) + 96\ (CC) - 457\ (S)^2 - 28\ (CC)^2 + 3\ (S)\ (CC)$$

S = 1, 2, 3 for juvenile, vegetative and reproductive phases, respectively.

CC = 1, 2, 3, 4, 5 for cover classes I, II, III, IV, and V, respectively.

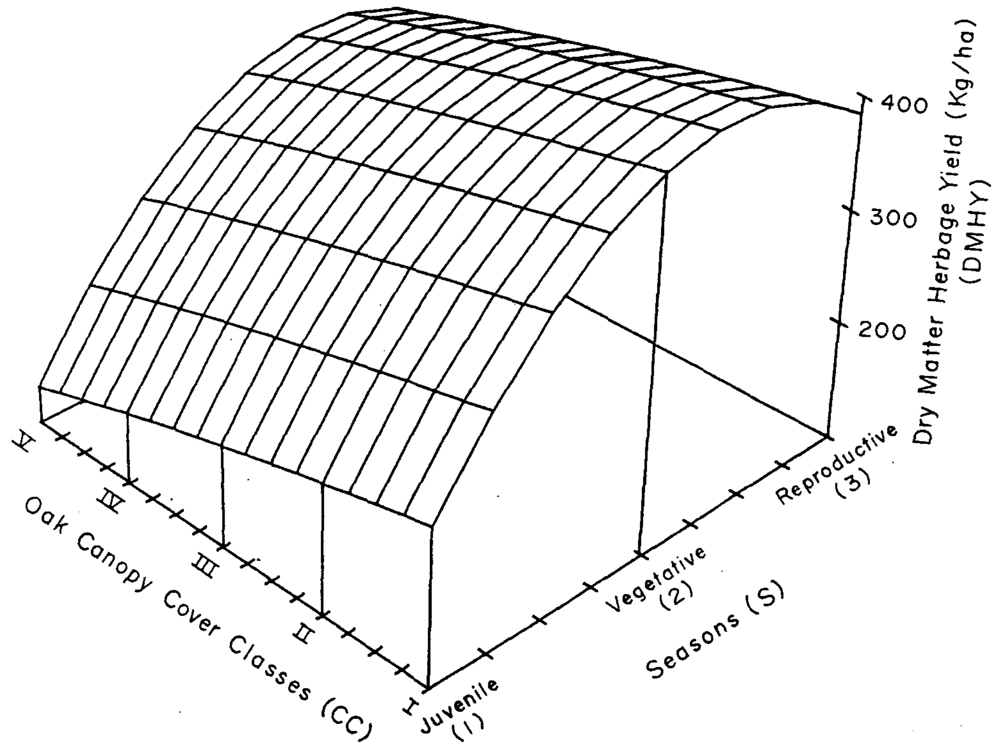


Figure 3-3. Effects of oak canopy cover classes and plant phenology on non-shrubby site herbage yields. 1982, 1983.

$$DMHY\ (r^2 = .56) = -129 + 479\ (S) - 19\ (CC) - 103\ (S)^2$$

S = 1, 2, 3, for juvenile, vegetative and reproductive phases, respectively.

CC = 1, 2, 3, 4, 5 for cover classes I, II, III, IV, and V, respectively.

vegetation reached its peak weight and stayed reasonably constant. This model type is very peculiar to annual rangelands as reported by Rattliff and Heady (1962).

Dry matter herbage yields also varied ($P < .05$) between the two years. They averaged, over all canopy cover classes for the three phenological phases and both sites, 299 and 498 kg/ha for 1982 and 1983, respectively.

Yield could have been different, from one year to another, for a number of possible reasons: (1) Differences in total annual precipitation varied by as much as 120 to 140 mm, depending upon the site. These differences had, probably, an effect on the total annual biomass. (2) Within the same year, weather patterns seemed to govern the seasonal herbage production. In 1982 the "opening" rains, initiating the germination process, were followed by a hot (Maximum = 26oC.) and a severe dry month of November. This occasional drought had probably curtailed plant growth and development over that particular year. Indeed, Hooper and Heady (1970), Murphy (1970), Duncan and Woodmansee (1975), and Pitt and Heady (1978) reported that fluctuations in annual grasslands herbage production are the direct result of both temperature and precipitation patterns. (3) The two previous severe dry years (1980, 1981) probably affected seed colony in terms of production, dispersal and biological functions. Pendleton et al. (1983) and Harper (1977) noted that though viable seeds may remain in the soil for years, seed production and distribution during each year are important determinants of the biomass and relative importance of species the following year. Ganskopp and Bedell (1981) noted that much of the drought-caused range deterioration reported by some researchers was the result of a predisposing series of low precipitation years followed by what was called a severe, one year drought.

No significant Year x oak Canopy Cover treatment interaction was found for two-year-average DMHYs. The lack of interaction may reflect the high variability in herbage production and the wide species diversity characterizing an annual grassland type. In addition, and for the particular case of Mamora Forest, the previous drought periods coupled with severe insect (*Lymantria dispar* L.) attack on trees, may have modified the oak environment. These two combined factors have led, particularly, to excessive oak leaf-shattering reducing the canopy cover volume. The year 1982 could be considered a recovery period for oak tree canopy reconstitution, and 1983 a period of gradual reversion to normal conditions. Similar effects were observed in Portugal in 1954 (Natividade, 1956).

Nutritive Quality of the Herbage Understory

Most components of herbage nutritive quality varied significantly ($P < .01$) among oak canopy cover classes, sites and seasons (Appendix I).

Canopy Cover Classes

The herbage produced under canopied subplots contained more crude protein, fat, and water but significantly less crude fiber than the herbage collected under open conditions (Table 3-2). All of these components, except fat, declined significantly below 25% oak canopy cover.

The presence or absence of canopy had no apparent effects upon the ash or the N.F.E. content of the total herbage understory. However, these two components were approximately 14 percent greater on the open stands. This difference approached significance at the .05 level.

Differences in the understory herbage nutritive quality could result from many factors. Changes in intensity and quality of light received by herbage under forested conditions, coupled with greater fertility and more favorable temperature range beneath the trees (Holland, 1969) may have influenced not only the forage nutrient uptake but also the annual growth cycle of the vegetation. Krueger (1981) noted that shaded plants tend to mature later in the growing season than those in the open; some shaded plants do not flower at all. Similar observations were reported in several studies (Clarke and Tisdale, 1945; Savage and Heller, 1947; Cook and Harris, 1950; Vallentine and Young, 1959).

Table 3-2.

Mean Percent of Herbage Understory Nutritive Contents Under Five Oak Canopy Cover Classes

Canopy Cover Classes	Crude Protein	Crude Fiber	Fat	Water
	% (Dry Matter Basis)			
I 75-100%	12.1a[1]	40.6a	3.6a	48.1a
II 50-75%	11.7a	41.7a	2.2ab	48.1a
III 25-50%	10.1ab	46.5b	1.2bc	46.5a
IV 0-25%	9.1b	48.7b	.6c	40.5b
V Openings	6.4c	53.2c	.7c	37.5b
$S\bar{y}$	.7	1.5	.3	1.4

[1]Means in each column followed by different letters differ ($P < .05$)

Sites

In most nutrients studied there was a highly significant ($P < .01$) difference between the shrubby and the non-shrubby site. Crude protein, fat, ash and moisture contents of the herbage were higher from the shrubby (G) than from the non-shrubby (NG) site, while crude fiber and N.F.E. showed the opposite relationship (Table 3-3). These results may be due to the shrubby site potential superiority over the non-shrubby (Appendix H). In G, the higher nutrient content of herbage was in response to a complex of micro-habitat conditions created primarily by the shrub layer. Through symbiotic N-fixation and litter fall, *Genista linifolia* L. may have accumulated nutrients from deep in the soil and redistributed them on the surface largely beneath the canopy. Because soil nutrients may become greater and more readily available under the shrub layer, herbage nutrient uptake could be higher on G than on NG site. Other factors such as the shrub extra-shading, greater soil water holding capacity, moderate soil temperature, and relatively more favorable physical soil features in G site may have also played some determinant roles.

Phenological Phases

Season strongly affected ($P < .01$) the amount of all herbage nutrients sampled. Moisture, crude protein, ash and fat contents declined as plant phenology progressed. Crude fiber and N.F.E. showed the opposite relationship (Table 3-4).

Table 3-3.

Herbage Nutritive Quality in Relation to the Shrubby (G) and Non-shrubby (NG) Sites

Site	Crude Protein	Crude Fiber	Fat	Ash	NFE	Water
		% (Dry Matter Basis)				
G	14.94[1]	43.26	1.82	6.91	33.16	49.21
NG	4.87	49.03	1.47	6.12	38.50	39.09
$S_{\bar{y}}$	2.05	7.18	.07	.16	4.29	6.06

[1]All means in a column differ ($P < .05$)

Table 3-4.

Nutritive Quality of Herbage Understory in Relation to Plant Phenology

Phenological Phases	Crude Protein	Crude Fiber	Fat	Ash	NFE	Water
	% (Dry Matter Basis)					
Juvenile	14.06a[1]	42.58a	1.72a	8.04a	33.56a	74.53a
Vegetative	10.23b	45.32a	2.02a	7.37a	35.24a	47.36b
Reproductive	5.43c	50.53b	1.20b	4.13b	38.70b	10.55c
$S_{\bar{y}}$	1.24	7.16	.12	.60	5.63	9.27

[1]Means in each column followed by different letters differ ($P < .05$)

Trends in herbage nutritive quality were mainly related to plant maturity. Stoddart et al. (1975) assigned changes in the seasonal nutritive value of forage to the variations in the stem-leaf ratios and to the actual changes in the composition within each plant part.

Species composition may have also a part in the seasonal forage value changes. In all nutrients, except N.F.E., the sharpest decline appeared beyond the vegetative stage. This, obviously, may recall some particular features and functioning of an annual rangeland. Annual plants, which are mostly dominant in Mamora Forest, show generally greater declines late in the season, in the most important nutrients such as proteins than perennials (Stoddart et al., 1975). Hart and Goss (1932) reported that, in the California annual rangelands, the quality of the herbage changed from being comparable to a protein-rich concentrate during the early vegetative phases to that of a poor roughage when dry.

The Season x Site treatment interaction had affected ($P < .05$) all herbage nutrients except crude fiber. However, crude fiber was approximately 10 percent greater on the NG than on G site. This difference approached significance at the .10 level.

Figure 3-4 shows that, over all phenological phases, percentages of crude protein were higher on the shrubby than on the non-shrubby site. Additionally, herbage crude protein content, on NG site, decreased rapidly from the juvenile to the vegetative phase, while on G site the sharpest decline appeared beyond the vegetative phase. These differences in the amounts and trends in herbage crude protein

Figure 3-4. Effects of plant phenology and sites on herbage nutritive quality.

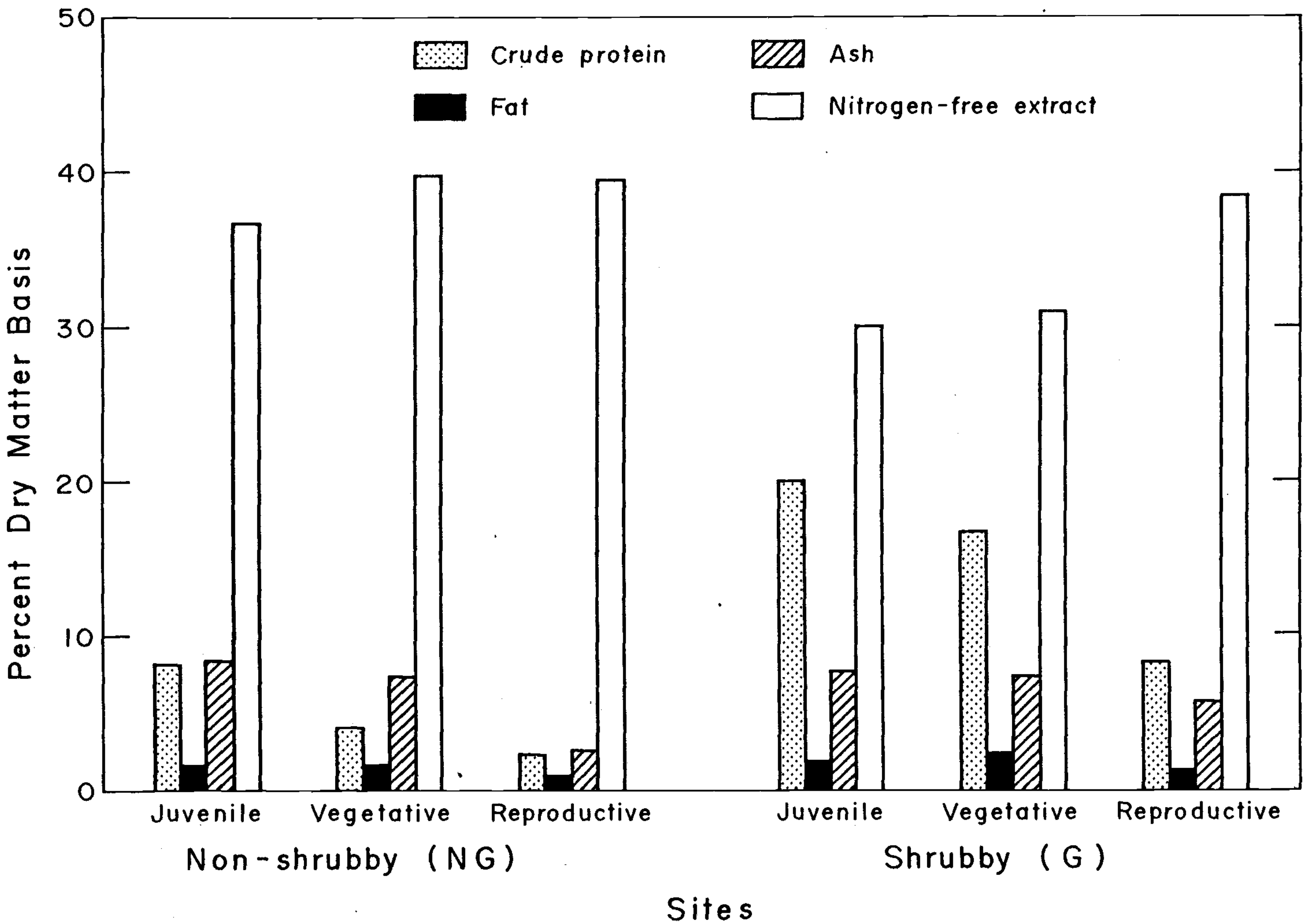

Crude protein
Ash
Fat
Nitrogen-free extract
Percent Dry Matter Basis
0
10
20
30
40
50
Juvenile
Vegetative
Reproductive
Juvenile
Vegetative
Reproductive
Non-shrubby (NG)
Shrubby (G)
Sites

Figure 3-4.

contents pointed out, particularly, the importance of the shrub layer on G site. The Genista linifolia L. shrub benefits could be summarized as follows: (1) It provides extra-shading delaying plant maturity and since protein and moisture contents have a high positive correlation (Campbell and Cassady, 1954), higher moisture content of plants, on G site, is probably responsible for the presence of more protein in these shaded plants. (2) It intercepts rain and thus prevents plant leaching (Guilbert et al, 1931). (3) Being a nitrogen-fixing bacteria bearer as most legume species (Metro and Sauvage, 1955), this shrub may be able to enhance soil nitrogen content and thereby the associated herbage crude protein content. Lawrence (1958) found that fallen leaves of young alder in Alaska, which have nitrogen-fixing nodules, added as much as 140 kg of N to the soil per hectare per year. (4) Prevents early drying of soil under drought conditions making plants dry later. The decrease in protein as soil moisture becomes deficient is at least caused by a breakdown of proteins occurring as leaves wilt (Thompson and Morris, 1966).

Conclusions

Understory herbage production and nutritive quality were affected by cork oak tree canopy cover. Their seasonal responses varied whether analyzing the forest community as a whole entity or considering each site separately. Herbage production from the shrubby site was two to three times higher than that from the non shrubby one. This reflected the potential superiority in terms of moisture and nutrient status, of G over NG site.

Tree crown cover alone does not govern totally herbage production and quality. Examining overstory-understory relationships requires consideration of both the canopy cover or tree density factor and site characteristics. In addition, these data suggest that Moroccan forest managers should consider each major site separately in developing the next Mamora Forest management plan.

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CHAPTER 4

Seasonal Understory Herbaceous Foliar Cover as Related to Tree Canopy Cover and Site Characteristics in a Portion of the Mature Mamora Cork Oak (*Quercus suber* L.) National Forest of Morocco[1]

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[1]This study was funded by the U.S.A.I.D. under the convention between the International Agricultural Programs of the University of Minnesota and the Institut Agronomique et Veterinaire Hassan II of Morocco.

Seasonal Understory Herbaceous Foliar Cover as Related to Tree Canopy Cover and Site Characteristics in a Portion of the Mature Mamora Cork Oak (*Quercus suber* L.) National Forest of Morocco

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Abstract

Understory herbage cover and composition, in relation to cork oak (*Quercus suber* L.) crown cover, were seasonally evaluated over two years on two distinctive sites of the Mamora National Forest of Morocco. Sites differed in the dominance (81%) of a legume-shrub (*Genista linifolia* L.) in one (G) and a near absence (4% cover) of this layer in the other (NG). Five oak canopy cover classes (75-100%, 50-75%, 25-50%, 0-25%, openings) and three vegetation phenological phases (juvenile, vegetative, reproductive) were studied.

Percentage cover of the total living ground vegetation, annual grasses and annual forbs varied among tree canopy cover classes. Vegetative ground cover tended to be similar from 25% to the most dense canopy, then declined as oak canopy cover declined. Annual grass cover decreased gradually as crown cover decreased. Annual forbs increased from the densest stand to 50% canopy cover and then remained the same as crown closure decreased. Percentage cover of these two plant groups, however, tended to be similar from 25% to the open stands.

The individual annual grass and annual forb species also reacted differently to changes in oak crown cover. Sweet vernal grass (Anthoxanthum odoratum L.), abundant under canopied stands, exhibited a rapid decline under open conditions. Rough dog's tail grass (Cynosorus echinatus L.), contributing the highest cover under the densest canopy, showed a sharp decline from 50% to the openings. Few of the 47 species of annual forbs persisted under the densest canopies. Cover of these species increased as tree canopy decreased.

Percentage cover of the total living ground vegetation, shrubs, oak seedlings and annual forbs was higher on the shrubby (G) than on the non-shrubby (NG) site. These differences appeared due to the higher moisture and nutrient status of the shrubby site.

Individual annual forb and shrub species also reacted differently from one site to another. Almost all the most important annual forbs and shrubs were more abundant on G than on NG sites.

Seasons affected ($P < .01$) percentage cover of the total living ground vegetation, grasses, and annual forbs. All these groups, except that of annual forbs, reached their peak cover during the vegetative phase. Annual forbs, however, exhibited their highest cover earlier than the other groups.

Individual annual grass species such as sweet vernal grass and Vulpia alopecuros Link, unimportant during the juvenile stage, increased rapidly during the vegetative phase, while rough dog's tail grass and rye grass (Lolium rigidum Gaud.) decreased as seasons progressed. Most of the perennial grasses and annual forb species increased in cover as seasons advanced. Orchardgrass (*Dactylis glomerata* L.), however, did not show any meaningful differences among seasons and *Rumex bucephalophorus* L. was erratic in occurrence.

Cover of plant groups, except those of grasslike and biennials, varied ($P < .10$) between years. Total vegetative ground cover as well as forbs were higher in 1983 than in 1982. Grasses, however, showed the opposite relationship.

Individual species also reacted differently from one year to another. Most of the important annual grass and perennial forb species were more abundant in 1983 than in 1982. Annual forb species showed the opposite relationship and perennial grass species were erratic in occurrence.

Over the two years, the Season x oak Canopy Cover treatment was significant ($P < .10$) for the perennials' group only. The lack of this particular interaction on annuals was probably due to the high fluctuations of this vegetation type over seasons and canopy treatments.

Introduction

Tree overstory influences not only the production and nutritive quality of the understory vegetation but also its foliar cover and composition. Several studies (Martin et al., 1955; Koshi, 1957; Pase, 1958; Murphy and Crampton, 1964; Young et al., 1967) have shown that a decrease in crown cover is associated with an increase in all classes of herbage. However, Ehrenreich and Crosby (1960) added that the release trend and increment vary from one class of herbage to another. Each individual vegetation species or group of species appears responding differently to environmental alteration. In addition, within the individual group of species, responses often are correlated to the degree and form of alteration.

Ecological study, done in Mamora Forest by Sauvage (1961), primarily emphasized the descriptive rather than quantitative aspect of the cork oak overstory-understory relationship. Also, considering the apparent forest trend due primarily to grazing abuse, periodical droughts, diseases, and inadequate management plans, Sauvage's study should be updated.

The objective of this study was to evaluate the seasonal foliar cover and composition of understory vegetation as related to cork oak (<u>Quercus suber</u> L.) tree canopy cover and site characteristics in a portion of the mature Mamora National Forest of Morocco.

Study Area

The study was conducted during 1982 and 1983 on two different sites located in the central southwestern part of the Mamora Forest. They are roughly 2 km apart, approximately 20 km east of Rabat (Appendix B). The sites differ ecologically in vegetation structure: one was dominated (81% cover) by a legume-shrub layer (Genista linifolia L.) while in the other the shrub layer is nearly absent (4% cover) (Appendix C).

Both sites are part of a mature cork oak stand. The topography is gently rolling with a westerly exposure. Elevation is approximately 40 m. Average annual precipitation is 475 mm, most of which falls between November and April. The mean annual maximum and minimum temperatures are 22°C and 12°C, respectively. The hottest month of the year is August with a mean temperature of 27°C and the coldest is January with a mean temperature of 6°C (Appendix E). Upland sites with sandy soils predominate. Surface soils are mostly loose sands, low in organic matter content with inherent low fertility. Subsoils range from very friable to very dense clays or sandy clays, derived chiefly from unconsolidated beds of non-calcareous clays and sands of the Plaisancian and Astian (Pliocene) era (Lepoutre, 1965). These subsoils are somewhat massive when wet but become hard and brittle upon drying. However, the nutrients leach easily and this affects herbage production, nutritive quality, and species composition.

Cork oak and a few individual trees of Mamora pear (Pirus Mamorensis Trabut) dominate the tree overstory of the mature community. Principal shrub understory species are _Genista linifolia_ L., _Lavandula stoechas_ L., and _Thymelaea lythroides_ Barr et Murb. The herbaceous layer consists largely of mixed annual grasses and forbs such as sweet vernal grass (_Anthoxanthum odoratum_ Trabut), soft chess (_Bromus mollis_ L.), pearl grass (_Briza maxima_ L.), spotted rockcist (_Helianthemum guttatum_ L.) and buck's horn (_Plantago coronopus_ Pilger). The most important perennial species recorded in these two sites were: Grey hairgrass (_Corynephorus canescens_ (L.)), orchardgrass (_Dactylis glomerata_ L.), _Paronychia argentea_ Lam., and cat's ear (_Hypochoeris radicata_ L.).

The area was under heavy continuous grazing use over a 9 month (October through June) period of the year since 1912. During the remainder of the year the main users, Oulad Malik and Foui commons, move their livestock, essentially composed of cattle (63%) and sheep (37%) of local breeds onto crop aftermath (Hudowicz, 1970).

Materials and Methods

Two 100 x 500 m exclosures were built, in January 1982, and two appended ones, in 1983, to protect the experimental plots (NG = Non-Genista plot; G = Genista plot) from grazing animals.

Each individual plot was divided into 42 subplots of 1200 m^2 (100 x 12 m) each and number of standing oak tree (stumps) per subplot (or density) was recorded. Ten subplots, corresponding to five different tree density classes with two replications were selected as follows:

Classes	Density (Stumps/ha)
DI	More than 300
DII	200-300
DIII	100-200
DIV	0-100
DV	Openings

A second stratification assessing oak tree canopy cover (CC) of each D subplot was also undertaken. In Temara cork oak Forest, Benessalah (1978) found a high correlation (r^2 = .78) between the two tree attributes. Two separate techniques, vertical crown projection and the spherical Model A-densiometer (Lemmon, 1965), were tested for crown measurements. Both techniques led to a very strong (r^2 = .89 and .92, respectively) correlation between CC and D (Appendix F).

In the study, the five canopy cover classes considered were:

Canopy Cover Classes	% Crown Cover
CCI	75-100
CCII	50-75
CCIII	25-50
CCIV	0-25
CCV	Openings

Because high variations in weather patterns have occurred during the past few years, no calendar sampling dates were predetermined. Herbaceous foliar cover data were collected three times per year, coinciding with the most apparent phenological phases (juvenile, vegetative, and reproductive). Yet, these three phases occurred, respectively, around the end of February and beginning of March; end of April, beginning of May, and mid June. A ten point frame (Sharrow and Tober, 1979) was used to estimate the percentage herbaceous foliar cover. This particular frame was found well suited to sampling annual rangelands (Heady and Rader, 1958). It has the advantage over the line intercept method, to be more accurate in measuring small units of cover (Pieper, 1978) and also more convenient to handle in sampling the shrubby plots. Plant species, except the mature tall _Genista linifolia_ L. shrub, as well as litter and bare ground hits were recorded within each subplot from twenty randomly located ten point frames. The optimum number of sampling units per subplot was estimated using the vegetative percentage cover-area curve (plotting) approach (Hopkins, 1955) based on preliminary trials. Because annual species cover changes rapidly during the growing season, the first replication of all treatments was sampled before the second in order to minimize the possible differences due to time.

Total percentage vegetative cover as well as percentages of plant cover/life span/growth form, in relation to oak canopy classes and site characteristics (presence or absence of Genista linifolia L. shrub) were evaluated using analysis of variance techniques. Botanical composition, which represents percentage cover each species is contributing to the total cover, was calculated (Levy and Madden, 1933).

Data were analyzed as a split, split, split plot design with sites as main plots and years, seasons, and canopy cover as sub-plots in a completely randomized design. Where appropriate, means were separated with Tukey's w-procedure (Steel and Torrie, 1980). Significant treatment effects were partitioned into orthogonal polynomial components and response surfaces were fitted by least squares regression procedures (Neter and Wasserman, 1974).

Results and Discussion

Effects of Oak Canopy Cover

Oak crown cover strongly affected (P < .01) percentage cover of the total living ground vegetation, grasses, forbs, annual grasses, and annual forbs (Appendix G).

Over all treatment variables, average living ground vegetation cover was similar (83 to 85%) among canopy classes I, II, and III (Table 4-1). Total living understory cover in classes IV and V (67 to 69%) was less (P < .01) than I to III. Percent cover of annual grasses decreased gradually as crown cover decreased. Annual forbs doubled in cover from class I to all other classes. Grass and forb groups cover tended to be similar below CC III.

Living ground vegetative cover could have been higher under canopied conditions for a number of possible reasons. (1) Favorable soil status, in terms of moisture and organic matter contents, stimulated plant establishment, growth, and proliferation. (2) Uneven animal distribution, during the previous grazing use, might have caused more damage on the initially-low potential-open stands than on the closed conditions. Hedrick et al. (1968) reported that animals, particularly cattle, preferred sites with low density of tree canopy cover while light or no use occurred on heavily shaded areas.

Among all vegetation groups and under all treatments, annual grasses comprised the highest proportion (42%) of the total ground vegetative cover. Retrogression, involving plant competition and

Table 4-1.

Effects of Oak Canopy Cover Classes (CC) on
Percentage Cover of the Total Living Ground Vegetaton (VGC),
Grasses (GR), Forbs (FOR), Annual Grasses (AGR)
and Forbs (AFOR)

	Mean Percentages				
CC	VGC	GR[2]	FOR[3]	AGR	AFOR
I 75-100%	84.0a[1]	66.9a	16.1a	57.5a	13.7a
II 50-75%	84.8a	55.4b	28.1b	46.5b	25.8b
III 25-50%	82.9a	50.5b	30.6b	42.2b	28.0b
IV 0-25%	69.4b	37.5c	30.4b	31.9c	27.8b
V Openings	66.9b	34.9c	30.0b	30.0c	27.4b
$S_{\bar{y}}$	1.8	2.7	1.3	2.3	1.2

[1] Means in each column followed by different letters differ ($P < .01$)

[2] GR included annual and perennial grasses

[3] FOR included annual and perennial forbs

natural selection, resulting from previous grazing pressure might have led to an influx of mobile annual species invading the entire forest community. The importance of these invaders, in Mamora Forest, reflects basic annual grassland traits as described by Talbot et al. (1939).

Annual grasses appeared to thrive better under canopied than under open stands, while annual forbs, below 75% oak canopy cover, remained unchanged. This could have resulted from two main reasons: (1) Being easily accessible to livestock, particularly on the non-shrubby site, open stands were more heavily grazed in the past than closed stands. Thus most of the palatable annual grass species could have either disappeared or moved into the more protected close stands and hence opened the site to unpalatable forbs (Ibnattya et al., 1972). (2) The lack of litter accumulation as well as the reduced moisture availability, under intermediate and open conditions, may have encouraged forbs proliferating to the relative disadvantage of annual grasses (Heady, 1961).

The individual annual grass and annual forb species also reacted differently to changes in crown canopy cover (Table 4-2). These changes may reflect the individual species response to shading as well as to other ecological factors created by the oak stand environment. *Anthoxanthum odoratum* L. was 11.6 to 13.6% cover from the densest to 25% canopy cover but was only 5.2 to 8.6% cover in open and semi-open conditions. *Cynosorus echinatus* L., contributed the highest (16.8%) cover under the densest canopy but made up 9.4% or

Table 4-2.

Effects of Oak Canopy Classes on Percentage cover (Cov.) and Composition (Comp.) of the Individual Annual Grass and Forb Species.

Species	Oak Canopy Cover Classes									
	I		II		III		IV		V	
	75 - 100%		50 - 75%		25 - 50%		0 - 25%		Openings	
	%Cov.	%Comp.	%Cov.	%Comp.	%Cov.	%comp.	%Cov.	%Comp.	%Cov.	%comp.
Annual grasses										
Anthoxanthum odoratum L.	12.4	14.8	13.6	16.1	11.6	14.0	5.2	7.5	8.6	13.0
Cynosorus echinatus L.	16.8	20.0	8.1	9.6	9.4	11.4	5.8	8.4	5.5	8.3
Lolium rigidum Gaud.	4.9	5.8	1.8	2.1	3.5	4.2	2.7	3.9	1.5	2.2
Vulpia alopecuros Link	9.2	11.0	13.1	15.5	9.4	11.4	7.6	10.9	6.0	9.0
Others (25 species)*	14.2	16.9	9.8	11.6	8.3	10.2	10.6	15.7	8.4	12.9
Totals	57.5	68.5	46.5	54.9	42.2	51.2	31.9	46.4	30.0	45.4
Annual forbs										
Helianthemum guttatum (L.)	0.2	0.2	4.2	5.0	2.2	2.5	3.9	5.6	1.9	2.8
Loephlingia hispanica L.	0.5	0.6	0.5	0.6	0.8	1.0	0.7	1.0	1.2	1.8
Rumex bucephalophorus L.	2.8	3.3	4.9	5.8	7.6	9.1	7.0	10.1	5.1	7.7
Tolpis barbata (L.)	3.5	4.2	5.6	6.5	9.0	10.9	4.6	6.7	8.3	12.4
Others (43 species)*	6.8	8.1	10.5	12.4	8.4	9.5	11.6	16.3	10.9	15.8
Totals	13.7	16.4	25.8	30.3	28.0	33.0	27.8	39.7	27.4	40.5

* See Appendix J.

less cover in the other four classes. Lolium rigidum Gaud. was somewhat erratic in occurrence, but was generally more important and more stable in cover under intermediate oak canopy stands than elsewhere. Vulpia alopecuros Link contributed 9 to 13% cover under canopied but 6 to 7.6% under open conditions. Some 25 other annual grass species (Appendix J) tended to decrease in cover and composition as oak crown cover decreased.

Few of the 47 species of annual forbs persisted under the densest canopies. Virtually, most of the individual species contributed more cover as oak canopy cover decreased (Table 4-2). However, Helianthemum guttatum (L.), though abundant at intermediate crown densities, was relatively unimportant under either very open or very dense stands.

Effects of Sites

Percentage cover of the total living ground vegetation, shrubs (mature Genista linifolia L. shrub species being excluded), oak seedlings, and annual forbs was different ($P < .10$) between the shrubby (G) and non-shrubby (NG) site.

Over all the vegetation phenological phases (juvenile, vegetative, reproductive) of the two years (1982, 1983) observations and under all the oak crown cover treatments (I, II, III, IV, V), average total vegetative ground cover was 7 percent higher on the shrubby (G) than on the non-shrubby (NG) site (Table 4-3). This result reflected the higher potentials of G over NG site, in terms of moisture

Table 4-3.

Effects of Sites on Percentage Cover of the Total Living Ground Vegetation (VGC), Shrubs (SHR), Oak Seedlings (TR) and Annual Forbs (AFOR)

	Mean Percentage			
Sites	VGC	SHR*	TR	AFOR
Shrubby (G)	81.00[1]	2.10	0.05	26.40
Non-shrubby (NG)	74.00	0.60	0.00	20.70
$S_{\bar{y}}$	1.67	0.22	0.01	0.53

*Mature *Genista linifolia* L. shrub species having been excluded

[1] Means in each column differ ($P < .10$)

availability, soil nutrient contents (Appendix H), and likely a greater mulch accumulation resulting from less past grazing use. Biswell (1956) postulated that much of the variation in vegetation cover of the annual grasslands resulted from variable plant residue. Also, Rossiter (1966) explained that mulch accumulation on the soil surface influences evaporation, soil temperature, activity of soil micro-organisms, infiltration, soil structure and soil nutrient status.

Percentage shrub cover, excluding mature Genista linifolia L., was more than three times higher on the shrubby than on the non shrubby site. No clear explanation could be made. However, most of the shrub species recorded appeared to attract grazing pressure by animals by the end of reproductive phase when the more valuable herbaceous species became scarce. By being more easily accessible and desirable to animals, shrub species occurring on NG site have been relatively more damaged than those on G site; some of them have even disappeared.

Although percentage cover of oak seedlings was low on the shrubby site (.05%), this figure has an appreciable value compared to the complete absence of any oak seedling on the NG site. Lepoutre (1965) reported that the lack of oak regeneration in Mamora Forest, is due to animal browsing and trampling as well as to moisture deficiency during the summer period. Ibnattya et al. (1972) added that the quantity of mature acorns, saved from human consumption, is very low and that limits greatly oak regeneration, over all the forest.

In G site, oak regeneration was favored not only by the suitable seedbed occurring beneath the Genista linifolia L. shrub but also by protecting oak seedlings from livestock damages and hiding acorns from gathering.

Annual forb cover was slightly higher on the shrubby than on the non-shrubby site. These differences reflected mainly the presence of some shade-loving annual forbs such as Anagalis arvensis L. and Andryala integrifolia L. and their near absence on the non-shrubby site (Table 4-4).

Individual annual forb and shrub species also reacted differently from one site to another (Table 4-4). All the individual annual forb species, except Helianthemun guttatum L. were more abundant on the shrubby than on the non-shrubby site. These differences could have resulted from the extra Genista linifolia L. shrub shade effect as well as from the overall habitat factors provided in the shrubby site. Also, all individual shrub species with Asphodelus microcarpus Salz. an exception, were more abundant on G than on NG site. Some periodically palatable shrub species such as Cistus salviifolius L. have completely disappeared from this non-shrubby site. This probably occurred because of easy animal accessibility onto the non-shrubby as compared to the shrubby site, during past grazing.

Effects of Vegetation Phenological Phases

Season affected ($P < .05$) percentage cover of the total living ground vegetation, annual and perennial grasses, and annual forbs. All

Table 4-4.

Mean Percentage Cover (Cov.) and Composition (Comp.) of the Individual Annual Forb and Shrub Species on the Shrubby and Non-shrubby Sites

	Sites			
	Shrubby (G)		Non-shrubby (NG)	
Species	%Cov.	%Comp.	%Cov.	%Comp.
Annual forbs				
Anagalis arvensis L.	1.6	1.9	0.15	0.2
Andryala integrifolia L.	0.6	0.8	0.07	0.1
Helianthemum guttatum (L.)	1.8	2.1	1.70	2.3
Loephlingia hispanica L.	5.4	6.6	4.36	5.9
Rumex bucephalophorus L.	5.4	6.6	4.36	5.9
Tolpis barbata (L.)	5.7	7.0	4.81	6.5
Others (23 species)**	5.9	7.3	5.25	7.1
Totals	26.4	32.3	20.70	28.0
Shrubs				
Asphodelus microcarpus Salz.	0.0	0.0	0.4	0.5
Cistus salviifolius L.	0.6	0.7	0.0	0.0
*Genista Linifolia L.	0.3	0.4	0.0	0.0
Lavandula stoechas L.	0.8	1.0	0.1	0.1
Others (4 species)**	0.4	0.5	0.1	0.1
Totals	2.1	2.6	0.6	0.7

* Mature <u>Genista lignifolia</u> L. Shrub being excluded

** See Appendix J.

these vegetation groups, except that of annual forbs, reached their peak cover during the vegetative phase. Annual forbs, however, exhibited their highest cover earlier than the others (Table 4-5). These results suggested that the sequence of vegetation maturity was consistent for plant groups; some groups started their most rapid proliferation earlier than others, and some deteriorated earlier than others. As cover of the individual annual forb species or groups declined early during the vegetative phase, that space appeared to be occupied by mostly annual grasses. Alternatively, at the reproductive stage, other annual forb groups surged and dominated the community.

Individual species reacted differently to seasons. Anthoxanthum odoratum L. and Vulpia alopecuros Link, unimportant during the juvenile stage, increased rapidly during the vegetative stage and persisted early in the reproductive phase (Table 4-6). Cynosorus echinatus L. and Lolium rigidum Gaud, however, decreased in cover as seasons progressed.

In the perennial grasses group, Corynephorus canescens (L.) and Poa bulbosa L. increased in cover as seasons advanced while Oryzopsis miliacea (L.) increased early in the season and then decreased as seasons progressed. Dactylis glomerata L., however, did not show any meaningful difference among seasons.

In the annual forb group, Helianthemum guttatum (L.) as well as Tolpis barbata (L.) increased from the juvenile to the reproductive stage. Rumex bucephalophorus L. and Loephlingia hispanica L. were somewhat erratic in occurrence.

Table 4-5

Effects of Vegetation Phenological Phases on Percentage Cover of the Total Living Ground Vegetation (VGC), Annual Grasses (AGR), Annual Forbs (AFOR), and Perennial Grasses (PGR)

	Mean Percentages			
Vegetation Phenological Phases	VGC	AGR	AFOR	PGR
Juvenile	73.7a[1]	35.8a	27.3a	5.7a
Vegetative	80.7b	46.7b	21.7b	9.0b
Reproductive	78.3b	42.4b	24.5b	7.4b
$S_{\bar{y}}$	0.8	1.2	0.6	0.3

[1]Means in each column followed by different letters differ ($P < .05$)

Table 4-6.

Mean Percentage Cover (Cov.) and Composition (Comp.) of the Individual Annual Grass, Perennial Grass, and Annual Forb Species under the Three Vegetation Phenological Phases.

Species	Phenological Phases					
	Juvenile		Vegetative		Reproductive	
	%Cov.	%Comp.	%Cov.	%Comp.	%Cov.	%Comp.
Annual grasses						
Anthoxanthum odoratum L.	4.10	5.60	13.70	17.00	13.00	16.60
Cynosorus echinatus L.	12.30	16.70	7.70	9.60	6.40	8.20
Lolium rigidum Gaud.	5.40	7.40	2.20	2.70	0.50	0.70
Vulpia alopecuros Link	0.50	0.70	14.00	17.30	13.00	16.60
Others (25 species)*	13.50	18.38	9.10	11.30	9.50	12.00
Totals	35.80	48.60	46.70	57.90	42.40	54.10
Perennial grasses						
Corynephorus canescens (L.)	0.66	0.90	1.21	1.50	1.33	1.70
Dactylis glomerata L.	4.42	6.00	4.27	5.30	4.07	5.20
Oryzopsis miliacea (L.)	0.07	0.10	0.56	0.70	0.16	0.20
Poa bulbosa L.	0.00	0.00	0.48	0.60	0.70	0.90
Others (7 species)*	0.55	0.70	2.48	3.00	1.14	1.50
Totals	5.70	7.70	9.00	11.10	7.40	9.50
Annual forbs						
Helianthemum guttatum (L.)	2.00	2.70	2.50	3.10	3.00	3.90
Loephlingia hispanica L.	0.70	1.00	0.60	0.80	1.00	1.30
Rumex bucephalophorus L.	7.10	9.60	5.10	6.30	4.50	5.80
Tolpis barbata (L.)	3.50	4.80	6.80	8.40	8.80	11.30
Others (43 species)*	13.90	18.90	6.70	8.30	7.20	9.20
Totals	27.30	37.00	21.70	26.90	24.50	31.50

* See Appendix J.

The Season x oak Canopy Cover treatment interaction was significant ($P < .10$) only for the perennial grass group. Figure 4-1 shows: (1) The highest grass cover occurred during the vegetative stage, when temperatures and precipitation were most favorable for growth, and under the 50-75% oak canopy class displaying probably high soil nutrient contents. (2) Over all seasons and canopy cover treatments, the lowest fluctuations in perennial grass cover occurred beyond the juvenile phase and from 25% canopy cover to the open stands. Under more harsh conditions, perennial grasses competed well with other plant groups to achieve an equilibrium. However, under canopied stands, other plant groups appeared to dominate perennial grass abundance. (3) The lowest perennial grass cover occurred under the most open stands and early in the growing season. This reflected the difficulty, of this particular plant group, to recover after severe dry years and damage of the past grazing.

The Season x Site treatment interaction strongly ($P < .01$) affected percentage cover of the total living ground vegetation as well as that of annual forbs. Total vegetative cover, except that of the reproductive phase, was higher on the shrubby than on the non-shrubby site. At the reproductive stage, differences between the two sites were not evident (Table 4-7). The lack of these differences may be due to extremely high fluctuations of the annual vegetation, at the end of the growing season, especially annual forbs. A higher cover of annual forbs occurred during the vegetative on shrubby than on the non-shrubby site. No meaningful differences were found in the two other seasons, however.

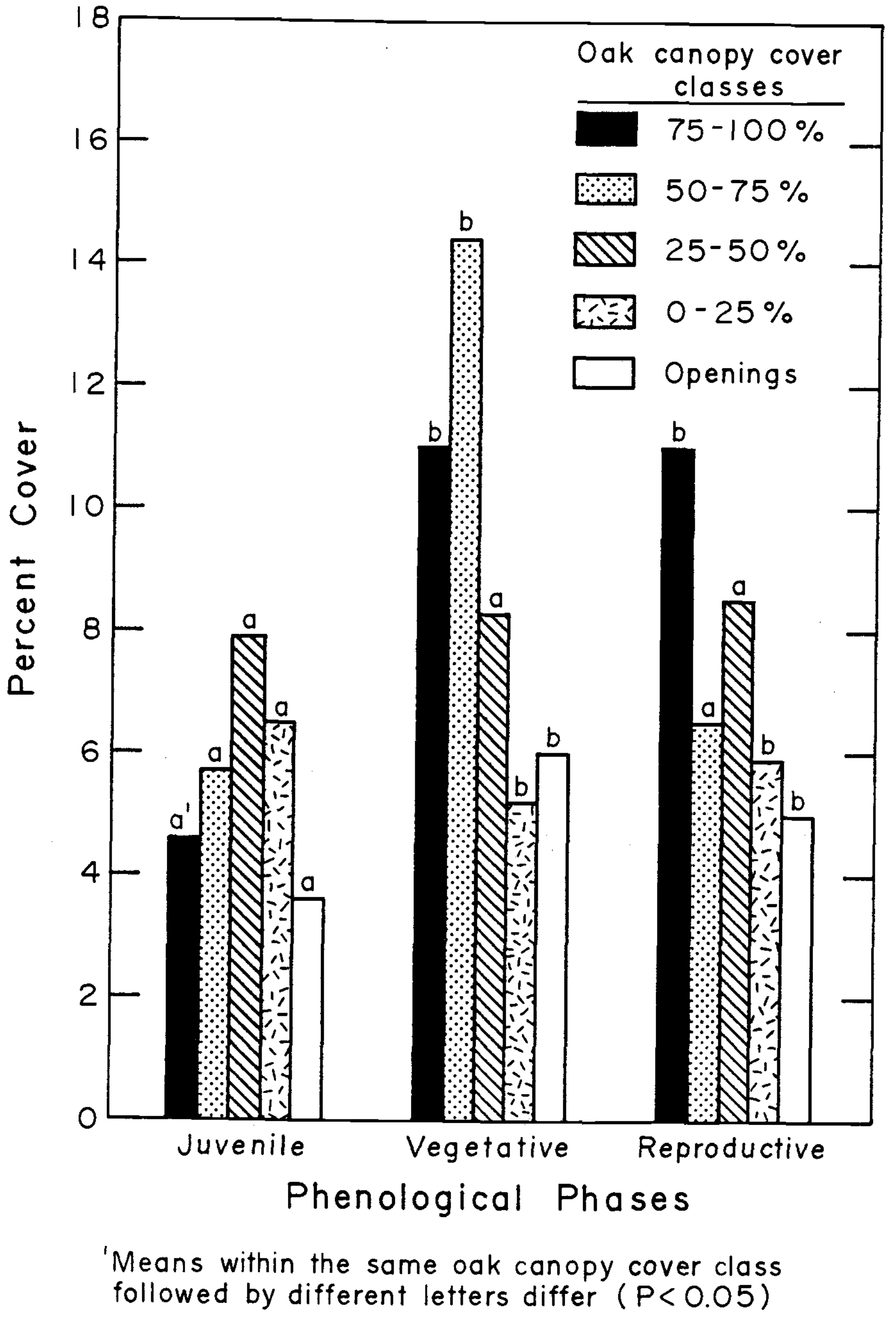

Figure 4-1. Effects of oak canopy cover and phenological phases on percentage cover of perennial grasses.

Table 4-7.

Effects of Seasons and Sites on Percentage Cover of the Total Living Ground Vegetation (VGC) and Annual Forbs (AFOR).
Data are mean ± Standard Error

		Percentages Cover	
Phenological Phases	Sites	VGC	AFOR
Juvenile	Non-shrubby	70.2 ± 4.7	25.4 ± 1.9
	Shrubby	77.3 ± 3.9	29.2 ± 2.7
Vegetative	Non-shrubby	76.1 ± 4.1	16.9 ± 0.8
	Shrubby	85.3 ± 4.6	26.5 ± 1.6
Reproductive	Non-shrubby	77.4 ± 4.3	25.8 ± 1.3
	Shrubby	79.1 ± 3.8	23.3 ± 1.7

Effects of Years

Cover of all plant groups, except those of grasslikes and biennals, varied ($P < .10$) between years. Total vegetative ground cover was higher in 1983 than in 1982 (Fig. 4-2). This probably reflected the impacts of the two previous severely dry years (1980 and 1981) on vegetation growth, development, and distribution.

Forb cover was two-fold higher in 1983 than in 1982. Grasses, however, declined from the first to the second year. These results were likely related to the date of opening rains (i.e., commencement date for growing season) as well as to the intensity and distribution of fall rains. In fall 1981, rains were earlier, greater and better distributed than in fall 1982 (Appendix E). These weather patterns for 1983 appeared to favor the more shallowly rooted annual grasses which depend upon a continual moisture supply for optimal growth (Pitt and Heady, 1978) to the disadvantage of forb species. In addition, the 1982 early fall rains, which were followed by a dry period (January) of over one month, favored a vegetative cover relatively high in forbs such as Rumex bucephalophorus L., Tolpis barbata (L.) and Astragalus algarbiensis Coss., which possess deep taproots that supplied water to the aboveground portions of these plants, during the critical period. Their relative abundance was particularly apparent at the end of the drought period. Their drought resistance made them more competitive with annual species during the beginning of the 1982 growing season. Shrubs behaved similarly. The oak

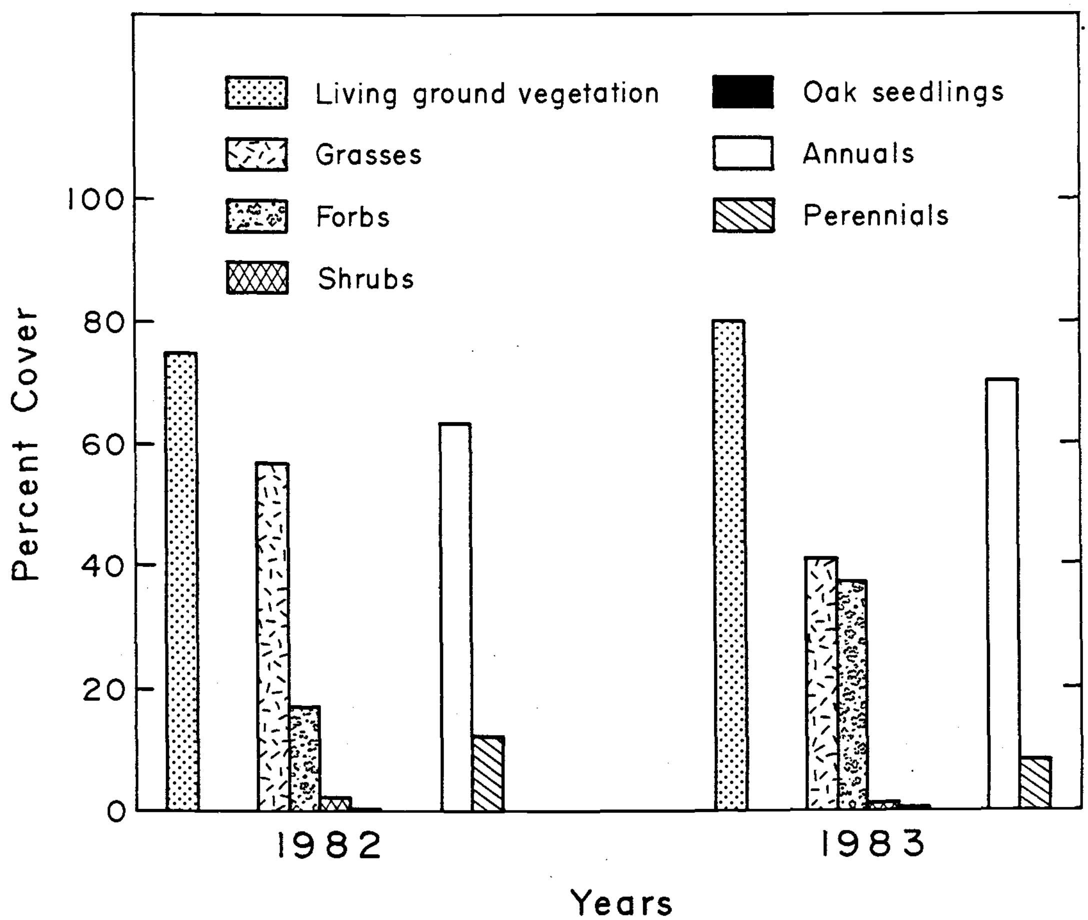

Figure 4-2. Effects of years on percentage cover of the total living ground vegetation, grasses, forbs, shrubs, oak seedlings, annuals and perennials. Plant group covers are on vegetative ground cover basis.

seedling relative occurrence came probably from their protection to grazing, trampling and acorn-gathering.

Individual species reacted differently from one year to another (Table 4-8). Fluctuations in individual species cover were in relation to many factors. Some were (1) Minimum tolerance to environmental factors, (2) differential resistance to the previous drought and grazing, (3) ability to compete.

All annual grasses, except Lolium rigidum Gaud., declined from 1982 to 1983. Annual forbs, however, showed the opposite relationship. Some of them, such as Rumex bucephalophorus L. and Tolpis barbata (L.) were two-fold higher in the second as compared to the first year.

Perennial grass species were somewhat erratic in occurrence. Dactylis glomerata L. as well as Poa bulbosa L. declined significantly in cover, from one year to another. Oryzopsis miliacea (L.), however, was four times higher in 1983 than in 1982. Corynephorus canescens (L.) stayed relatively constant.

All perennial forbs, except Carlina corymbosa L., were almost two-fold higher in 1983 than in 1982.

Among the individual shrub species, Cistus salviifolius L. as well as Lavandula stoechas L. declined in cover from 1982 to 1983. Genista linifolia L., however, showed the opposite relationship. Asphodelus microcarpus Salz. was virtually constant, from one year to the next.

Table 4-8.

Mean Percentage Cover (Cov.) and Composition (Comp.) of the Individual Grass, Forb, and Shrub Species over 1982 and 1983

Species	1982 %Cov.	1982 %Comp.	1983 %Cov.	1983 %Comp.
Annual grasses				
Anthoxanthum odoratum L.	11.8	15.5	8.50	10.7
Cynosorus echinatus L.	10.6	14.0	7.10	9.0
Lolium rigidum Gaud.	1.4	1.9	4.20	5.3
Vulpia alopecuros Link	10.1	13.3	7.70	9.7
Others (25 species)*	13.7	18.0	8.20	10.3
Totals	47.6	62.7	35.70	45.0
Annual forbs				
Helianthemum guttatum (L.)	2.3	3.0	2.70	3.4
Loephlingia hispanica L.	0.5	0.7	1.00	1.3
Rumex bucephalophorus L.	3.9	5.2	7.40	9.3
Tolpis barbata (L.)	4.1	5.4	8.60	10.9
Others (43 species)*	4.6	6.0	14.00	17.6
Totals	15.4	20.3	33.70	42.5
Perennial grasses				
Corynephorus canescens (L.)	1.0	1.3	1.10	1.4
Dactylis glomerata L.	6.4	8.4	2.10	2.6
Oryzopsis miliacea (L.)	0.1	0.2	0.40	0.5
Poa bulbosa L.	0.6	0.8	0.07	0.1
Others (7 species)*	0.8	1.0	2.03	2.6
Totals	8.9	11.7	5.70	7.2
Perennial forbs				
Paronychia argentea Lam.	0.7	1.0	1.30	1.6
Carlina corymbosa L.	0.5	0.7	0.30	0.4
Halimium libanotis Lange	0.0	0.0	0.20	0.3
Hypochoeris radicata L.	0.2	0.2	0.40	0.5
Others (5 species)*	0.4	0.5	0.70	0.9
Totals	1.8	2.4	2.90	3.7
Shrubs				
Asphodelus microcarpus Salz.	0.2	0.3	0.16	0.2
Cistus salviifolius L.	0.5	0.7	0.00	0.0
*Genista linifolia L.	0.0	0.0	0.32	0.4
Lavandula stoechas L.	0.6	0.8	0.16	0.2
Others (4 species)*	0.5	0.7	0.26	0.3
Totals	1.8	2.4	0.90	1.1

* Mature <u>Genista linifolia</u> L. Shrub being excluded
* See Appendix J.

The Season x oak Canopy Cover treatment was significant ($P < .10$) for the perennial group only.

A linear component of S, plus a quadratic element of CC were independent variables in the two-year model. The response surface consisted of parallel straight lines for S and power curves for CC treatments (Fig. 4-3). The lowest and highest points of this surface corresponded to treatments Juvenile - Openings (low) and Reproductive - CC III (25% cover) (high), respectively. The two tails of the canopy cover curve indicate a decrease in cover. These may be either to the high competition of shrubs as well as annuals and to the extreme shading (canopied stands), or to the moisture and nutrient scarcities in open conditions. The middle portion of the CC curve reflects the oak canopy range where perennials reached their peak percent cover and stayed reasonably constant.

For 1982, the response surface for perennial cover (Fig. 4-4) has up to quadratic terms for both CC and S treatments and their linear interaction term. The lowest and highest points of this surface correspond with treatments Juvenile - Openings (low) and 25% Cover - Reproductive (high), respectively. Perennial cover, up to a canopy cover class II (25-50%), increased in a curvilinear fashion as S advanced to the vegetative stage and then started declining beyond that phase.

Perennial cover response surface for 1983 (Fig. 4-5) has up to quadratic terms for both CC and S treatments and their linear interaction term. The lowest and highest points of this surface were

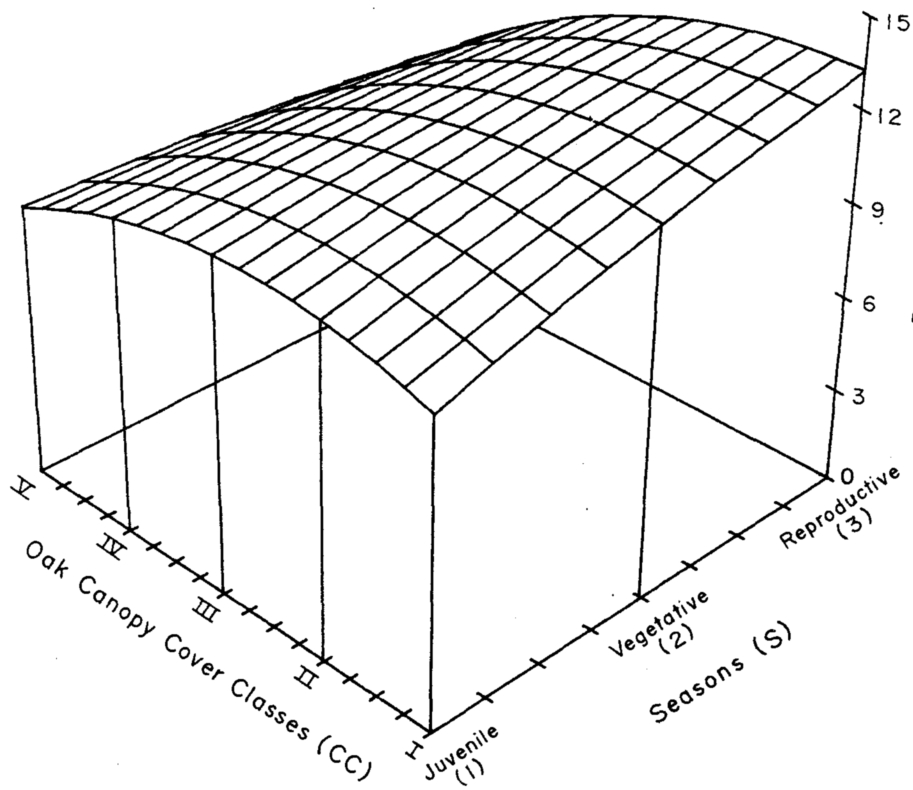

Figure 4-3. Effects of oak canopy cover classes (CC) and plant phenology (S) on percentage perennial cover (P) (vegetative ground cover basis). 1982, 1983.

$$\% P \ (r^2 = .37) = 4.90 + 3.00 \ (S) + 2.30 \ (CC) - .34 \ (CC)^2$$

S = 1, 2, 3 for juvenile, vegetative, and reproductive phases, respectively.

CC = 1, 2, 3, 4, 5 for cover classes I, II, III, IV, and V, respectively.

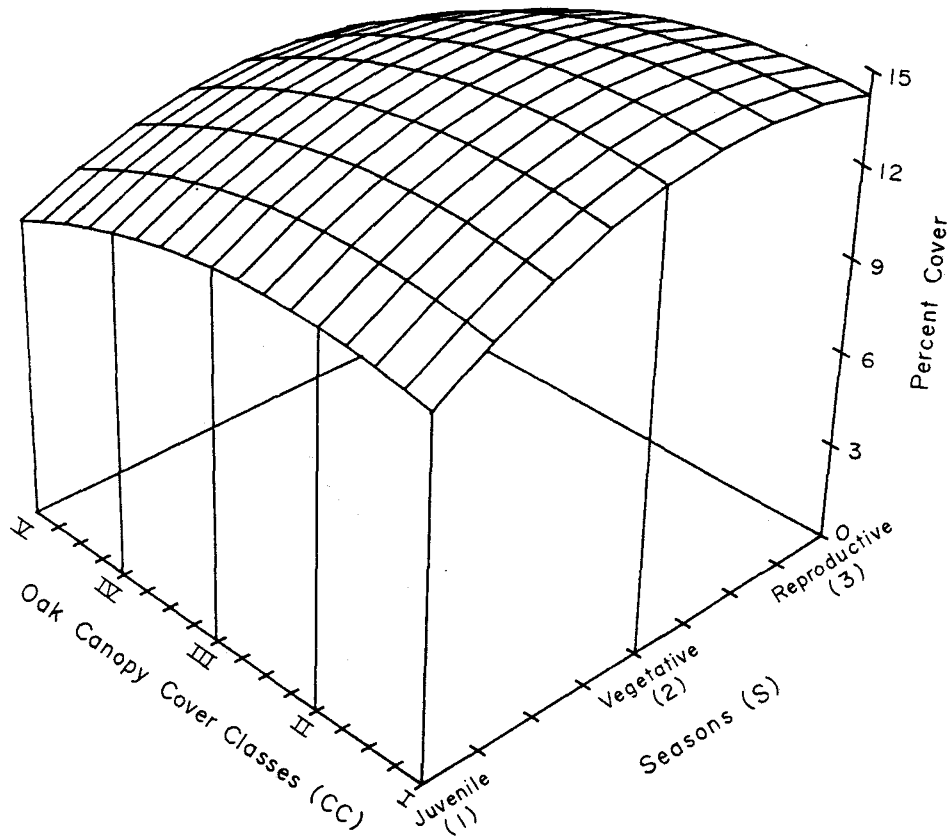

Figure 4-4. Effects of oak canopy cover classes (CC) and plant phenology (S) on percentage perennials cover (P) (vegetative ground cover basis). 1982.

$$\%P\ (r^2 = .34) = 3.00 + 7.80\,(S) + 1.60\,(CC) - 1.60\,(S)^2 - .29\,(CC)^2 - .23\,(S)\,(CC)$$

S = 1, 2, 3 for juvenile, vegetative, and reproductive phases, respectively.

CC = 1, 2, 3, 4, 5 for cover classes I, II, III, IV, and V, respectively.

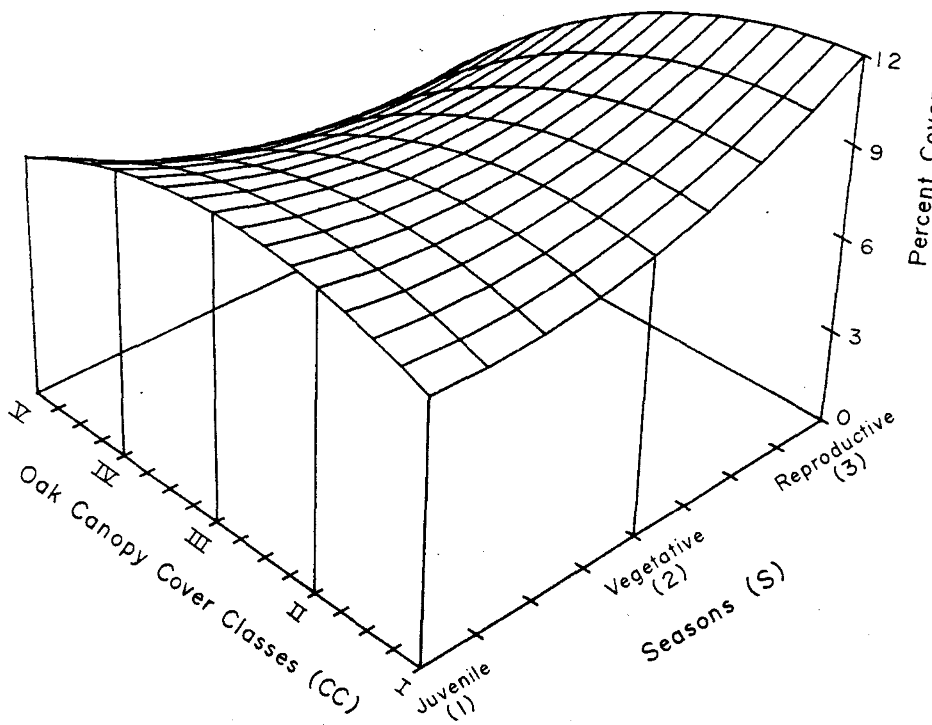

Figure 4-5. Effects of oak canopy cover classes (CC) and plant phenology (S) on percentage perennial cover (P) (vegetative ground cover basis). 1983.

$$\%P\ (r^2 = .37) = 5.70 - 1.90\,(S) + 3.10\,(CC) + 1.10\,(S)^2 - .40\,(CC)^2 - .77\,(S)\,(CC)$$

S = 1, 2, 3, for juvenile, vegetative, and reproductive phases, respectively.

CC = 1, 2, 3, 4, 5 for cover classes I, II, III, IV, and V, respectively.

analogous to those obtained in 1982's curve. However, the concaved-S curve indicates a decline in perennial cover from the juvenile up to vegetative stage. This, probably, resulted from environmental stresses such as low and unfavorable temperatures and precipitation (January), hampering the perennial's growth processes.

Conclusion

Changes in oak tree canopy cover resulted in changes in the most important groups of herbage. Both amounts and direction of change in these groups varied from one season to another, between sites and between years. Each species group or, to a large extent, individual species, appeared to have its own way to thrive in a given environment. The kind and degree of changes or alterations of any species niche component was reflected in the group or individual species occurrence.

In managing Mamora National Forest for the dual purposes of grazing use and timber production, attention must be given not only to oak tree canopy cover or density, but also to all the intrinsic and extrinsic environmental factors influencing herbage cover and composition.

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CHAPTER 5

Effects of One and Two Growing Seasons' Protection From Grazing on Seasonal Cork Oak (*Quercus suber* L.) Understory Herbage Production and Foliar Cover in a Portion of the Mature Mamora National Forest of Morocco[1]

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[1]This study was funded by the U.S.A.I.D. under the convention between the International Agricultural Programs of the University of Minnesota and the Institut Agronomique et veterinaire Hassan II of Morocco.

Effects of One and Two Growing Seasons' Protection From Grazing on Seasonal Cork Oak (*Quercus suber* L.) Understory Herbage Production and Foliar Cover in a Portion of the Mature Mamora National Forest of Morocco

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Abstract

The effects of one (1983) and two (1982 and 1983) grazing seasons' protection from grazing on cork oak (*Quercus suber* L.) understory herbage production, foliar cover, and species composition were seasonally evaluated in 1983 on two distinctive sites of the Mamora National Forest of Morocco. Sites differed in the dominance (81% cover) of a legume-shrub (*Genista linifolia* L.) in one (G) and a near absence (4% cover) of this layer in the other (NG). On each site, a 100 x 500 m exclosure was built in January 1982 (1982-83 protected plot) and an appended one in the following year (1983 protected plot). Five oak canopy cover classes (75-100%, 50-75%, 25-50%, 0-25%, openings) and three vegetation phenological phases (juvenile, vegetative, reproductive) were studied.

Period of rest affected ($P < .10$) current annual herbage production as well as percent cover of the total living ground vegetation, grasses, forbs, and oak seedlings. Overall average herbage yields were 30% more from 1982-83 than from 1983 protected plots ($P < .05$). Herbage yields could have been different for a number of reasons.

The most likely one appeared related to mulch accumulation. Herbage production was over twice as high on the shrubby site compared to the non-shrubby site regardless of period of rest. Herbage yields behaved differently with the influence of both canopy cover class and site. On the non-shrubby site herbage yields were greater with two years protection under all canopy classes. However, on the shrubby site, yields in the two classes from 50 to 100% canopy were similar whether protected one or two growing seasons. With other classes, yields were higher when protected two seasons ($P < .05$).

Percent ground cover of all living vegetation, annual grasses, and perennial grasses was higher where protected two growing seasons as compared to only one season ($P < .05$). Perennial forb cover was similar under the two protection treatments. Percent cover of oak seedlings also was higher ($P < .05$) on two seasons compared to one season protected plots probably resulting from mulch accumulation and acorn protection.

Herbage production and percent cover of all living ground vegetation, annuals and perennials varied ($P < .10$) between phenological phases due to period of protection. Herbage yields were 30% higher in all phases on 1982-83 than on 1983 protected plots. The static increment increase in yields resulted probably from the existing perennial species gaining more and more vigor and progressively dominating the 1982-83 protected plots. This effect was more prominent during the reproductive phase. At this phenological stage, although percent cover of total living vegetation as well as that of annuals tended to be similar, under both protection treatments, percent cover of perennials was more than twice higher on 1982-83 than on 1983 plots. The two growing seasons' protection had probably encouraged some taller perennial grass species to proliferate and to be systematically recorded while, in the one growing season's protected plots, perennials were still prostrate and masked by dominant maturing annual plants.

Introduction

During the past few years there has been considerable discussion among Moroccan foresters and range managers regarding the relative merits and the scale of application of rest and grazing in deteriorated rangelands. The lack of data regarding the amount of rest necessary for recovery of these depleted areas coupled with the continued need for more grazing lands for public use appears to hamper range restoration and improvement action.

The advantages of a specialized grazing program are generally stated in terms of improving range conditions (Heady, 1961). However, any particular grazing system has both advantages and disadvantages in its application. The rest from grazing allows the established plants to gain in vigor and produce more seed. Seedling establishment is encouraged and palatable plant species may thrive. The result should be higher and more stable herbage yields. The establishment of systems with periods of rest and grazing requires fencing and/or guarding and thus significant changes from current management.

Restoring overgrazed ranges, through protection from grazing animals would require variable rest periods depending upon: (1) Actual range condition, (2) site characteristics, and (3) level of improvement to be achieved. McLean and Tisdale (1972) estimated from 20 to 40 years for depleted ranges in the rough fescue (Festuca scabrella) and ponderosa pine zones of southern British Columbia to recover to excellent range condition when fully rested. They added that little change in plant composition occurred inside exclosures placed on poor condition range in less than 10 years following fencing. Being unstable and variable to a surprising degree, annual rangeland types appear to require a shorter time for their recovery. Talbot et al. (1939) reported that, under complete protection from livestock, striking shifts in herbage production and species composition can be brought about in two years' time or less.

The objectives sought in this study were to assess the effects of one and two growing seasons' protection from grazing on cork oak (Quercus suber L.) understory herbage production and foliar cover, on two different sites and under varying oak canopies, in a portion of the mature Mamora National Forest of Morocco.

Study Area

The study was conducted during 1983 on two different sites located in the central southwestern part of the Mamora Forest. They are roughly 2 km apart, approximately 20 km east of Rabat (Appendix B). The sites differ ecologically in vegetation structure: one was dominated (81% cover) by a legume-shrub layer (Genista linifolia L.) while on the other the shrub layer was nearly absent (4% cover) (Appendix C).

Both sites are a part of a mature cork oak stand. The topography is gently rolling with a westerly exposure. Elevation is approximately 40 m. Average annual precipitation is 475 mm, most of which falls between November and April. The mean annual maximum and minimum temperatures are 22°C and 12°C, respectively. The hottest month of the year is August with a mean temperature of 27°C and the coldest is January with a mean temperature of 6°C (Appendix E). Upland sites with sandy soils predominate. Surface soils are mostly loose sands, low in organic matter content with inherent low fertility. Subsoils range from very friable to very dense clays or sandy clays, derived chiefly from unconsolidated beds of non-calcareous clays and sands of the Plaisancian and Astian (Pliocene) era (Lepoutre, 1965).

Cork oak and a few individual trees of Mamora peak (Pirus mamorensis Trabut) dominate the tree overstory of the mature community. Principal shrub understory species are Genista linifolia L., Lavandula stoechas L., and Thymelaea lythroides Barr et Murb. The herbaceous layer consists largely of mixed annual grasses and forbs such as sweet vernal grass (Anthoxanthum odoratum Trabut), softchess (Bromus mollis L.), pearl grass (Briza maxima L.), spotted rockcist (Helianthemum guttatum L.) and buck's horn (Plantago coronopus Pilger). The most important perennial species recorded on these two sites were: Grey hairgrass (Corynephorus canescens (L.)), orchard-grass (Dactylis glomerata L.), Paronychia argentea Lam., and cat's ear (Hypocheris radicata L.).

Since 1912 the area has been under heavy continuous grazing use over a 9 month (October through June) period. During the remainder of the year the main users, Oulad Malik and Foui commons, move their livestock (63% cattle and 37% sheep of local breeds) onto crop after-math (Hudowicz, 1970). In 1972, a range survey conducted by the Danish mission (Eaux et Forets, 1972) revealed, for the overall Mamora Forest, a stocking rate of 0.8 AU/ha, twice the legal carrying capacity. Additionally, animal distribution over the territory was unequal.

Materials and Methods

Two 100 x 500 m exclosures were built in January 1982 and two appended ones in 1983 to protect the experimental plots (NG = Non-Genista plot; G = Genista plot) from grazing animals.

Each individual plot was divided into 42 subplots of 1200 m^2 (100 x 12 m) each and the number of oak trees (stumps) per subplot (or density) was recorded. Ten subplots, corresponding to five different tree density classes with two replications were selected as follows:

Classes	Density (stumps/ha)
DI	More than 300
DII	200-300
DIII	100-200
DIV	0-100
DV	Openings

A second stratification assessing oak tree canopy cover (CC) of each D subplot was also undertaken. In Temara cork oak forest, Benessalah (1978) found a high correlation (r^2 = .78) between the two tree attributes. Two separate techniques, vertical crown projection and the spherical Model A-densiometer (Lemmon, 1965), were tested for crown measurements. Both techniques led to a very strong (r^2 = .89 and .92, respectively) correlation between CC and D (Appendix F).

In the study, the five canopy cover classes considered were:

Canopy Cover Classes	% Crown Cover
CCI	75-100
CCII	50-75
CCIII	25-50
CCIV	0-25
CCV	Openings

Herbage production and botanical cover data were collected three times over the year, coinciding with the most apparent vegetation phenological phases (juvenile, vegetative and reproductive).

Direct clipping (Pieper, 1978), at ground level and through the use of randomly located transects, was used to determine the standing crop within each subplot. Areas previously clipped were avoided. The number of samples considered as well as the size and shape of quadrats varied from one plot to the other. Preliminary trials for determining the optimum number of sampling units as well as the most efficient quadrat size and shape were undertaken in each individual plot. Using the standing crop-area curve (plotting) approach (Hopkins, 1955) 40 and 20 samples per subplot and of unequal sizes were found sufficient in sampling G and NG plots, respectively. In the NG plot, a circular 1 m^2 quadrat appeared to be the most efficient in sampling vegetation±of this particular site. This 1 m^2 quadrat not only has the advantage of ease of conversion from grams/m^2 to kg/ha but also exhibits a lower boundary error than any other shape. The G plot, being characterized by a tall dominant shrub, limited the ease of access and manipulation. Thus, a 3-sided rectangular (.40 x 60 m) quadrat was well suited in sampling herbaceous vegetation. Pieper (1978) reported that it is generally conceded that rectangular quadrats are more efficient than circular or square quadrats in areas of sparse or scattered vegetation. The herbaceous vegetation, taken as a single sample late in the morning of clear sky days, was clipped at ground level, weighed, and then stored in bags to be dried during the same day in a forced-air oven at 105°C.

A ten point frame (Sharrow and Tober, 1979) was used to estimate the percentage herbaceous cover. This particular frame was found well suited to sampling annual rangelands (Heady and Rader, 1958). It has the advantage, over the line intercept method, of higher accuracy in measuring small units of cover (Pieper, 1978) and handling convenience when sampling shrubby plots. Plant species, except the mature tall Genista linifolia L. shrub, as well as litter and bare ground hits were recorded within each subplot from twenty randomly located ten point frames. The optimum number of sampling units per subplot was estimated using the vegetative percentage cover-area curve (plotting) approach (Hopkins, 1955) based on preliminary trials. Because annual species cover changes rapidly during the growing season, the first replication of all treatments was sampled before the second in order to minimize the possible differences due to time.

Herbage production, total percentage vegetative cover, and percentages of plant cover/life span/growth form, in relation to oak canopy cover classes, site characteristics (presence or absence of Genista linifolia L. shrub) and protection treatments were evaluated using analysis of variance techniques. Data were analyzed as a split, split, split plot design with sites as main plots and protection from grazing (PP: 1982-83 protected plots, RP: 1983 protected plots), seasons, and canopy cover as sub-plots in a completely randomized design. Where appropriate, means were separated with Tukey's w-procedure (Steel and Torrie, 1980).

Results and Discussion

Herbage production and percent cover of total living ground vegetation, grasses, forbs, and oak seedlings were significantly affected ($P < .10$) by periods of rest from grazing (Appendix K). When herbage yield data were combined from all canopy classes, both sites and three phenological phases, yields were 612 kg/ha under two seasons' rest compared to 479 kg/ha for one season's rest (Table 5-1).

Herbage yields could have been different for a number of possible reasons. The most likely one appeared related to mulch accumulation. The importance of this factor has been observed and documented by several California range scientists (Hormay and Fawsett, 1942, Bentley and Talbot, 1951, Hormay, 1960). Hooper and Heady (1970) suggested that natural mulch is one of the most important determinants of forage production in annual grasslands and that the removal of all mulch, by grazing or clipping, before the first rain in the fall: (1) Reduces the proportion of desirable forage species in the stand, (2) lowers forage quality, and (3) reduces subsequent forage production as compared to areas where mulch has not been removed. The 1972 range survey conducted by the Danish mission (Eaux et Forets, 1972) revealed that throughout the Mamora Forest the stocking rate at that time exceeded the carrying capacity by far. Animal distribution over the territory was unequal. Also, forest users do not move their animals onto crop aftermath before the

Table 5-1

Effects of Grazing-Protection Treatments on Dry Matter Herbage Yield (DMHY) and on Percentage Cover of the Total Living Ground Vegetation (VGC), Grasses (GR), Forbs (FOR) and Oak Seedlings (TR)

Protection Treatments	DMHY kg/ha	Mean Percentages			
		VGC	GR[1]	FOR[2]	TR
1982 and 1983	612*	84	53	27	0.38
1983	473	78	41	36	0.04
$S_{\bar{y}}$	20	0.9	1.7	1.3	0.05

*Means in each column differ ($P < .05$)

[1]Grasses include annual and perennial grasses

[2]Forbs include annual and perennial forbs

end of June, when the last few kilograms of plant residue are depleted and then turn them back into the forest early in the fall.

Herbage production on the shrubby site was over twice that on the non-shrubby site ($P < .01$) whether protected from grazing one season or two seasons (Table 5-2). This reflected the potential superiority of G over NG in terms of soil moisture and nutrients' status (Appendix H). The relative increment of yield difference between protection periods was approximately 30 percent higher due to two growing seasons' protection ($P < .10$). This may have been due to the dissemination pattern and proliferation speed of annual species.

Herbage yields also varied significantly ($P < .05$) among oak canopy cover classes both within and between sites due to protection period (Table 5-3). On the shrubby site herbage production was similar under classes I (75-100%) and II (50-75%) whether protected one or two growing seasons. However, production was lower for the remaining classes when protected only one season. For the non-shrubby site, herbage production was consistently less when protected only one season ($P < .05$). These results may reflect the effects of the _Genista linifolia_ L. shrub and, in some instances, oak tree density on animal distribution. The tangling spiny-shrub reduced livestock accessibility, resulted in more mulch accumulation, and hence more herbage production on the shrubby than on non shrubby site.

Percent cover of the total living ground vegetation was 6 percent higher ($P < .05$) on 1982-83 than on 1983 protected plots (Table

Table 5-2

Effects of Two Growing Seasons' Protection on Herbage Production from Two Sites

	Dry Matter Herbage Yields (kg/ha)		
Sites	1982-83 Protected	1983 Protected	$S_{\bar{y}}$
Shrubby (G)	851	663	27
Non-shrubby (NG)	374	284	13
$S_{\bar{y}}$	69	55	

Means in each column differ ($P < .01$)

Means in each row differ ($P < .10$)

Table 5-3.

Effects of Grazing-Protection Treatments on Herbage Production on Two Sites under Five Oak Canopy Cover Classes

	Dry Matter Herbage Yields (kg/ha)					
	Shrubby Site (G)			Non-Shrubby Site (NG)		
Oak Canopy Cover Classes (CC)	1982-83 Protected	1983 Protected	$S_{\bar{y}}$	1982-83 Protected	1983 Protected	$S_{\bar{y}}$
I 75-100%	826a[1]	785a	6	502a	303b	29
II 50-75%	902a	879a	11	408a	349b	9
III 25-50%	962a	685b	40	361a	291b	10
IV 0-25%	696a	501b	28	297a	214b	12
V Openings	866a	362b	73	303a	243b	9

[1]Means in each row within each site category followed by different letters differ ($P < .05$).

5-1). The grazing-protection treatment might have affected seed production, dispersal, and other biological functions. Pendleton et al. (1983) and Harper (1977) noted that although viable seeds may remain in the soil for years, seed production and distribution during each year are important determinants of the biomass and relative importance of species the following year.

Percent cover of grasses was 8% higher on the 1982-83 than on the 1983 protected plots. Percent cover of forbs, however, showed an opposite relationship (Table 5-1). These responses, made apparent by individual species within the plant groups, also seemed to be related to mulch accumulation. Plant residue likely favored some taller annual grasses such as Anthoxanthum odoratum L., Lolium rigidum Gaud. and Vulpia alopecuros Link to the relative disadvantage of some forb species such as Hypocheris radicata L. and Loephlingia hispanica L. (Table 5-4). Yet, grass dominance, due to mulch accumulation, was associated with loss of some valuable annual legume species such as Lotus maroccanus Shoen., Ornithopus compressus L., and Trifolium subterraneum L. These forb species, though generally low in cover and composition over the study sites, were virtually absent on the 1982-83 protected shrubby plots, particularly from the densest to 50% oak canopy cover, where plant residue occurred the most. Perennial forbs, however, remained unchanged over protection treatments.

Perennial grass cover was 10% higher on 1982-83 than on 1983 protected plots (Table 5-4). However, all the most abundant

Table 5-4.

Mean Percentage Cover (Cov.) and Composition (Comp.) of the Individual Grass and Forb Species on 1982-83 and 1983 Protected Plots.

Species				
Grasses				
Annual grasses				
Anthoxanthum odoratum L.	9.50	11.40	7.90	10.00
Cynosorus echinatus L.	7.50	9.00	7.30	9.20
Lolium rigidum Gaud.	4.60	5.60	3.90	5.00
Vulpia alopecuros Link	8.60	10.40	7.10	9.00
Others (25 species)*	6.80	8.20	9.50	12.00
Subtotals	37.00	44.50	35.70	46.20
Perennial grasses				
Corynephorus canescens (L.)	1.28	1.54	1.02	1.30
Dactylis glomerata L.	2.28	2.74	2.00	2.52
Oryzopsis miliacea (L.)	0.42	0.50	0.39	0.49
Poa bulbosa L.	1.58	1.90	1.41	1.79
Others (7 species)*	10.54	12.67	0.88	1.14
Subtotals	16.10	19.35	5.70	7.20
Totals	53.10	63.82	41.40	53.40
Forbs				
Annual forbs				
Helianthemum guttatum (L.)	0.28	0.34	0.35	0.45
Loephlingia hispanica L.	1.13	1.36	3.29	4.17
Rumex bucephalophorus L.	7.70	9.26	7.85	9.95
Tolpis barbata (L.)	9.08	10.91	8.22	10.42
Others (43 species)*	5.60	6.73	13.72	17.39
Subtotals	23.79	28.60	33.43	42.37
Perennial forbs				
Paronychia argentea Lam.	1.31	1.58	1.19	1.51
Carlina corymbosa L.	0.32	0.39	0.43	0.55
Halimium libanotis Lange	0.22	0.27	0.27	0.34
Hypocheris radicata L.	0.43	0.52	0.33	0.42
Others (5 species)*	0.93	1.12	0.71	0.90
Subtotals	3.21	3.86	2.93	3.71
Totals	27.00	32.46	36.36	46.08

*See Appendix J

individual species were similar between the two protection treatments. Differences occurred in the proliferation of other species, low in individual cover, on the 1982-83 protected plots. These species also would exist on the 1983 protected plots but were underdeveloped and hidden by taller annual species and, therefore, escaped from being recorded. Also, one year grazing-protection could stimulate perennial species recovery vigor, and development rather than their establishment.

Percent cover of oak seedlings was also higher ($P < .05$) on 1982-83 than on 1983 protected plots (Table 5-1). This occurred, probably, for two main reasons: (1) on recently protected plots, exclosures were built in January 1983 while the highest acorn production was still evident. Plots protected since January 1982, however, could take advantage of the total current acorn crop as well as that part of the production saved from human gathering and livestock losses (consumption and trampling). (2) Mulch accumulation probably enhanced soil moisture and nutrients status and hence increased the rate of seedling success. The higher rate in oak regeneration on the 1982-83 plots may not be due to protection only. Other ecological factors might be associated with the protection effects. Even on the 1982-83 protected plots, the highest population in oak seedlings occurred during the vegetative phase and then declined as the season advanced. This decline was, however, slower on the 1982-83 than on 1983 protected plots.

Herbage production and percent cover of all living ground vegetation, annuals and perennials varied ($P < .10$) between phenological phases due to period of protection (Table 5-5). Herbage yields were a rather consistent 30% higher in all phases on 1982-83 than on 1983 plots. This static increment increase in herbage was probably due to the existing perennial species gaining more and more vigor and progressively dominating the 1982-83 protected plots. This effect was more prominent during the reproductive phase when some annual species started declining in cover. Additionally, during this particular phenological phase, although percent cover of total living ground vegetation as well as that of annuals tended to be similar, under both protection treatments, percent cover of perennials was more than twice higher on 1982-83 than on 1983 plots. The two growing seasons' protection had probably encouraged taller perennial grass species such as *Oryzopsis miliacea* (L.) and *Dactylis glomerata* L. to proliferate and to be systematically recorded. In the one growing season's protected plots, most of individual perennial species were prostrate, underdeveloped, and masked by some dominant maturing annual plants.

Table 5-5.

Effects of One (1983) and Two (1982-83) Growing Seasons' Protection and Plant Phenology on Dry Matter Herbage Yields (DMHYs) and on Percentage Cover of the Total Living Ground Vegetation (VGC), Annuals (A), and Perennials (P)

Phenological Phases	DMHY kg/ha			Percentage Cover: VGC[2]			Percentage Cover: A			Percentage Cover: P		
	1983	1982-83	$S_{\bar{y}}$	1983	1982-83	$S_{\bar{y}}$	1983	1982-83	$S_{\bar{y}}$	1983	1982-83	$S_{\bar{y}}$
Juvenile	276a[1]	369b	13	77a	82b	0.7	68a	57b	1.6	9a	24b	2.2
Vegetative	697a	867b	24	82a	87b	0.7	74a	66b	1.1	8a	20b	1.7
Reproductive	447a	601b	22	77a	80a	0.4	68a	64a	0.6	9a	16b	1.0
$S_{\bar{y}}$	43	51		0.6	0.7		0.7	1.0		0.1	0.8	

[1]Means in each row and within each category followed by different letters differ ($P < .10$).

[2]VGC is the sum of annuals, perennials and biennals.

Conclusions

The complete exclusion of grazing animals, in a portion of the mature Mamora cork oak Forest, for a one year period led quickly to an increase in herbage production and in total living ground vegetation cover associated with changes in percent cover of plant groups and that of individual species. However, increments and directions of changes in all these vegetation components varied from one oak canopy cover class to another, between sites, and between seasons and were likely and mostly related to mulch accumulation.

The precise pathway(s) by which mulch affected understory herbage production and attributes is not completely understood. Nevertheless, Rossiter (1966) postulated that plant residue on the soil surface influences evaporation, soil temperature, activity of soil micro-organisms, infiltration, soil structure, and soil nutrients' status.

Two growing seasons' protection from grazing also had encouraged perennial species to develop and oak seedlings to be established. However the high success rate of germinating acorns and seedling growth might have resulted not only from the short term protection but probably from the combination of this factor with other environmental factors.

This study brought together the first definitive information related to the recovery rate of two depleted sites under one year protection from grazing. Extensive application of rest from grazing over all the Mamora Forest may appear to be quite beneficial upon these results. However, combined research should be undertaken so that by the time of the next Mamora management plan (1992) there will be sufficient socio-biological-economic data for its development.

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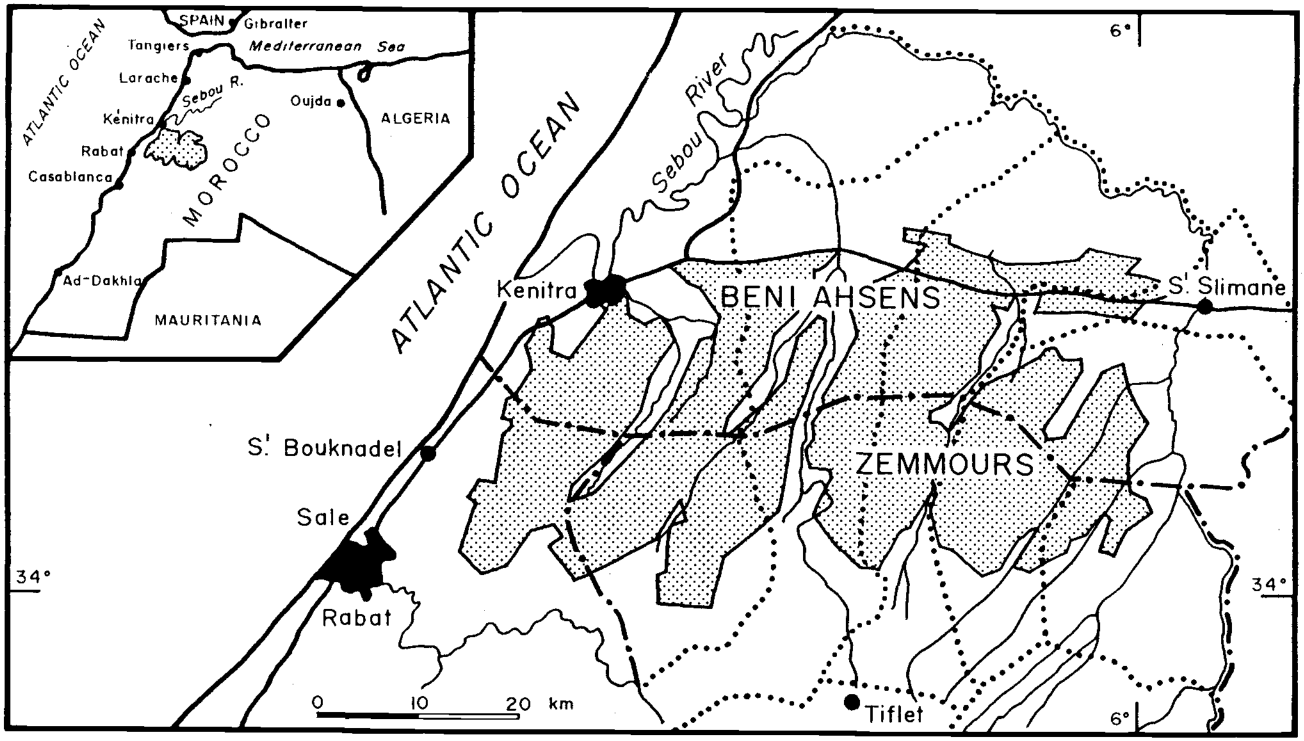
APPENDICES

APPENDICES

K. One and Two Growing Seasons' Protection (P) Effects and Interactions with Site (Si), Oak Canopy Cover (CC), and Plant Phenology (S). The Combined Analysis of Variance Consists of Dry Matter Herbage Yield (DMHY), Living Ground Vegetation (VGC), Grasses (GR), Forbs (FOR), Grasslikes (GL), Shrubs (SHR), Oak Seedlings (TR), Annuals (A), Perennials (P), Biennals (B), Annual Grasses (AGR), Perennial Grasses (PGR), Annual Forbs (AFOR), and Perennial Forbs (PFOR).

Appendix A.

Mamora National Forest Geographical and Administrative Situation.
(Eaux et Forets, 1977)



Mamora National Forest territory

Central Fire-break trench

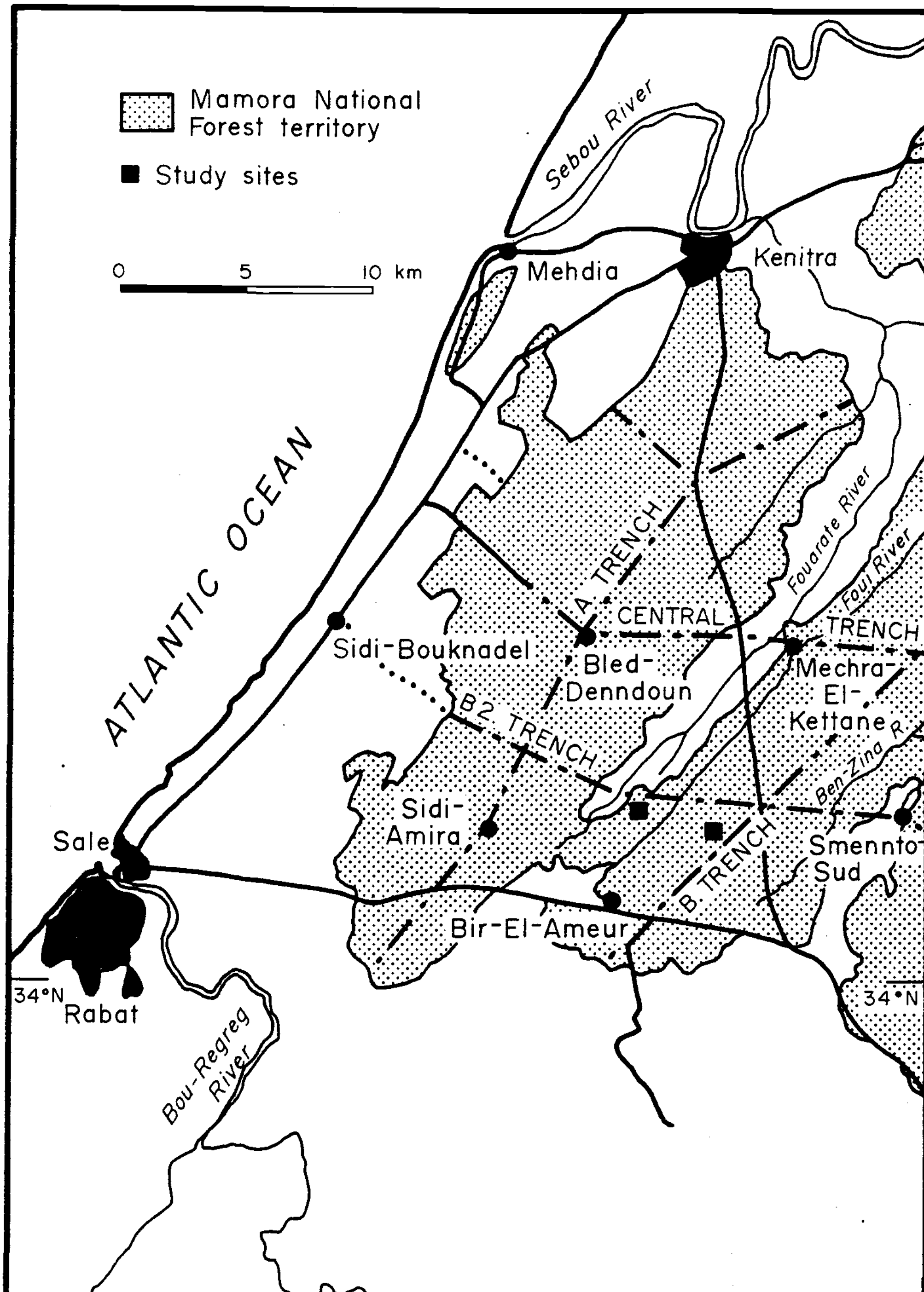
Actual limits of the rural commons

Rivers and springs

Roads

Appendix B

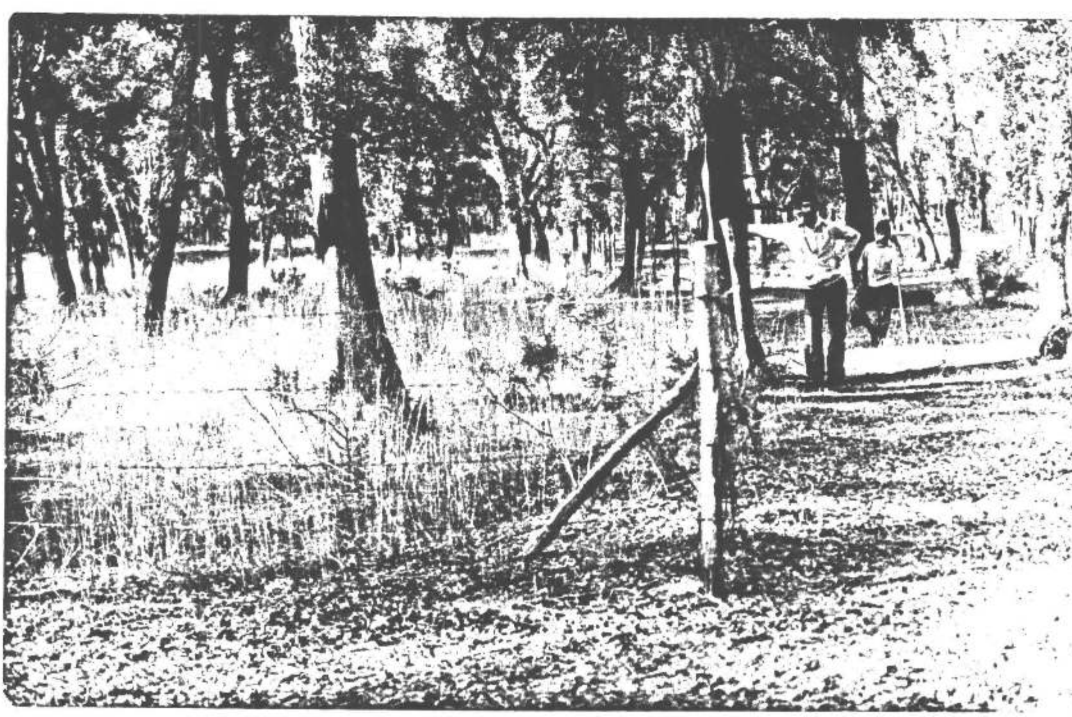
Localization of the Shrubby and Non-shrubby Sites.



Appendix C

Shrub (Genista linifolia L.) Layer Features on the Shrubby (G) and Non-shrubby (NG) Sites

C-a. Shrubby site plot (G).

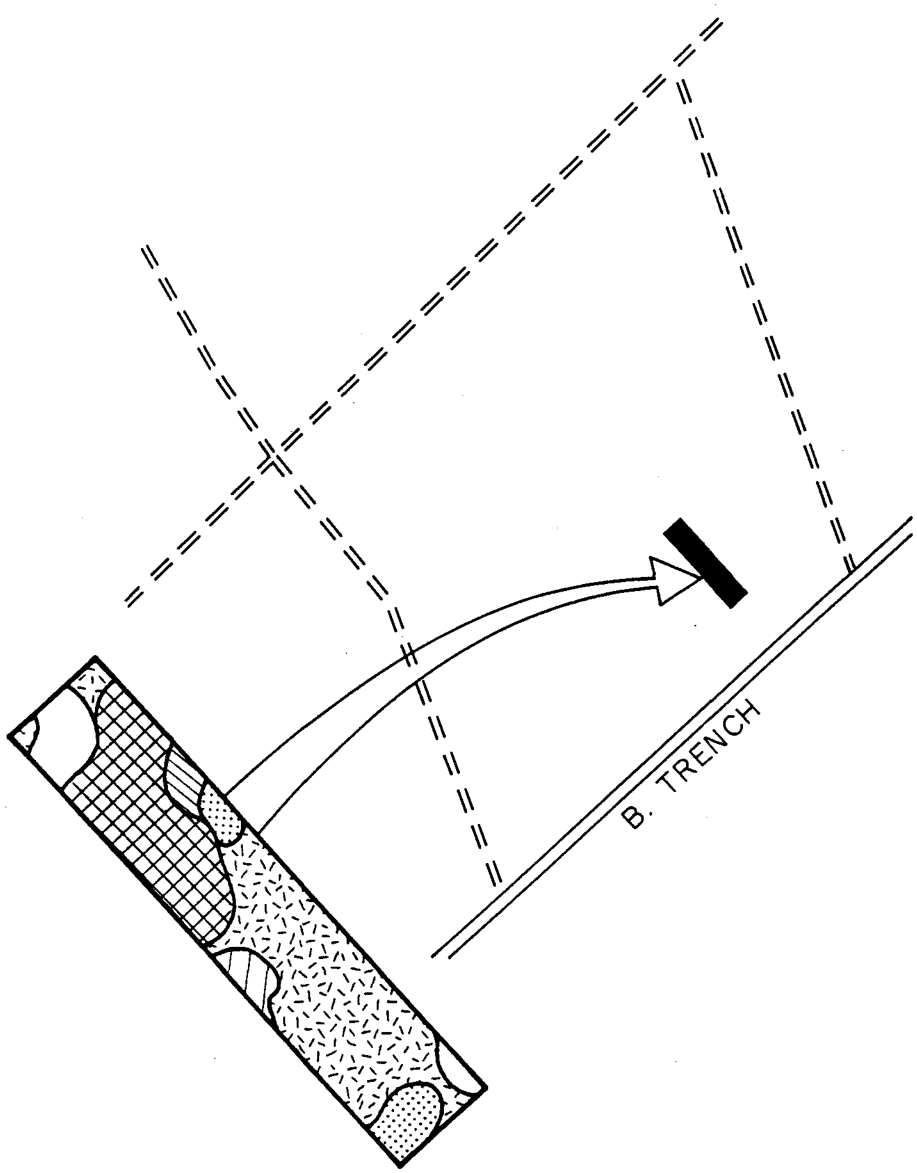


C-b. Non-shrubby site plot (NG).

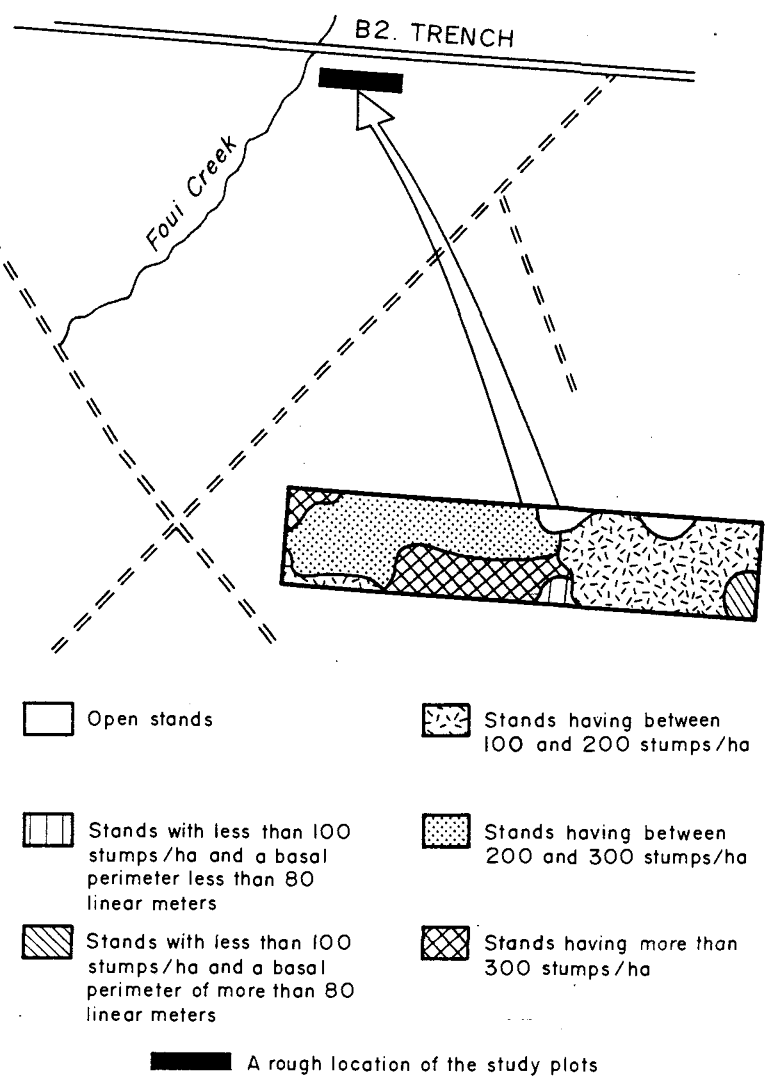
Appendix D.

Cork Oak Density Classes Surrounding the Two Study Site Plots. (Eaux et Forets, 1973).

D-a. Shrubby site localization; Total area 250 ha; Scale 1:20,000
Study plot = 100 x 500m



D-b. Shrub (Genista linifolia L.) Layer Features on the Shrubby (G) and Non-Shrubby (NG) Sites



Appendix E.

Climatological Data of G and NG Sites and of Two Nearest Other Stations (Rabat-Sale, Kenitra)*. M, m and P are mean monthly maximum temperature, mean monthly minimum temperature, and mean monthly precipitation

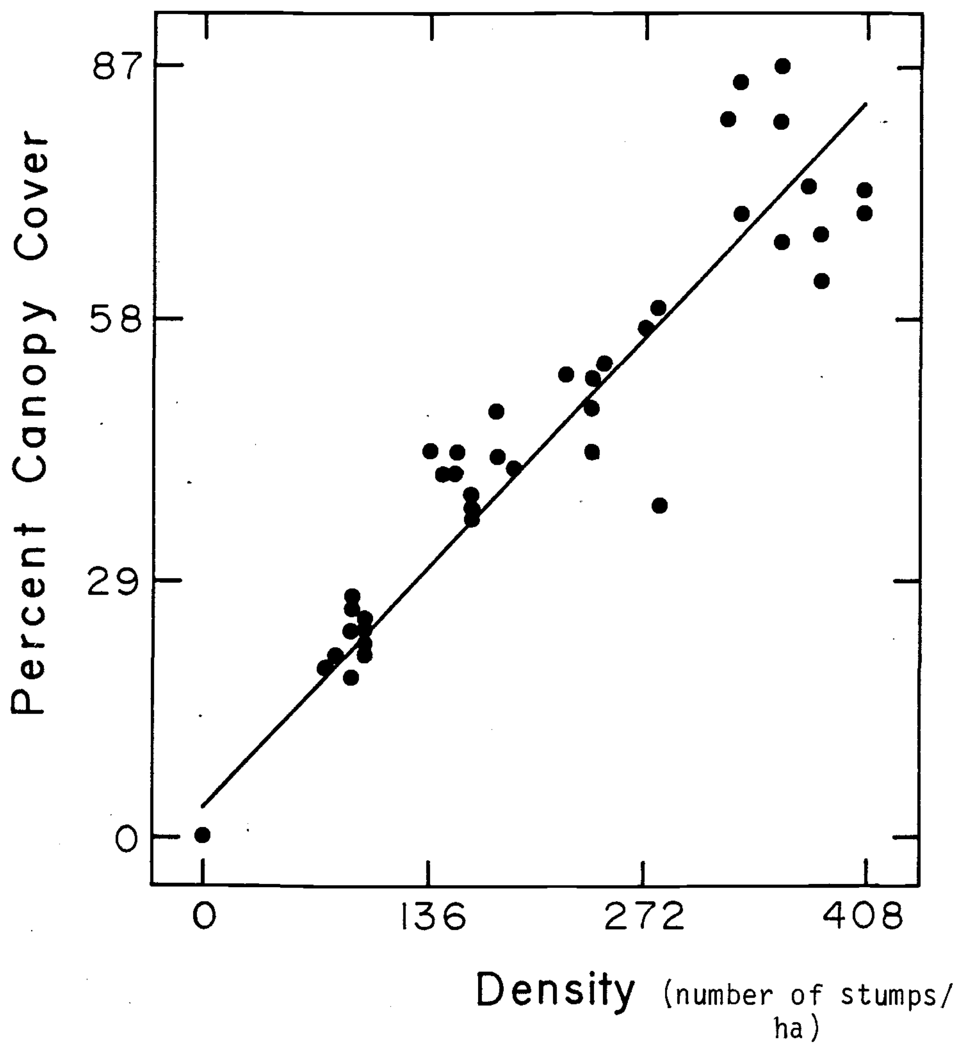
* Data provided by Service of Climatology, Casablanca-Anfa, Morocco.

Station	M,m,P	Year	J	F	M	A	M	Months J	J	A	S	O	N	D	Means or Totals
	P	1980	123.2	2.0	114.1	54.3	20.9	0.3	0.0	0.0	4.7	47.0	113.5	11.5	491.5
		1981	16.8	21.0	36.4	53.5	24.6	0.8	0.0	0.0	3.8	4.2	0.0	125.5	286.6
		1982	89.2	62.3	35.8	106.4	2.6	0.3	1.0	0.0	2.8	52.6	56.0	68.9	477.9
		1983	0.0	146.2	51.4	40.4	14.1	0.0	0.0	0.1	0.9	5.2	76.7	109.9	444.9
Rabat-Sale	M	1980	17.2	17.9	19.2	21.2	21.2	24.5	27.4	28.0	28.8	24.6	11.7	16.7	22.2
		1981	16.2	17.4	20.5	20.6	20.6	24.9	26.1	25.7	25.6	24.8	25.3	18.9	22.1
		1982	17.8	18.3	20.0	14.1	14.1	24.5	25.9	27.3	25.3	21.8	19.7	16.1	20.9
		1983	17.4	16.3	22.0	21.3	21.3	25.6	24.7	25.3	27.1	26.5	22.2	18.7	22.4
	m	1980	7.2	8.3	9.3	10.5	12.9	15.9	16.6	17.9	18.4	14.6	10.8	6.6	12.4
		1981	5.4	7.3	10.7	11.4	12.3	16.8	17.7	17.5	16.7	14.9	12.8	11.4	12.9
		1982	8.8	9.2	9.4	11.9	22.7	16.4	17.3	18.2	17.4	10.9	10.9	7.1	13.5
		1983	6.3	8.5	11.3	11.8	11.6	16.3	16.7	17.5	17.9	14.4	14.4	9.5	13.1
	P	1980	118.9	6.3	138.9	30.9	32.5	0.2	0.0	0.0	14.5	73.9	107.7	27.2	551.0
		1981	29.0	24.8	27.2	62.6	39.1	2.0	0.0	0.0	11.5	6.6	0.0	155.0	357.8
		1982	107.8	49.9	37.2	110.8	5.0	0.0	0.4	0.0	0.7	27.7	110.6	50.8	500.9
		1983	0.0	231.2	32.3	30.8	3.1	0.0	0.0	0.5	0.0	5.1	93.4	148.0	544.4
Kenitra	M	1980	17.0	18.0	18.8	21.6	22.1	25.5	28.6	28.9	29.8	25.1	20.0	17.0	22.7
		1981	16.4	17.8	21.0	19.8	21.3	26.1	27.0	26.7	26.4	25.4	26.2	19.2	22.8
		1982	17.9	18.4	20.1	20.9	23.3	25.0	26.4	28.2	26.2	22.4	20.0	16.5	22.1
		1983	17.6	16.9	21.8	22.0	21.1	26.3	25.3	26.1	28.0	27.4	22.9	19.0	22.9
	m	1980	5.9	8.2	9.0	10.7	13.3	16.7	17.7	18.7	19.2	14.5	10.5	6.3	12.6
		1981	4.5	6.4	10.2	11.5	12.8	17.6	18.6	18.6	17.0	14.9	11.4	11.0	12.9
		1982	7.6	8.6	9.4	11.9	14.1	16.7	17.7	18.7	18.3	12.6	10.4	6.2	12.6
		1983	5.0	8.2	10.7	11.4	12.0	16.7	16.9	17.9	18.3	14.5	13.8	8.3	12.8

Site	M,m,P	Year	J	F	M	A	M	Months J	J	A	S	O	N	D	Means or Totals
	P	1982	84.6	46.5	10.7	111.4	0.1	0.0	0.0	0.0	5.1	54.6	63.6	64.8	441.4
		1983	0.0	251.4	48.8	46.4	16.8	0.0	0.0	0.2	1.1	6.1	77.8	111.1	559.7
NG	M	1982	16.9	17.7	19.2	19.7	13.7	24.1	25.9	26.9	24.9	22.1	18.9	17.2	20.6
		1983	18.2	16.1	22.3	22.0	21.1	24.9	24.4	25.4	27.0	25.7	22.4	18.3	22.3
	m	1982	8.1	8.8	9.0	11.5	20.9	15.8	15.9	17.8	18.1	13.1	10.8	6.9	13.1
		1983	6.1	8.8	10.8	11.6	11.6	15.9	16.4	17.8	17.8	16.1	15.4	9.8	13.2
	P	1982	84.5	52.2	41.1	58.2	9.4	0.0	0.0	0.0	6.0	68.5	54.0	77.1	451.0
		1983	0.0	244.1	36.2	34.1	2.9	0.0	0.0	0.0	0.0	6.7	110.1	151.2	585.2
G	M	1982	17.7	18.1	21.2	21.9	22.6	24.7	25.9	28.0	25.7	21.7	20.6	16.2	22.0
		1983	16.8	16.8	22.0	22.0	21.0	25.9	25.7	25.8	28.8	27.2	23.1	20.1	22.9
	m	1982	7.3	8.4	8.7	12.2	12.7	15.8	16.8	17.9	18.3	11.9	11.4	6.7	12.3
		1983	4.1	6.7	11.2	11.2	11.7	17.1	17.9	17.8	18.7	13.7	13.9	8.1	12.7

Appendix F.

Relationship (r^2 = .92) Between Oak Tree Canopy Cover (%) and Density (Number of Stumps/ha). % Canopy Cover = 3.7 + .2 Density.



Appendix G.

The Combined Analysis of Variance Consists of Dry Matter Herbage Yield (DMHY), Living Ground Vegetative Cover (VGC), Grasses (GR), Forbs (FOR), Grasslikes (GL), Shrubs (SHR), Oak Seedlings (TR), Annuals (A), Perennials (P), Biennals (B), Annual Grasses (AGR), Perennial Grasses (PGR), Annual Forbs (AFOR), and Perennial Forbs (PFOR). 1982,1983

		Mean Squares													
Source	D.F.	DMHY	VGC	GR	FOR	GL	SHR	TR	A	P	B	AGR	PGR	AFOR	PFOR
Sites (Si)	1	3653710.0**	1077.5***	49.7	363.2*	0.71*	68.01*	0.060*	577.6*	98.2	1.21*	68.5	7.1	400.6*	5.8
Error a	2	83170.0	10.4	17.5	18.4	0.08	7.50	0.007	64.8	86.2	0.13	84.2	227.8	42.6	7.7
Years (Y)	1	1188750.0**	338.7*	7155.7***	11296.4***	0.23	24.37**	0.060*	1395.6**	332.6***	0.53	4238.2***	306.1**	10044.1***	29.6**
Y x Si	1	134885.0	204.3	220.0*	524.8*	0.94*	31.10***	0.060*	745.7**	16.5	3.47*	136.2	11.0	370.8**	7.7
Error b	2	21861.0	39.5	26.1	52.0	0.11	0.20	0.007	17.5	2.3	0.32	31.5	7.3	17.5	0.8
Oak Canopy (CC)	4	132491.0**	1819.3***	4169.3***	920.2***	0.34	2.78	0.010	1318.7***	58.3	2.37	3023.6***	82.5	903.2***	1.7
CC x Si	4	80734.0	14.7	12.6	19.2	0.73**	3.10	0.013	49.6*	50.7	3.54	119.2*	80.2	10.2	9.8
CC x Y	4	95416.0	174.9***	51.5	249.7***	0.32	1.80	0.013	195.3***	14.4	1.38	30.9	61.2	253.6***	1.2
CC x Si x Y	4	53015.0	13.4	75.1	100.3*	0.26	2.90	0.013	77.4**	78.3**	6.45	94.5	19.6	127.2**	5.2
Error c	16	40965.0	27.8	60.0	38.2	0.19	1.50	0.010	19.3	25.8	3.15	41.4	36.7	31.2	7.3
Seasons (S)	2	1276750.0***	498.3***	1958.4***	505.4***	1.20*	0.15	0.020	315.9***	14.6	3.62	1193.1***	110.0**	318.9***	11.0
S x Si	2	430159.0***	152.7***	30.0	309.7***	0.29	0.73	0.020	161.9***	0.7	4.09*	11.0	31.4	372.7***	4.5
S x Y	2	108986.0***	186.8***	299.6***	28.5	0.06	4.00	0.020	61.9*	28.6	2.21	438.5***	6.0	35.8	7.8
S x CC	8	22936.0	4.0	58.3	62.6	0.40	3.40	0.022	38.4	44.1*	3.09*	81.0	58.9*	66.4	3.8
S x Si x Y	2	86335.0***	37.0*	308.2***	346.8***	0.25	3.40	0.022	2.4	49.3	0.73	137.3	44.8	250.2***	11.6
S x CC x Y	8	14418.0	24.8	72.6	28.1	0.11	1.20	0.023	44.5*	28.2	1.11	68.4	48.9	34.3	5.1
S x Si x CC	8	24347.0	13.8	29.4	51.8	0.58	3.00	0.023	26.2	46.4**	0.58	23.0	58.7*	56.3	10.4
S x Si x CC x Y	8	9469.0	7.0	29.9	19.5	0.11	2.80	0.023	17.5	10.0	1.90	51.7	27.3	25.8	2.6
Error d	40	16257.0	13.0	38.5	42.1	0.38	2.20	0.013	21.3	20.4	1.61	73.0	27.9	44.3	10.0
Total	119														

* Significant at the .10 level
** Significant at the .05 level
*** Significant at the .01 level

Appendix H.

Soil Physical and Chemical Properties for
Shrubby (G) and Non-Shrubby (NG) Sites

		Physical Particle size (%)			Chemical Exchangeable cations (meq/100g)										
Site	Soil depth -cm-	Sand	Silt	Clay	pH	K	Ca	Mg	Na	OM %	C %	N %	C:N	P %	H_2O %
NG	0-10	91.98	4.10	3.91	5.2	.12	1.12	.44	.58	1.69	1.31	.17	8:1	.05	5.91
	10-20	91.56	4.49	3.93	5.2	.17	1.62	.37	.60	1.60	1.02	.20	5:1	.04	4.10
	20-25	92.08	4.25	3.66	5.4	.16	1.00	.29	.59	1.74	.98	.43	2:1	.05	3.59
G	0-10	91.58	4.60	3.80	5.5	.38	1.57	.45	.48	5.05	5.67	.53	10:1	.07	10.26
	10-20	92.40	4.37	3.68	5.6	.20	2.31	.83	.31	3.88	2.59	.73	3:1	.03	4.33
	20-25	86.24	6.95	6.80	5.5	.48	3.75	.41	.48	3.62	1.87	.84	2:1	.19	3.53

Appendix I.

Analysis of Variance of the Herbage Understory Nutritive Quality at Three Collection Dates of 1983

		Mean Squares					
Source of Variation	D.F.	Crude protein	Crude fiber	Fat	Dry Matter	Ash	Nitrogen-free Extract
Sites (Si)	1	1521.38***	499.16***	1.80*	1534.80***	9.460***	428.27**
Error a	2	7.30	2.40	.17	4.50	.001	15.80
Oak Canopy Class (CC)	4	64.46***	324.36***	18.40***	279.60***	2.34*	31.54
CC x Si	4	5.14	33.52**	.13*	59.10***	2.10*	29.89
Error b	8	4.80	7.15	.04	7.75	.70	12.35
Seasons (S)	2	373.88***	326.23***	3.47***	20616.60***	87.42***	137.40***
S x CC	8	6.11	10.78	.57***	107.64***	.77	21.03
S x Si	2	62.29***	21.79	.46***	216.89***	20.83***	73.95**
S x CC x Si	8	2.62	3.24	.15**	73.86***	.59	7.37
Error c	20	4.70	11.84	.06	6.85	1.22	13.35
Total	59						

* Significant at the .10 level
** Significant at the .05 level
*** Significant at the .01 level

Appendix J.

List of Plant Species Recorded in both Shrubby (G) and Non-shrubby (NG) Sites, over all Phenological Phases, in both Years (1982,1983), and under the Five Oak Canopy Cover Classes.

Genus Name[5]	Scientific Name Ssp. Epithet and Authorship	Varietal Epithet and Authorship	Form Epithet and Authorship	Family Name	Common Name[3]	Life Form[1]	Life Span[2]
GRASSES							
Agrostis	elegans Thore	-	-	Gramineae	-	Th	A
Ammochloa	involucrata Murb.	-	-	"	-	"	"
Anthoxanthum	odoratum ssp. ovatum Trabut	-	Mamorae Lindb.	"	Annual vernal grass	"	"
Avena	Longiglumis Dur.	genuina Maire	glabrifolia Malz.	"	-	"	"
Brachypodium	distachyum (L.)	genuinum Guss	typicum Pamp.	"	-	"	"
Bromus	mollis L.	-	-	"	Soft brome grass	"	"
Bromus	rigidus R. sep. maximus Desf.	-	-	"	-	"	"
Briza	maxima (L.)	-	pubescens (Nic.)	"	Pearl grass	"	"
Corynephorous	canescens (L.)	-	-	"	Grey hairgrass	H	P
Cynodon	Dactylon (L.)	genuinus Maire	-	"	Bermuda grass	G	"
Cynosorus	echinatus L.	-	-	"	Rough dog's tail grass	Th	A
Dactylis	glomerata L.	hispanica Koch	-	"	Cock foot grass	H(G)	P
Festuca	caerulescens Desf.	-	-	"	-	"	"
Festuca	paniculata ssp. spadicea L.	baetica (Hack.)	-	"	-	"	"
Gaudinia	fragilis ssp. eu-fragilis Maire	-	-	"	-	Th	A
Holcus	lanatus L.	altissimus Coss.	-	"	Duffel grass	G	P
Hyparrhenia	hirta (L.)	-	-	"	Indian lemon grass	H	"
Koeleria	pubescens (Lam.)	valdepiloza (Hack.)	-	"	-	Th	A
Lagurus	ovatus L. ssp. communis Mess.	-	-	"	Foxtail	"	"
Lolium	multiflorum ssp. Gaudinii (Parl.)	-	laeviculme (Maire)	"	Bearded rye-grass	"	"
Lolium	rigidum Gaud	-	genuinum	"	Rye grass	"	"
Oryzopsis	miliacea (L.)	-	typica Maire	"	-	H(Ch)	P
Panicum	repens L.	-	-	"	-	G	"
Poa	bulbosa L. ssp. eu-bulbosa Hayek	-	vivipara	"	Bulbous meadow grass	H	"
Stipa	gigantea Link	genuina Maire	-	"	-	H(G)	"
Trisetaria	panicea (Lam.)	Typica (Domin)	panicea Maire	"	-	Th	A
Vulpia	alopecuros Link	-	Lanata Boiss	"	-	"	"
FORBS							
Ajuga	Iva (L.)	genuina Deb.	elegans Maire	Labiatae	Musky bugle	H	P
Anagalis	arvensis L. ssp. latifolia (L.)	-	-	Primulaceae	Bird's tongue	Th	A
Andryala	integrifolia L. ssp. eu-integrif. Maire	typica Maire	-	Synantheraceae	Downy sowthistle	H(b)	A or B
Antirrhinum	Oruntium L.	-	-	Scrophulariaceae	Calf snout	Th	A
Anthyllis	hamosa Desf	-	-	Leguminosae	-	"	"

Genus Name[5]	Scientific Name Ssp. Epithet and Authorship	Varietal Epithet and Authorship	Form Epithet and Authorship	Family Name	Common Name[3]	Life Form[1]	Life Span[2]
FORBS							
Arenaria	marginata Brot. ssp. eu-marg. Maire	macrosperma Maire	rodantha Maire	Caryophyllaceae	-	Th	A
Armeria	mauritanica Wallr.	eu-mauritanica Sauv.	-	Plumbaginaceae	-	H	P
Asterolinum	Linum-stellatum (L.) Duby	-	-	Primulaceae	Flax star	Th	A
Astragalus	algarbiensis Coss.	-	-	Leguminosae	-	"	"
Biscutella	didyma L.	-	-	Cruciferae	Buckler mustard	"	"
Bunium	Fontanesii (Pers.) Maire	eu-mauritanicum Maire	-	Umbelliferae	-	G	P
Carduus	myriacanthus Salzm.	-	-	Synantheraceae	-	Th	A
Carlina	corymbosa L.	-	-	"	-	H	P
Centaurea	pullata L.	typica Maire	pullata Maire	"	-	Th	A
Cerastium	glomeratum Thuill.	-	apetalum Dum.	Caryophyllaceae	Mouse-ear chickweed	"	"
Chenopodium	murale L.	-	-	Chenopodiaceae	Wall goose-foot	"	"
Chrysanthemum	viscido-hirtum (Schott)	-	-	Synantheraceae	-	"	"
Coronilla	repanda (Poiret) ssp. eu-repanda	-	typica Maire	Leguminosae	-	"	"
Cotyledon	breviflora (Boiss) ssp. Salzmani	rhodantha	-	Crassulaceae	-	Th(s)	"
Echium	plantagineum L.	plantagineum Sauv.	-	Boraginaceae	-	Th	"
Erodium	bipinnatum Willd.	Huguetii	-	Geraniaceae	-	"	"
Euphorbia	Falcata L.	Acuminata (Lam.)	-	Euphorbiaceae	-	"	"
Evax	pygmaea (L.) ssp. pygmae nom.	maroccana Braun-Bl.	-	Synantheraceae	-	"	"
Filago	gallica L.	-	-	"	Corn cudweed	"	"
Galium	viscosum Vahl ssp. Bovei (Boiss)	hesperium Maire	-	Rubiaceae	-	Th	A
Geranium	molle L.	-	-	Geraniaceae	Culverfoot	"	"
Geranium	Robertianum L. ssp. purpureum	-	-	"	Adder's tongue	"	"
Haliumium	Libanotis Lange	-	-	Cistaceae	-	Ch	P
Helianthenum	guttatum (L.)	-	-	"	Spotted rockcist	Th	A
Hypochoeris	radicata L. ssp. eu-rad. Maire	heterocarpa Moris	-	Synantheraceae	Cat's ear	H	P
Linaria	bipartita (Vent.) ssp. linogrisea Maire	typica Maire	-	Scrophulariaceae	Cloven-flowered toad flax	Th	A
Loeflingia	hispanica L. ssp. bactica Maire	micrantha Maire	-	Caryophyllaceae	-	Th	A
Lotus	arenareus Brot.	-	-	Leguminosae	-	"	"
Lotus	maroccanus Shoen.	-	-	"	-	"	"
Lupinus	lutheus L.	-	-	"	Spanish violet	"	"
Malcolmia	patula (Lag.) ssp. Broussonetii (DG)	-	-	Cruciferae	-	"	"
Medicago	truncatula Gaertn	narbonensis Ser.	-	Leguminosae	Hedge-hog	"	"
Ononis	Maweana Ball	Font-Queri Pau	-	"	-	"	"
Ormenis	mixta (L.) ssp. multicaulis Maire	-	-	Synantheraceae	-	Ch(b)	"
Ornithopus	compressus L.	-	-	Leguminosae	-	Th	A
Ornithopus	roseus Shoen.	-	-	"	-	"	"
Paronychia	argentea Lam.	argentea nom.	-	Caryophyllaceae	Mountain Knotgrass	H	P
Plantago	coronopus ssp. eu-coronopus Pilger	Mamorae nov.	-	Plantaginaceae	Buck's horn	Th	A
Polycarpon	tetraphyllum L.	vulgare Willk.	-	Caryophyllaceae	Four-leaved allseed	"	"
Ranunculus	paludosus Poir.	acutifolius Freyn	-	Ranunculaceae	-	H	P

Genus Name[5)]	Scientific Name Ssp. Epithet and Authorship	Varietal Epithet and Authorship	Form Epithet and Authorship	Family Name	Common Name[3)]	Life Form[1)]	Life Span[2)]
FORBS							
Rumex	bucephalophorus L. ssp. gallicus (Steinh)	Subaegaeus Maire	-	Polygonaceae	-	Th	A
Scorpiurus	muricata L. ssp. sulcata (L.)	-	-	Leguminosae	Prickly caterpillar	"	"
Senecio	leucanthemifolius Poiret ssp. Poiretiarus Maire	-	-	Synantheraceae	-	"	"
Sherardia	arvensis L.	-	-	Rubiaceae	Corn madder	"	"
Silene	gallica L.	Silvestris	-	Caryophyllaceae	Little brown pigs	"	"
Sonchus	oleraceus L.	-	-	Synantheraceae	Hare's colewort	"	"
Tillaea	muscosa L.	genuina Maire	-	Crassulaceae	-	"	"
Tolpis	barbata (L.) ssp. eu-barbata	macrantha Maire	-	Synantheraceae	Yellow hawkweed	"	"
Trifolium	angustifolium L. ssp. eu-angusitfolium Maire	-	-	Leguminosae	-	"	"
Trifolium	resupinatum L.	-	-	"	Annual strawberry clover	"	"
Trifolium	subterraneum L.	-	-	"	Subclover	"	"
Urginea	maritima (L.)	stenophylla Maire	-	Liliaceae	-	G	P
Vicia	tetrasperma (L.) ssp. pubesceus Ash.	eriocarpa Rouv	-	Leguminosae	Common Wood Vetch	Th	A
GRASSLIKES							
Carex	distachya Desf.	-	-	Cyperaceae	-	H(G)	P
Chamaerops	humilis L.	typica Maire	-	"	Dwarf fan palm	Ch	"
Juncus	capitatus Weig.	-	-	Juncaceae	-	Th	A
SHRUBS							
Asparagus	albus L.	-	-	Liliaceae	-	NPh	P
Asphodelus	microcarpus Salz.	-	-	"	-	NPh(G)	
Cistus	salviifolius L.	-	-	Cistaceae	-	Ch(NPh)	"
Genista	linifolia L.	angustifolia (Webb)	-	Leguminosae	-	NPh	"
Lavandula	Stoechas L. ssp. Linneana Roz.	-	-	Labiateae	Cast me down	Ch(NPh)	"
Retama	monosperma (L.)	-	-	Leguminosae	-	NPh	"
Thymelaea	lythroides Barr. et murb.	-	-	Thymelaeaceae	-	"	"
Ulex	Boivinii Webb.	-	-	Leguminosae	-	Ch(NPh)	"
TREES							
Pirus	mamorensis Trabut	eu-mamorensis Maire	-	Rosaceae	-	Ph	P
Quercus	suber L.	-	-	Fagaceae	Cork oak	"	"

1.) Life forms were assigned according to Sauvage nomenclature (1961a). Ph: Phanerophytes; NPh: Nanophanerophytes; Ch: Chamaephytes; H: Hemicryptophytes; G: Geophytes; Th: Therophytes; b: Biennal; s: Crassulescent; C: Uncertain.

2.) Life spans were assigned according to the nomenclature used in U.S. Range Surveys. A: Annual; B: Biennal; P: Perennial.

3.) Common names were assigned according to the nomenclature used by Gerth Van Wijk (1911).

4.) Growth forms were assigned according to the U.S.D.A.'s nomenclature. Grasses; Forbs (broad-leaved flowering herbs plus ferns and allied familes); Grasslikes (Sedges and rushes); Shrubs; Trees.

5.) Genus name, scientific name ssp. epithet and authorship, varietal epithet and authorship, form epithet and authorship, and family name were assigned according to Sauvage (1961a).

Appendix K.

One and Two Growing Seasons' Protection (P) Effects and Interactions with Site (Si), Oak Canopy Cover (CC), and Plant Phenology (S). The Combined Analysis of Variance Consists of Dry Matter Herbage Yield (DMHY), Living Ground Vegetative Cover (VGC), Grasses (GR), Forbs (FOR), Grasslikes (GL), Shrubs (SHR), Oak Seedlings (TR), Annuals (A), Perennials (P), Biennals (B), Annual Grasses (AGR), Perennial Grasses (PGR), Annual Forbs (AFOR), and Perennial Forbs (PFOR).

		Mean Squares													
Source	D.F.	DMHY	VGC	GR	FOR	GL	SHR	TR	A	P	B	AGR	PGR	AFOR	PFOR
Protection (P)	1	579149***	492.1***	4082.6***	2112.7***	0.40	6.6	3.30***	1792.66***	4108.8***	0.72	51.3	3312.6***	2788.6***	38.9*
P x Si	1	72077*	3.0	111.1	285.5***	0.03	6.9	0.40	65.31	94.0**	0.08	227.9*	2.8	291.9**	2.3
P x CC	4	70188**	36.7***	283.8***	181.8***	0.03	2.6	0.30	43.64	38.8	0.50	129.1	86.5	51.2	45.3***
P x S	2	76751**	10.9**	273.6***	224.8***	0.15	0.1	0.28	121.64**	153.2***	1.00	176.3*	65.1	171.0*	8.6
P x CC x Si	4	91049***	7.1*	33.9	47.8	0.26	4.2	0.28	80.31*	49.4*	0.70	49.6	7.5	51.5	0.7
P x S x Si	2	25860	113.8***	342.4***	138.4**	0.65*	0.7	0.07	454.11***	844.6***	0.07	136.4	414.1***	27.6	47.0**
P x S x CC	8	18089	11.1***	62.2	49.2	0.66**	2.8	0.46**	25.96	32.7	1.34	28.8	55.2	57.3	10.9
P x S x Si x CC	8	30608	40.2***	40.1	60.5*	0.48**	1.4	0.45*	87.38**	45.4*	2.11	62.3	67.5	65.1	17.7
Error	30	22361	3.3	42.7	27.7	0.21	3.5	0.20	31.38	21.4	1.31	65.5	42.8	59.4	9.4
Subtotal	60														
Total	119														

* Significant at the .10 level
** Significant at the .05 level
*** Significant at the .01 level