PD-AAR-260
ISN: 8[illegible]

PURDUE UNIVERSITY
International Education and Research
International Programs in Agriculture

IE&R

IPIA

PORTUGAL UNIVERSITY INSTITUTES DEVELOPMENT PROJECT

(Contract AID/NE-C-1701)

REPORT ON
SHORT-TERM STAFF ASSIGNMENT

Submitted by
DR. STEPHEN C. BUNTING
Range Resources Department
University of Idaho

July 6, 1984 - August 3, 1984

PORTUGAL UNIVERSITY INSTITUTES DEVELOPMENT PROJECT

(Contract AID/NE-C-1701)

REPORT ON

SHORT-TERM STAFF ASSIGNMENT

AT THE

INSTITUTO UNIVERSITARIO DE TRAS-OS-MONTES E ALTO DOURO (IUTAD)

VILA REAL, PORTUGAL

July 6, 1984 - August 3, 1984

Submitted by

DR. STEPHEN C. BUNTING
Range Resources Department
University of Idaho

TABLE OF CONTENTS

INTRODUCTION 1

SUMMARY OF ACTIVITIES 2

OBSERVATIONS AND RECOMMENDATIONS 3
Current Research 3
Future Research 5
University and Faculty Development 8

APPENDICES
Appendix A--Outline of Paper Developed by Francisco Rego and Stephen C. Bunting

Appendix B--Dissertation Research Study Plan of Francisco Rego

Appendix C--Approval of Program for Doctoral Degree of Francisco Rego

PORTUGAL UNIVERSITY INSTITUTES DEVELOPMENT PROJECT
(Contract AID/NE-C-1701)

Report on
Short-term Staff Assignment

Submitted by
Dr. Stephen C. Bunting
Range Resources Department
University of Idaho

July 6, 1984 - August 3, 1984

INTRODUCTION

This visitation to the Instituto Universitario de Tras-os-Montes e Alto Douro (IUTAD) was a follow-up to the initial visit in 1982. The general objective was to review the ongoing research being conducted by Eng. Francisco Rego on the use of prescribed fire in the pine forests of northern Portugal. Eng. Rego is currently on the IUTAD faculty and will use a portion of this research to fulfill the requirements of a Ph.D. degree at the University of Idaho. I feel that Eng. Rego has made excellent progress and will make valuable contributions in the future.

Specific objectives of the visit included: 1) Review the current fire research being conducted by IUTAD, 2) Continue development and evaluation of the fire management program being conducted by the Portuguese Forest Service in cooperation with IUTAD, 3) Review material currently taught in the forest range management course (Silvopastoricia), and 4) investigate the potential for fire research in other vegetation types of Portugal.

SUMMARY OF ACTIVITIES

July 7

Arrive in Lisbon

July 9 - 13

Visited with AID personnel in Lisbon. Sampled vegetation plots with Eng. F. Rego at St. Tome, Serra do Marao and Amarante.

July 16 - 20

Continued vegetation sampling at Vieira do Minho. Summarized vegetation data in order to determine whether or not unburned sites needed to be sampled every year in future. Summarized plant productivity data and began development of a sampling strategy to estimate this parameter. Outlined a paper to be authored by Eng. F. Rego and myself on Portuguese pastoral systems. This paper will be submitted to Rangelands. (See Appendix A)

July 23 - 27

Met with Eng. Jose Moreira da Silva of the Portuguese Forest Service to observe prescribed burned areas of previous years in Minho. There is currently a bark beetle (Ips) outbreak in some forests of this region. It has been suggested by some that there is a relationship between the bark beetles and fire. We assisted Dr. Maria Teresa Cabral in sampling infected trees for beetles.

The course outline of Silvopastoricia was reviewed. A sampling system to establish the relationship between shrub age and productivity was developed and tested.

July 30 - August 3

Met with Eng. J. Moreira da Silva in Porto to discuss continued use of prescribed burning by the Forest Service.

Traveled to Serra da Estrela in order to observe the high elevation vegetation of that region. Met with the Forest Service in Manteigas to discuss the potential for using prescribed fire. Observed recent wildfire that occurred in Douglas-fir *(Pseudotsuga menziesii)*. Discussed post-fire rehabilitation, needed research and the potential for using fire to prevent the recurrence of these types of fires.

Met with Eng. Joao Bugalho, Director, Wildlife Department, Forest Service, Lisbon. Toured Tapada de Mafra National Park to observe the use of prescribed burning being conducted there and to discuss the potential for other types of research at that preserve.

August 4

Leave Lisbon

OBSERVATIONS AND RECOMMENDATIONS

Current Research

The research that was initiated during the first short-term visit has progressed well under the direction of Eng. F. Rego. Research plots have been established with the cooperation of the Forest Service in four locations in Tras-os-Montes and Minho. At each location, sample plots have been prescribed burned during the fall of 1982 and the spring of 1983. In addition, unburned control plots were also established. These plots were sampled prior to treatment and have been resampled annually since that time.

Study sites on four areas which have been prescribed burned in previous years have also been established and sampled. These are in the same general areas as the experimentally burned plots and will be used to more rapidly establish the post-burn successional sequence. A study plan of this research has been written by Eng. Rego (see Appendix B) and accepted by a graduate committee as being suitable for his dissertation research (Appendix C).

A major difficulty that is being encountered is the problem of disturbance to the study sites by the local people. The recently burned areas provide more nutritious forage for animals and these sites are eagerly sought out by the shepherds of the areas. This is a common problem in fire research and was anticipated. We expect the use by animals to decline as the resprouting vegetation becomes older.

During the time I was in Portugal, vegetation sampling was completed for the current year. These data were then summarized in order to check for a potential problem in the sampling method. We were concerned that the annual variation in vegetation composition would increase sampling variation to a point where our method of detecting vegetation change would not be as sensitive as desired. The data from the unburned plots was summarized for two years, 1983 and 1984. When comparing these data very little variation was observed. We concluded that our sampling method was adequately sensitive for our needs. Additionally, it was decided that the annual variation on the unburned sites between years was not large enough to warrant sampling every year and that these plots would be sampled on a less frequent basis.

It was decided while I was in Portugal this time that we needed a more easily obtained estimate of shrub biomass. The current method was

too time consuming and resulted in a poor estimate. Using research previously conducted at IUTAD, we began to develop a regression equation to predict shrub biomass from plant height and cover. The regression equations will be developed for the early post-burn period in which we are sampling. If successful, they will be applied to longer periods and refined as the data become available.

In addition to the vegetation data, soil is being collected on the study sites. Mesofauna is being extracted in order to determine changes in these populations. These soil samples will be analyzed by standard chemical methods by the Soil Fertility Laboratory at IUTAD to determine changes in the fertility of soil as a result of prescribed burning. Initially the soils were sampled every three months after the fire. The data shows that the most rapid changes have occurred during the first two years of the study. It has been decided that since the changes at this time are rather small, that in future years only one sample per year will be taken. Our data shows that late summer is the most appropriate time to sample.

The data collected to this point will be entered into the University of Idaho computer system during the 1985-1986 academic year for preliminary analysis. The vegetation will be resampled during the next summer and this data will then be used as the basis for Eng. Rego's doctoral dissertation.

Future Research

The research needs of Portugal concerning the use of forests and baldios (shrub dominated areas) by domestic livestock are just now beginning to be addressed. The most pressing needs are for solutions

to problems that are resulting from more intensive management of these vegetation types in order to provide more wood and animal products. As management intensifies, the conflicts between the various uses usually become more serious.

Although some initial work has been done to classify the vegetation of northern Portugal, no concerted effort has been attempted to organize the information into a formal classification system. A classification system is useful in predicting the potential productivity of the sites present in the region. These systems are also useful as a framework for data storage and retrieval. As more research is finished, the classification system can be used to determine which sites this information can best be applied.

In Northern America, the most common approach to classification of forest and shrub vegetation has been to use undisturbed vegetation as a measure of site's potential plant community and then relate the successional plant communities to this site's composition. Due to the long history of human occupation and subsequent disturbance in Portugal, this approach would be difficult if not impossible. I would suggest a classification system based primarily on soil characteristics. Certainly the soils have also been disturbed by human occupation, but the modifications of soils are more permanent than those on the vegetation composition. The potential vegetation types can then be related to the soil classification system.

The research on prescribed burning will need to be continued. The effects on soil and vegetation should be followed through several burning cycles to determine the long-term effect. The Forest Service has many questions concerning the application of prescribed burning in other

forest types such as *Pinus sylvestris* and *Pseudotsuga menziesii*. The role of fire in site preparation, regeneration and fuel reduction is not clearly understood in these types. There is a clear need for another scientist to conduct research in this area. Eng. Rego's interest and training are in the area of understory vegetation, succession and soils. A forest scientist who is interested in prescribed burning research would complement the work of Eng. Rego.

Fire is commonly used by the pastoralists to improve the quality of forage on the baldios. These areas are often burned during the summer which may escape and burn into the forested areas or recently established plantations. Burning can probably be conducted during other times of the year and still meet the pastoralists objectives without endangering the adjacent forest. I would recommend a program be developed with the cooperation of the Forest Service to evaluate this practice and to encourage burning at other times of the year if necessary. This program should assess the effect the season of burning has on vegetation composition, forage quality and ease of maintaining control of the prescribed fire.

There are a number of other areas of potential research in the use of prescribed fire in northern Portugal. It has been noted on several prescribed burns that the populations of Ips have increased dramatically. This has been primarily found on the lower elevation sites in western Minho. It is not known at this time how these outbreaks of Ips are related to fire. Dr. Cabral is currently studying the biology of the various species but no research has been initiated on the interaction of the Ips populations with fire. If population

changes are related to fire, they may be more sensitive to fires at particular seasons or fires of high intensity. The Ips may also attack trees more readily on some sites than others or attack stands of *Pinus pinaster* of a particular age. This relationship must be known if prescribed fire is to be widely used in this region of the country.

There also exists opportunities to cooperate on research with the Wildlife Department of the Forest Service. They are conducting research on the use of prescribed fire to manage wildlife habitat at Mafra National Park. IUTAD has expertise which could be used to strengthen this research and also extend fire-wildlife habitat research to other portions of the country. The partridge and the rabbit are two important game species in Portugal and prescribed fire has been used in the management of these species in other parts of the world.

University and Faculty Development

Although some progress is being made, many of the problems and limitations noted in the report of the first assignment are still present. There is currently an effort underway to catalog the library collections and make them more readily accessible to the faculty and students of IUTAD. However, the library is small and needs to be substantially enlarged. Without the support of a library, the faculty is at a disadvantage when preparing research proposals and manuscripts in competition with other universities in Europe. An enlarged library could also improve the teaching quality and enable the faculty to keep courses current with changing technologies in their fields.

It would be useful for the faculty to have the university library develop an exchange program with libraries of other universities in the region. This would reduce the need to own certain volumes and make more literature available to the faculty while the IUTAD library is being developed.

Research is also highly dependent upon adequate computer facilities. The facilities presently at IUTAD are not able to handle many of the statistical packages used in data analysis. As the faculty develops the ability and equipment to collect more sophisticated data, their statistical analysis needs will also become more computer dependent. A computer with greater capabilities will also be useful in departmental and university administration.

The cadre of faculty working in applied ecology areas is small and could be enlarged to become more effective. The addition of faculty with an interest in subjects such as the effects of fire on regeneration mentioned previously would enhance their ability to conduct research and complement the research of Eng. Rego.

Travel to professional meetings and research stations should continue to be encouraged and supported. Interchange between other scientists who are working on similar problems is essential to the continued development of the faculty. This development will result in higher quality teaching and a more productive and enthusiastic research faculty.

APPENDIX A

Outline of Paper Developed by
Francisco Rego and Stephen C. Bunting

RANGELANDS OF PORTUGAL

by

Francisco Rego
and
Stephen C. Bunting

Outline of a manuscript to be submitted to Rangelands. Published by the Society for Range Management.

I. Introduction- this section to include:

A. General physiognomy of the country

B. Cultural differences between north and south

C. Climatic zones of Portugal

II. Climax vegetation types of Portugal

A. Causes for vegetation diversity
1. evolution
2. glaciation
3. importation of exotic species
4. topograghic, edaphic and climatic differences

B. Major climax vegetation types
1. deciduous oak (*Querion occidental* alliance)
2. evergreen oak (*Querion fagineae* alliance)
3. juniper (*Juniperion nanae* alliance)
4. chapparal (*Oleo-ceratonion* alliance)

III. Actual vegetation types found in Portugal

A. Types of seral vegetation

B. Causes of seral vegetation types
1. fire- accidental and prescribed
2. grazing
3. intensive agriculture
4. reforestation

IV. Future of grazing

A. Establishment of annual pastures in south

B. Establishment of perennial pastures in north

C. Management of shrublands with fire

D. Interaction with reforestation efforts

V. Figures needed for manuscript

A. Map of Portugal indicating climax vegetation alliances

B. Historic and present livestock movements between summer and winter ranges

C. Trends in livestock numbers in Portugal

D. Photograph of fire mosaic in northern Portugal

17

APPENDIX B

Dissertation Research Study Plan of
Francisco Rego

EFFECTS OF UNDERSTORY BURNING ON *PINUS PINASTER* FORESTS IN NORTHERN PORTUGAL

by

Francisco M.C. Castro Rego

A study plan submitted to the College of Forestry, Wildlife and Range Sciences

May 1, 1984

14

CONTENTS

Pag.

1. INTRODUCTION 1

2. OBJECTIVES 6

3. LITERATURE REVIEW 7

3.1 - Effects of fire on vegetation 8

3.1.1 - Vegetation Related to Mediterranean Climate 8

3.1.2 - Fire effects on vegetation 12

3.2 - Effects of fires on soils 20

3.2.1 - Chemical soil parameters 20

3.2.2 - Physical soil parameters 25

3.2.3 - Soil organisms 26

4. METHODS 28

4.1 - Site selection 28

4.1.1 - Selection criteria 28

4.1.2 - Number of sites 31

4.2 - Methods for sampling vegetal change 31

4.2.1 - Frequency composition 31

4.2.2 - Shrub cover 34

4.2.3 - Shrub biomass and productivity 34

4.3 - Methods to measure fire effects on the overstory ... 39

4.4 - Methods to detect soil changes 40

4.5 - Methods for studying forage quantity and quality ... 42

15

1. INTRODUCTION

Fire is a very important factor all over the world, but particularly in regions with a Mediterranean type of climate. In the Mediterranean Basin fire, together with grazing, played a decisive role in the development of the actual vegetation. In this area some reasons justify the great importance of fire (*Castillo*, 1981):

- existance of a dry and hot season
- dominance of sclerophyllous vegetation
- old and permanent human settlements

The use of fire by shepherds and farmers is evident since at least the Iron Age (*Le Houérou*, 1974), but *Garrod* and *Bates* (1937),cited by *Naveh* (1974) refer evidence of the use of fire by the Upper Paleolithic man, some 50 000 years ago. In Spain, the Torralba man used fire since the *MINDEL II* glaciation (*Castillo*, 1981), some 400 000 years ago.Portugal has probably had a similar history. Shepherds and farmers could achieve with fire theirmain objectives of better pasture or more croplands.

Documentation on the use of fire exists in historical books as the Bible and Talmud (*Naveh* 1974), and the Iliad, by Homer or the Georgics, by Virgil (*Liacos*, 1974). There are documents on the use of fire in Portugal since the XII century.

The negative consequences of fire have been demonstrated in some areas, specifically in the basin of Mondego River, where erosion was (and still is) important. So, in the XV century, some special laws were enacted to eliminate the use of fire near the river (*Neves*, 1978).

Currently forest fires still burn large areas of the country with a rate superior to the normal afforestation capacity (*Silva* 1981). The areas burnt by forest fires in Portugal and other Mediterranean countries are shown in table 1.

TABLE 1. Areas burnt by forest fires

Country	Forest and (1) shrubland area (10^3ha)	Areas burnt (10^3 ha)						Percentage of forest and shrubland burned annually
		1974	1975	1976	1977	1978	1979	
Portugal (2)	2 500	32	82	21	12	68	48	1.8
Spain (3)	26 818	140	187	162	68	435	272	0.8
France (3)	13 022	38	21	88	20	47	70	0.4
Italy (3)	8 146	103	55	51	93	111	111	1.4
Greece (3)	2 608	33	31	8	54	20	21	1.1

(1) *Le Houerou* (1974); (2) *Martins* (1981); (3) *Velez* (1981)

These areas are burned in spite of the effort made by the Forest Services and other institutions in fire suppression. So, it is easy to understand that traditionally fire was considered by people involved in fire suppression as the major enemy of the Mediterranean forest.

The major causes of wildfires are included in Table 2. It is interesting to note the low incidence of naturally caused (lightning) fires.

Table 2. Major causes of wildfires in Mediterranean region

Causes	Percent of total Number	Percent of total Area
Lightning	1.6	2.4
Railways	1.9	2.1
Carelessness	42.2	40.4
Arson	14.6	10.3
Unknown	29.4	30.2
Various	10.3	10.4

Susmel (1973)

The idea that fire is an ecological factor, and that its importance was only increased but not started by humans, is relatively recent. In southern France and North Africa, the role of fire in vegetation began to be studied 60 years ago. Research on Portuguese vegetation in that field has been very few and disperse. In spain, *Rico* (1978) states that research on the effects of fire at that time was few or none. In 1977, some Spanish foresters were present in a meeting organized by FAO/UNESCO on Forest Fires in the Meditarranean region, and in the Symposium on the "Environmental Effects of Fire and Fuel Management in Mediterranean ecosystems". Since then some research started (*Munoz*, 1980). Specific areas of research include:

1. Study of the evolution of vegetation after wildfires

2. Experimental use of prescribed burning to reduce fuel loads on forest
3. Experimental use of grazing to reduce fuel loads on forest
4. Study of the evolution of fuel loads in Andalucia

The use of prescribed burning is being studied in Galicia (*Hidalgo* 1981).

In Portugal the coming of Dr.*EDWIN KOMAREK* in 1976 was, in the opinion of *Silva* (1981), "a very important point in the history of the portuguese silviculture". Since then, the interest of fire ecology started and the use of prescribed burning made the first steps.

In 1982 the Forest Services began a program including the use of prescribed burning in order to control wildfires. At their request some research began to be undertaken by the Instituto Universitario de Tras-os-Montes e Alto Douro (I.U.T.A.D.). The changes in soil and vegetation following prescribed fire are currently being studied.

This research study plan proposes to quantify the effects of prescribed burning on soils and vegetation, in order to assess the best frequency and season of burning to maximize forage production and minimize fire hazard.

This type of research is considered as a very important point all over the world. The priorities for research in Mediterranean ecosystems were proposed by *Agee* (1982) are:

- Productivity of shrublands under different grazing and burning management
- Concentration of nitrogen and phosphorus
- The effects of fire in the productivity, structure and diversity of the plant and animal communities

Kickert et al. (1976), refers to two problems that are listed by land managers and scientists as having priority:

- Fire frequency, litter accumulation, nutrients, fire intensity, decomposition
- Nutrients, fire intensity, succession, fire frequency

The study proposed will increase the scientific knowledge of the effects of fire, giving to the Forest Services and Agricultural Services the possibility of better using prescribed burning as a management tool.

2. OBJECTIVES

The main objectives will be:

a. Determine the best season for burning, fire intensity and frequency in order to minimize fire hazard.

b. Determine the best season for burning, fire intensity and frequency in order to maximize forage production.

c. Determine the effects of prescribed fire in the chemical and biological properties of soils.

d. Study the community changes including regeneration of *Pinus pinaster*.

3. LITERATURE REVIEW

Effects of fire on vegetation and soils will be reviewed. Effects of fire in fauna are important but, as they are not going to be studied at this stage, they won't be discussed.

However, it is important to refer one of the first studies conducted in Portugal on Fire Ecology. Insect attacks on pine (*Pinus pinaster)* wood was studied in detail, and three new species for the portuguese entomofauna identified. The species found were: *Pityogenes quadridens* Hartig, *Pogonochaerus perroudi* Muls., *Monohamus galloprovincialis* Ol., *Criocephalus polonicus* Mots., *Pissodes notatus* F., *Melanophila acuminata* De Geer, *Sirex juvencus* L. (*Neves et al.*, 1978).

The next sections are presented based on available information from other countries specially when ecological conditions are expected to have similarities.

3.1 - Effects of fire on vegetation

3.1.1 - Vegetation Related to Mediterranean Climate

Mediterranean areas in the world are essentially, and even exclusively, defined by their climate (*Barbero* and *Quezel*, 1982). It is clearly understood that "plants living in separate but climatically similar areas often resemble each other to some extent" (*Jonhson*, 1973). When there is no obvious close relationship between similar organisms, these similarities are explained by the effects of similar environmental conditions on their evolution. This is called "convergent evolution".

The concept of convergence can also apply to plant communities and ecosystems. Convergent ecosystems show some similar biological and physical features (*Jonhson*, 1973).

Various authors have reconized the physiognomic and climatic similarities in the areas of the world having a mediterranean bioclimate (*Quezel*, 1979). This is probably due, among other factors, to the existence of educational and research centers in those areas.

However, authors from the different regions don't have the same idea on the mediterranean climate. One of the most distinctive characteristics of that climate is the concentration of rainfall in the winter half year. Also the total amount of precipitation must be sufficient to support a continuous vegetative cover but insufficient to support a mesophytic arboreal growth (*Aschmann*, 1973). This author defines these limits as 275 and

900 mm of annual rainfall, out of which more than 65 to 70 percent occurs in winter. The hours per year when temperature < $0^{o}C$ should not exceed 3 percent of the total.

These limits seem too restrictive for the Mediterranean Basin, contradicting observations concerning vegetation structures (*Quezel*, 1982). Therefore, other classifications have been used for the Mediterranean Basin countries.

Köppen (1923) climatic type Cs — a warm C climate with a mild humid winter (with at least one month below $18^{o}C$) and a dry summer season (s) — can be considered as typical of much of the mediterranean regions as pointed out by *Specht* (1982). Within this climate the dry summer can be classified as mild summer (Csb climate, hottest month below $22^{o}C$) or hot summer (Csa climate, hottest month above $22^{o}C$). Also the classifications by *Emberger* (1930) and *Bagnouls* and *Gaussen* (1957) have been widely used by Mediterranean bioclimatologists.

The vegetation types in these regions are arranged according to altitudinal levels, as it is known that all around the Mediterranean Sea there is a pronounced increase in precipitation with increased elevation (*Aschmann*, 1973).

Various authors prosed classifications based on elevation. *Quezel* (1976) summarizes the relationships between these different criteria, proposed by himself, *Ozenda* (1970), *Gaussen* (1954), *Tomaselli* (1970), and *Birot* and *Dresch* (1964).

Zinke (1973) proposes a Mediterranean Soil-Vegetation catena observed for Italy, Greece and California according to elevation. The in

clusion of soil properties and types is very important and yet not generally referred. A table adapted from those works is presented:

Elevation	Soil	Vegetation type
0 - 500 m	Xerorendzina or Serozem	Grassland. Annual grasses and herbs
	Mediterranean red earths	Macchia or chaparral
		Oak woodlands
500 - 1000	Terra bruna — Brown forest soil	Hardwood forest-lower beech forests, scrub oak forest
		Closed cone pine forest (*Pinus pinaster*, etc.)
1000 - 1600	Terra bruna lisciviata or Gray brown podzolic	Coniferous forest Hardwood forest
> 1600	Ranker soil	High mountain pasture

In Portugal *Souto Cruz* (n.publ.) refers the following schematic altitudinal arrangement for the climacic vegetation:

Xero - Thermo - Mediterranean level*	*Euphorbia* sp. *Convolvulus* sp. *Withania* sp.
Thermo - Mediterranean level*	*Olea europea* *Ceratonia siliqua*

Meso - Mediterranean level*	*Quercus faginea* *Acer monspessulanum* and evergreen oaks: *Quercus rotundifolia* *Quercus coccifera* *Quercus suber*
Supra - Mediterranean level* < 600 m	Deciduous oaks *Quercus robur*
500 - 1500	*Quercus pyrennaica* *Castanea sativa*
Mountain and Oro-Mediterranean level* > 1500	*Erica australis* *Betula celtiberica* *Pinus sylvestris* *Juniperus communis* *Cytisus purgans*

This will be the classification to use in the next pages.

* *levels as classified by Quezel* (1982).

3.1.2 - Fire effcts on vegetation

In the Supra-Mediterranean level, oak and chestnut forests were extensively replaced by coniferous forest, and specially pine forests , that are among the most flammable ecosystems in the region (*Trabaud*,1981; *Cruz*, 1981).

Stabilized pine forests are only possible with an adequate management, natural or artificial (*Castillo*, 1981). This can be accomplished with fire, namely by controlled burning (*Goldammer*, 1981).

The role of fire depends a lot on fire frequencies: after a wildfire on a closed stand of *Pinus pinaster*, pioneer grasses and shrubs, together with pine seedlings colonize the site. If a new fire occurs in this stage, 10 to 15 years later (*Folch y Guillen*, cited by *Rico Rico* , 1978), the community returns to a shrubby stage or even, with more frequent fires, to a herb stage (*Castillo*, 1981).

If a new wildfire occurs after 25-35 years (*Folch y Guillen* cited by *Rico Rico*, 1978) the stand is mature and has fertile cones: the seeds are disseminated by cones which often burst during fires (*Le Hoverou*, 1974; *Trabaud*, 1970; 1980; 1981) and find mineral soil where competition is weakest and where mineral nutrients are abundant. At this fire frequency pine forests may perpetuate themselves indefinitely (*Trabaud*, 1981), with no change in the floristic composition.

Clearly, if fire doesn't get in the community for one hundred years or more (*Folch y Guillen* cited by *Rico Rico*, 1978), primeval oak and chestnut forest can tend to reestablish. These broadleaved hygrophytic species act as an effective fire barrier, because they exist on areas with

abundant moisture, and fire spends most of its heat evaporating water (*Velez*, 1981). Thus, sometimes these are considered species which "do not burn"; the fact is that if a fire does occur they usually die (*Velez*,1981, *Castillo*, 1981). In that case succession from pine forest to hardwoods is interrupted by fire. *Williamson* and *Black* (1981) reported that, in a mixed oak-pine woodland, fire temperature was sufficiently higher under pines to ensure elimination of the oaks in the vicinity of adult pines. Therefore , at a fire frequency of less than 100 years the community evolves to a fire climax dominated by pines. This process is very similar to the one described by *Davis et al.* (1980) for fire- maintained ponderosa pine stands in Douglas-fir habitat types.

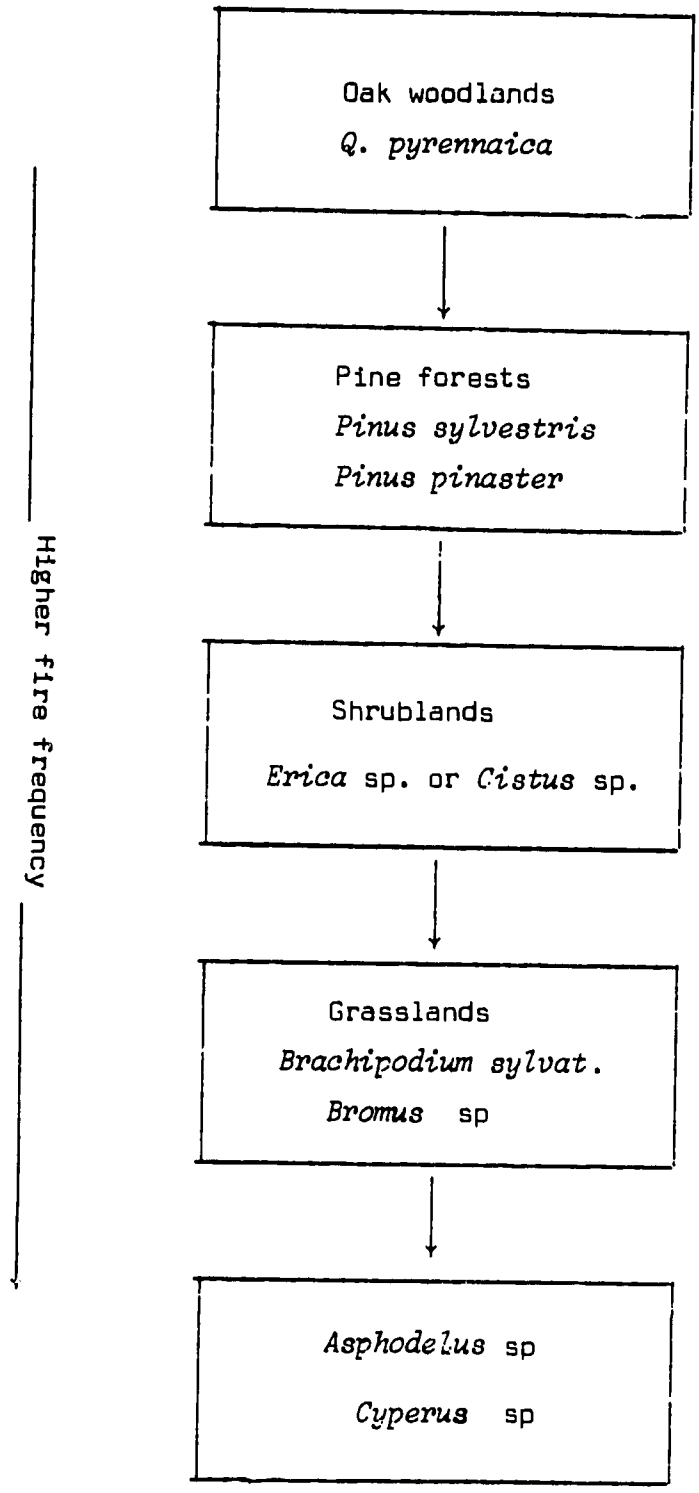
In Portugal, observation of *Rozeira* (1944) cited by *Pereira* (1982) and the work by *Braun-Blanquet*, *Pinto da Silva* e *Roseira* (1956) refer that the communities which the dominant species is *Quercus pyrennaica* were converted, by fire and overgrazing, to shrublands with *Erica* .

A simplified model of vegetation related to fire frequencies is found in *Castillo* (1981) modifying another proposed by *Molinier* (1976); (fig. 1).

That model implies that all forest fires are severe crown fires. This is not true in many cases. Underburning can be very important in stabilizing pine plantations (*Goldammer*, 1981), and occur naturally in Ponderosa pine forests (*Biswell*, 1972; *Hall*, 1977; *Wright*, 1978; *Davis et al.*, 1980; *Lotan et al.*, 1981).

These light and creeping surface fires (*Biswell*, 1972) were very frequent in natural forests. Fire scars and ring count studies have shown

Fig. 1



Model proposed by *Castillo* (1981)

that fire frequency was 4 years (*Van Wagtendonk* (1972) cited by *Biswell* 1973) between 5-25 years (*Lotan et al.*, 1981), 10 years (*Hall*, 1977) , 8-10 years (*Biswell*, 1972), 8-11 for climax ponderosa pine and 7-19 for ponderosa pine that was seral to Douglas-fir (*Pseudotsuga menziesii*) (*Arno*, 1976 cited by *Wright*, 1978). *However* fire wouldn't cause a fire scar if pitch or needles were not present (*Hall*, 1977), allowing the suspiction that fires were more frequent than the data indicate (*Biswell*, 1972).

For a long time in Europe policies of fire exclusion and suppression were undertaken. Natural management with fire was replaced by artificial management and a new equilibrium was obtained. Fire was not burning the understory of pine forests, but grazing, harvesting for fuel or livestock "beds" or cutting by Forest Services resulted on a constant removal of the understory fuels. Also planted stands are much more dense than natural stands, resulting in less fuel buildup.

In Portugal, after 1939 with the Afforestation Plan, domestic animals began to be kept outside forests, the economy of paysans (very dependent on grazing activity) was destroyed and emigration (in the sixties) began. Therefore, harvesting the undergrowth by villagers decreased a lot. Forest Services personnel was not able to do all their tasks, and excess buildup of fuels began. It is obvious that nowadays we are dealing with an "exceptional" decade of severe crown forest fires.

The obvious solution of prescribed burning as a beneficial tool in the management of pine forests is now being considered.

For a reasonable use of this technique it is very important to

have a sound predictive model for the response of the understory vegetation to fire. This research project aims to develop such a model, according to the principles proposed by *Catelino et al.* (1979).

Two phases are important to distinguish: evaluation and prediction in secondary succession.

Evaluation can be done by successive sampling after disturbance, but this can take long years, as in the case of forest communities. In forest stands tree age data has been used to evaluate secondary succession, under the assumption that older trees represent late succession. When dealing with understory species, where age is not easily recognized, multivariate analysis can be used (*Huschle* and *Hironaka*, 1980).

Prediction of secondary succession has been done according to various models.

The classical concepts of succession (*Clements*, 1916; *Odum*, 1969) assume that, following a disturbance, the community gradually regenerates a semblance in structure and composition of its former self, by an orderly and predictable series of species replacements (*Noble* and *Slatyer*, 1977).

This idealized process has been challenged in recent times. There is evidence that fire characteristics can have some effects in the vegetation sequences. The most important fire factors are (*Le Hoverou*, 1974):

a. the way vegetation burns

b. the fire rotation itself

c. the season when fire occurs

Also, initial floristic composition of a community imediately after a disturbance and differential growth in the early stages can dominate the sub

sequent pattern of development (*Egler*, 1954 and *Drury* and *Nisbet*, 1971, 1973 as cited by *Noble* and *Slatyer*, 1977). Therefore more flexible models were proposed: *Horn* (1974) used observed probabilities of species-by-species replacement to predict successional changes. *Vogl* (1974) sees vegetational changes in chaparral as a series of simple, repetitive cycles. However *Zedler* (1977) refers the importance of life history attributes of plants to predict the response of chaparral to management. This is in agreement with the more recent models.

Recent models consider life history attributes and reproduction strategies to predict successional changes. *Connel* and *Slatyer* (1977) proposed a broad system of successional processes in terms of species facilitation, tolerance and inhibitive properties. *Noble* and *Slatyer* (1977) define a small set of species attributes that are vital to the reproduction and survival of a species within the community. A classification scheme is then built up by assigning combinations of the vital attributes to the species. *Catelino et al.* (1979) present approaches to refine and improve that scheme, that showed descriptive and predictive value in three Mediterranean ecosystems.

Problems were encountered when applying the multiple pathway method (*Catelino et al.*, 1979) the understory species. One of the problems is that one site can be "uniform" on the scale of the overstory trees,but still having micro-environmental differences in the scale of understory plants. The other problem these authors foundwas related to the lack of information on the life history and vital attributes (as defined by *Noble* and *Slatyer*, 1977) of the understory species.

In our case the lack of information is also existing, but the effect of fire is some of the understory species has been documented:

Chamaespartium tridentatum is referred to decrease in its presence one year after a prescribed fire (*Hidalgo* and *Temes*, 1982).However *Almeida et al.* (1981) found an important increase in its cover three years after a wildfire. Due to the little information available in the biology and physiology of the species these authors don't provide any explanation for the results found.

Calluna vulgaris is a very important species in Europe (Scotland for example) where its ecology and biology have been studied carefully. The mode and vigour of re-establishement of *Calluna* depends in a large measure from its age (*Nicholson* and *Robertson*, 1958; *Gimingham*, 1972): vegetative regeneration fails in old stands (>15 years) and regeneration from seed takes place. Also excessive heat, above 500°C, applied for one minute to the stem base, is generally lethal, irrespective of the age of the plant (*Whittaker*, 1960 cited by *Gimingham*, 1972).

In Spain, *Velez* (1981)refers that *Calluna* can sprout from a stump. *Hidalgo* and *Temes* (1982) report that recuperation of *Calluna* in a *Ulex-Chamaespartium* community is very slow one year after a prescribed fire. In Portugal, *Almeida et al.* (1981) report a decrease in cover three years after a wildfire, but also a small increase three years after a prescribed fire; This can be due, in some extent, to the temperature factor as described before.

Erica sp. behaves in a way similar to *Calluna*. Both Ericaceae may produce vigorous stump sprouts (*Le Hoverou*, 1974; *Gimingham*, 1972 ;

Velez, 1981; *Trabaud*, 1981) and, when killed by fire re-establish entirely from seed (*Gimingham*, 1972). This author refers that *Erica cinerea* (on the drier ground) and *Erica tetralix* (on wet peaty soils) may regenerate faster tahn *Calluna*. *Le Hoverou* (1974) and *Trabaud* (1981) consider *Erica arborea* and *E. scoparia* as species that dominate the burned forests or maquis due to their sprouting ability. *Almeida et al.* (1981) recorded a decrease in cover of *Erica australis*, three years after a wildfire, the same happening in a prescribed fire. *Erica umbellata* showed an increase in cover, three years after a wildfire.

Ulex sp is also adapted to fire. *Velez* (1981) states that it can sprout from a stump, and F. *Sineiro* (1980) reports the importance of the regeneration by seedlings. This author refers other studies (*Moss*,1959; *Hyde* and *Suckling*, 1953) where 3000-3500 seeds of *Ulex* per square meter were found. These seeds can be stimulated by fire (*Sineiro*, 1980) justifying a great stability in the community after fire (*Hidalgo* and *Temes* , 1982; *Almeida et al.*,1981).

The informations on fire effects on these species will be tested in this work and will contribute for the predictive model for secondary succession.

3.2 - Effects of fires on soils

There is some information on the effects of fires on soils for some types of vegetation. It is obvious, however, that fire effects de - pend on fire intensity, fuel quality and quantity.

Here we make a summary of some works on fire effects on soils made in different conditions: *Siren* (1974) and *Braathe* (1975) worked in the Scandinavian coniferous forests; *DeByle* (1975, 1981) and *Parker & Williams* (1975) refer to the Larch/Douglas-Fir Forests of western *Montana*; *Biswell* (1973) works refer to Ponderosa-pine grassland stands; *Temes* (1982), *Hidalgo* (1981) worked in *Pinus pinaster* and *Pinus radiata* stands in Northern Spain; *Gimingham* (1972), *Kenworthy* (1964) and *Allen et al.* (1969) worked in *Calluna* stands in Scotland.

Some general conclusions can be drawn from these works:

3.2.1 - Chemical soil parameters

— Soil pH

Burning generally causes a pronounced increase in the pH value, specially in the surface layers (*Valenzuela*, 1959; *Braathe*, 1974; *Siren*, 1974; *DeByle*, 1976; *DeByle* and *Parker*, 1981; *Temes*, 1982). This can be explained by the release of K_2O but specially Ca O, caused by fire (*Siren*, 1974).

– Nutrient contents

Total quantity of elements in the fuel can be lost in smoke or deposited in the ash. In table 1 losses of nutrients in smoke for various elements are shown, as presented by *Gimingham* (1972), according to the results of a study conducted by *Allen* (1964).

TABLE 1

Losses of nutrients in smoke from burning *Calluna* (% of the original content, corrected for dry weight)

	TOTAL LOSSES	
	"Normal" burn (550-650°C)	"Severe" burn (800-825°C)
N	67.8	76.1
C	60.5	67.5
S	50.2	56.3
P	0.6	3.5
K	1.4	4.9
Ca	0.1	2.4
Mg	0.4	2.1

The availability of these mineral nutrients in soil is usually enhanced by forest fires (*Ahlgren* and *Ahlgren*, 1960), by deposition in the ash. Distinction between wildfires and prescribed burnings will not be done, because their ecological effects are in many respects rather similar (*Siren*, 1974).

The effects of fire in the total content and availability of

some nutrients is presented:

TOTAL NITROGEN

Most of the nitrogen in soils is in the organic fraction. Combustion of the organic matter volatilizes much of the nitrogen (*Gimingham*, 1972; *DeByle* and *Parker*, 1981).

However a considerable part can be converted by moderate heating into ammonia and partly retained by the remaining unburnt lower layer of the humus (*Siren*, 1974). Also, decreased soil acidity and increased soil fertility after fire can stimulate microbiological activities which favour N - fixation (*Hanioja*, 1961 cited by *Diren*, 1974; *Castillo*, 1981).

So, the balance between direct consumption and indirect increase can explain the different results present by various authors:

Biswell (1973) states that although total nitrogen in the system is temporarily decreased, an increase of available nitrogen in the substrate can be observed.

DeByle (1975) and *DeByle* and *Parker* (1981) refer no alterations on the nitrogen content of the mineral soil after burning or during the following year.

Temes (1982) found a significant decrease of total nitrogen in the surface 5 cm of the soil, when organic matter of this layer decreased significantly from 25.79% to 16.20%.

PHOSPHORUS

Total phosphorus content of the surface organic layer increases

imediately after fire, (*Valenzuela*, 1959) but can be reduced during the next year (*DeByle*, 1975).

Leaching of the duff-ash layer can acount for the observed increase of available phosphorus in the surface of the mineral soil (*DeByle*, 1975; *Biswell*, 1972? ; *Temes*, 1982).

Much leaching of phosphorus from the mineral soil is unlikely because it is deposited in a relatively insoluble form (*Gimingham*, 1972) specially in acid soils (*Temes*, 1982).

However some leaching can occur according to *Castillo* (1981), explaining the results obtained by *Temes* (1982).

POTASSIUM

Potassium content in the surface organic layer increases imediately after fire (*Valenzuela*, 1959; *DeByle*, 1975; 1981). During the subsequent years leaching and erosion, together with the processes of mineralization may lead to a considerable loss of potassium from the humus layer (*DeByle*, 1975, 1981; *Braathe*, 1974).

However, according to *Viro* (1969) cited by *Braathe* (1974) and *DeByle* (1975, 1981), the greater part of this loss is fixed in the mineral soil underneath.

This highly soluble element (*Gimingham*, 1972) is very likely leached from the mineral soil, explaining the significant decrease reported by *Temes* (1982), two years after burning, after having a significant increase imediately after the fire.

CALCIUM

Some authors like *DeByle* (1975) and *Hidalgo* (1981) found no significant changes in calcium content of soils.

Others, however, state that there is a heavy Ca O release caused by fire (*Siren*, 1974; *Temes*, 1982, *Madeira* and *Pereira*, 1981).

SODIUM

DeByle (1975; 1981) reports no significant changes in the amount of exchangeable sodium in the mineral soil. However soluble sodium showed a significant decrease.

MAGNESIUM

Total magnesium content of the surface organic horizon shows a significant decrease one year after burning according to *DeByle* (1975, 1981). However, in the same study exchangeable magnesium increased significantly in the mineral soil.

Temes (1982) recorded in the surface 5 cm a significant increase imediately after burning(like *Valenzuela*, 1950) followed by a decrease two years later.

CATION EXCHANGE CAPACITY

Cation exchange capacity did not change as a result of burning, in the study conducted by *DeByle* (1975).

3.2.2 - Physical soil parameters

— Texture

Temes (1982) found a significant decrease of the percentage of clay and silt in the surface 5 cm, 2 years after burning. As there is not a corresponding increase of those fractions in the lower levels, the author concludes that there was an important loss by erosion.

— Organic matter

There is a decrease of the organic matter in the surface organic horizon, as in the surface of the mineral soil (*Valenzuela*, 1959 ; *Braathe*, 1974; *DeByle* 1975, 1981; *Madeira* and *Pereira*, 1981; *Castillo* , 1981; *Temes*, 1982).

— Water Repellency

There was a temporary increase in % repellent soil samples after fire, particularly under intense burns (*DeByle* and *Parker*, 1981).The driest south-facing aspects exhibited the most adverse and permanent effects to soil and vegetative characteristics (*Parker* and *Williams*,1975).

These effects are detrimental to soil erosion control and, in general, to watershed performance.

3.2.3 - Soil organisms

Effects of fire in soil organisms have not been investigated very extensively, because of its apparent lack of direct economic importance and the involved procedures sometimes required in their study (*Ahlgren*, 1974).

However they are important as indicators of change in soil conditions and as important contributors to soil texture and recycling of nutrients (*Ahlgren*, 1974). Much of the work in this field has been concerned with the nitrogen cycle (*Dunn* and *DeBano*, 1977; *Margaris*, 1977; *Arianoutsou-Faraggitaki* and *Margaris*, 1982; *Sotres*, 1982).

Algae are expected to be affected by fire and to show subsequent successional changes but few information is available (*Ahlgren*, 1974).

The response of bacteria, actynomicetes and fungi varies according to soil conditions, fire intensity and duration (*Ahlgren*, 1974; *Margaris*, 1977, *Dunn* and *DeBano*, 1982).

Moist soils do not become as hot during fires as dry soils, but microorganisms are more sensitive to wet heat than dry heat (*Dunn* and *DeBano*, 1982).

In general, heat causes a decrease in *bacteria* populations just after fire, but if the soil is wet the population recovers quickly and can become more numerous than before (*Ahlgren* and *Ahlgren*, 1965 cited by *Margaris*, 1977; *Sotres*, 1982). In this case nitrification process is more intense after fire (*Arianoutsou-Faraggitaki* and *Margaris*, 1982).

However *Dunn* and *DeBano* (1982) state that nitrifying bacteria are very sensitive to fire and do not recover quickly (*Powlson*, 1976 cited by *Dunn* and *DeBano*, 1982). This apparent contradiction can be explained by different soil and fire conditions.

Actinomycetes response to fire is similar to *bacteria*, but sometimes considered more thermal resistant (*Ahlgren*, 1974; *Dunn* and *DeBano*, 1982).

As to the *fungi*, their number is reduced after the fire but some multiply significantly as shown by their names (Pyronema or "pyrophilous discomycetes") as stated by *Ahgren* (1974) and *Margaris* (1977). The same authors refer also qualitative changes in the different successional stages.

Effects of fire in *soil fauna* has been very scarsely studied. However it is possible to refer that populations are reduced by fire and, with the exception of the mesofaunal species and spiders, those reductions are explained mainly by postfire changes in the environment(*Ahlgren*,1974).

Mesofauna include mites, collembolans and other very small arthropods (*Metz* and *Farrier*, 1971). These authors report a great reduction of mites in the forest floor and soil within 24 hr after fire. Reduction in collembolans was only noted in the forest floor. This is induced by fire temperature in soil. Recovery to preburn population levels in 3 to 4 years are recorded for both mites and collembolans, explaining the high populations in periodic burns (*Metz* and *Farrier*, 1971).

4. METHODS

4.1 - Site selection

4.1.1 - Selection criteria

The area under study is the mountain range between Minho and Trás-os-Montes provinces. This corresponds, in the ecological division of Portugal made by *Manique e Albuquerque* (1954), to the region referred as Alto Portugal (fig. 2).

Within the region, sites are selected according to various criteria:

1. Having a tree cover of *Pinus pinaster* (mature stands)
2. Having a reasonable chance of not being disturbed after the treatments (burns). The major problems are:
   a. Grazing. A great portion of the forest lands are grazed extensively. Sites are to be selected where domestic livestock is not important.
   b. Cutting. This activity decreased significantly but still deserves to be considered. Sites are selected where this activity is not common at the moment.
3. Sites should cover a wide variety of ecological situations, so the conclusions can have a more easy generalization.

Location of sites are expected to be in Marão, Vila Real, Pedras Salgadas and Vieira. Location of these places is shown in fig.

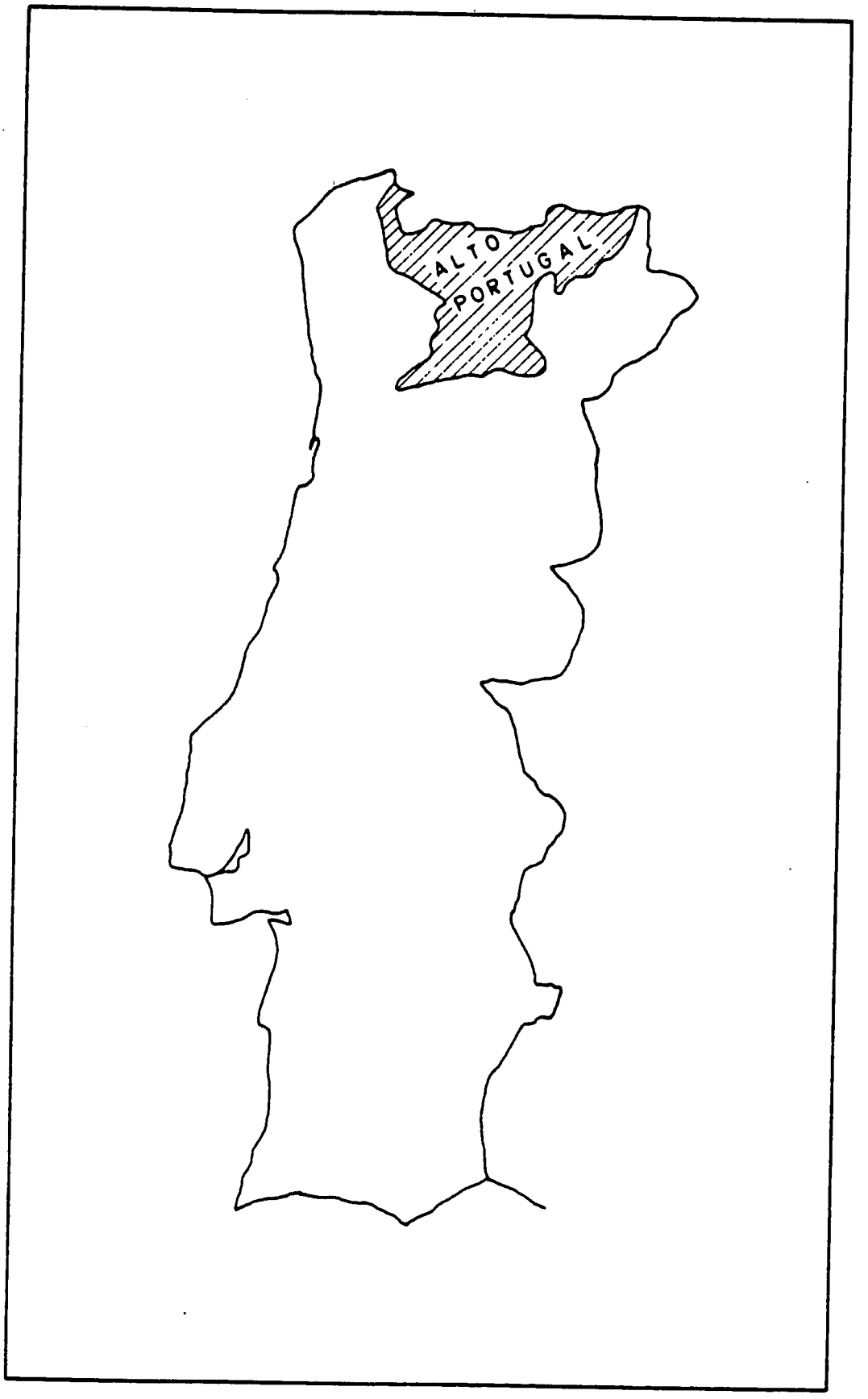


Fig.2 - Alto Portugal (ecological region as defined by Manique e Albuquerque, 1954).

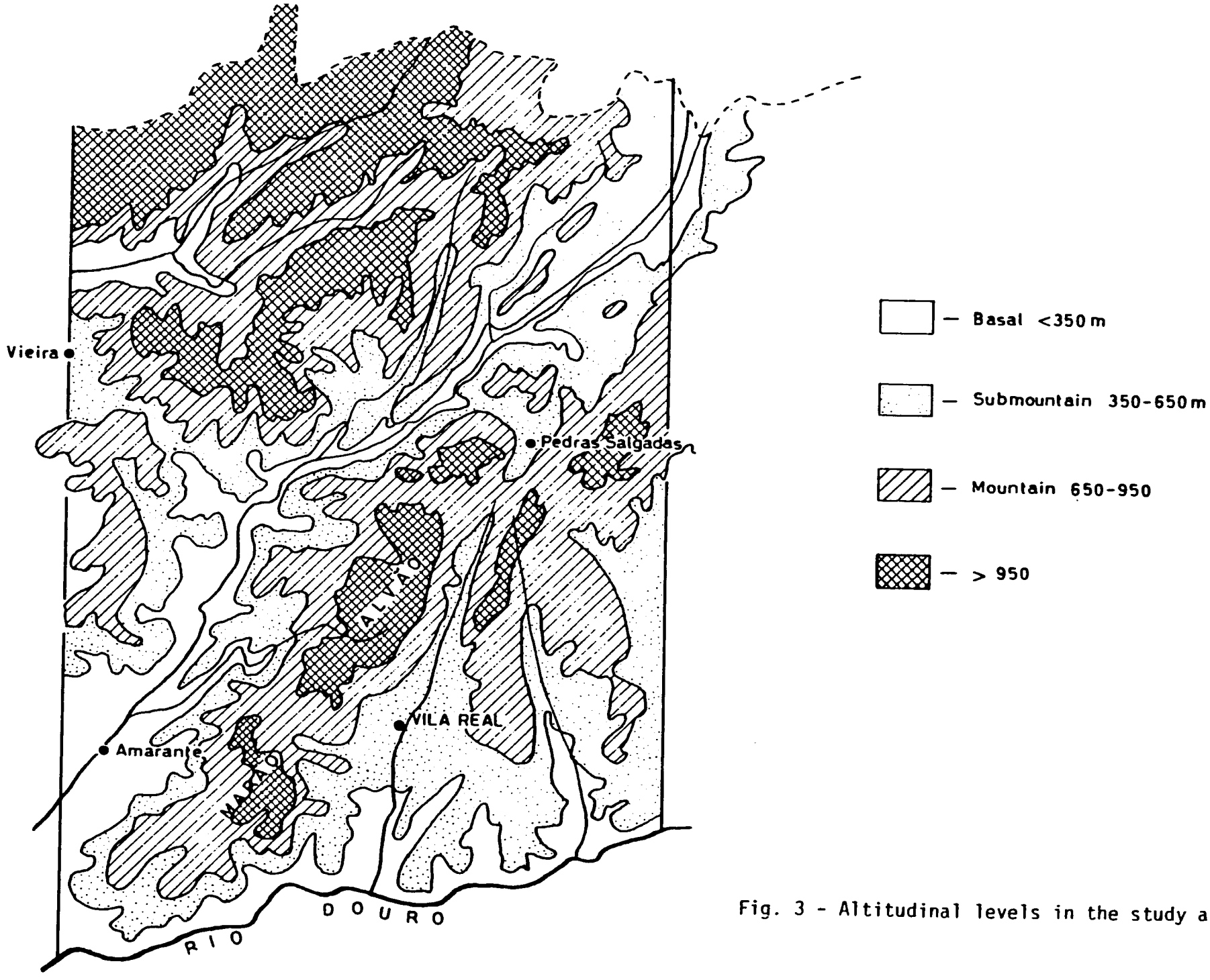


Fig. 3 - Altitudinal levels in the study area.

4.1.2 - Number of sites

Four different locations are to be selected in order to implement the experiment. In each location there will be a plot burned in the Fall (or Winter) season and another is the Spring season. Another plot is left out for control.

In order to have rapid information on the ecological effects of burning four older prescribed burns will be sampled, too. The selection criteria will be the same. However, as the prescribed burning technique is very recent in Portugal, the choice is very limited and we have to expect some problems, namely with grazing by domestic livestock. These older burns could be from 2 to 4 year old at the beginning of the experiment.

4.2 - Methods for sampling vegetal change

4.2.1 - Frequency composition

Monitoring vegetation change is very important in terms of detecting the effects of the different treatments. Absolute characteristics of vegetation, such as cover yield or density are not perfectly adequate for measuring trend. Cover and yield are affected by seasonal and yearly variations. Density is not so dependent on climatic flutuations but "defining the individual becomes more difficult when working with perennial herbaceous species which propagate vegetatively" (*Strickler* and *Stearns*, 1963). The same problems arise with shrubs that produce both multiple - stemmed and single - stemmed plants.

A method is needed for detecting change which would be reasonably

simple, pratical, accurate, and technically sound as pointed out by *Parker* and *Harris* (1959). Determination of presence or absence of plants within a fixed area is a rapid and objective method (*Frischknecht*, 1980). *Brown*(1954) adds that frequency data is readily analyzed statistically. Frequency data is dependent on quadrat size, plant unit size, density, and distribution of plants.

When designing our sampling method we can only alter quadrat size. *Archibald* (1952) proposed a method to optimize the size of the quadrat to use for a given species. Plotting the percentage frequency against the logarithm of the area of different quadrats, various S-shaped curves are obtained. The point of inflexion of those curves determine the quadrat size to use. The percentage frequency at that point varies from 50 to 75 per cent.

It is obvious that the optimum quadrat size would differ from species to species, depending on the size, density and distribution of the plants. So, an effort was made to use different sizes of plots. *Frischknecht* (1980) used the double-frequency technique, a method that simultaneously determines frequency on two sizes of plots. The method of nested plots was already presented by *Dombois* and *Ellenberg* (1974) as a system for establishing minimal area for sampling plant communities. In the nested frequency plot method, three or four variously sized plots are located (nested) within each other in a single configuration, and frequencies are recorded in each plot (*Smith et al.* not published). This system allows the use of data from the quadrat size more sensitive of change for each species.

Also the use of different sizes of plots can be used in the ge

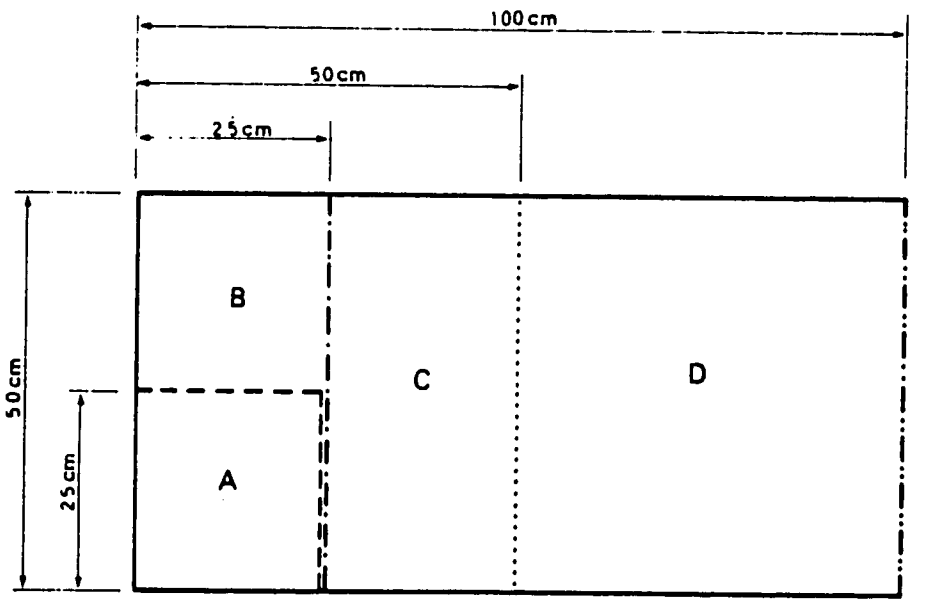
neration of a distribution index - (DI) as follows (*Frischknecht*, 1980):

$$DI = \frac{\%\text{frequency per smaller plot}}{\%\text{frequency per bigger plot}}$$

This system can obviously be used with the nested frequency plot method. The change in the distribution index over a period of time can also be detected and analyzed.

The change in vegetation can be analyzed by the "evolution index", that represents the active occurrence of the species at the time of the observation compared to the species occurrence at the beginning of the experiment, before any treatment (*Trabaud*, 1974).

Nested frequency plot technique will be used to measure vegetation change. The configuration of the nested plots is shown in fig.4



- - - - - - limits of plot A (25x25 cm)
—·—·—·— limits of plot B (25x50 cm)
····· limits of plot C (50x50 cm)
—··—··—··— limits of plot D (50x100 cm)

Fig. 4 - Diagram of frequency plot to be used in study

At each site and treatment the sampling unit (a metal frame) is located along the three 34 m transects, spaced uniformly, for a total of 100 locations. Frequency of ocurrence of each species within each of the four plots should be recorded before the treatments and yearly, in the next summer seasons.

4.2.2 - Shrub cover

Measurements of cover are to be done in the beginning and yearly after the burns, in each site and treatment. The method choosed is the line intercept, as proposed by *Canfield* (1941). This method is generally objective and relatively accurate (*Hutchings* and *Pase*, 1963).

The same lines that were used for frequency data will be used for cover. So, three lines of 34 m each were used for each treatment-site. The measurements are recorded in a manner so that the data can be done in the office. This allows the possibility of spliting the line. The sampling unit, originally a line of 34 m, can be changed for a line of half-length (17 m). This can be advantageous in terms of statistical treatment.

The lenght of the lines are very similar to those proposed by *Canfield* (1941): 50 feet (15,5 m) for sampling areas with 5 to 15% of ground cover, and 100 feet (31 m) for areas with from 0.5 to 3% of cover.

4.2.3 - Shrub biomass and productivity

Change in biomass is very important to determine burning frequency. As the main species involved in this process are shrubs, we decided to use a method adapted for these plants.

Measurement of biomass can be accomplished by (a) direct measurements of plant weight, (b) measurement of plant characteristics that are related to weights in a known relationship, or (c) some combination of these methods (*Risser*, 1980).

As there is no information available on relationships between biomass and other plant parameters (cover, density, height, or some combination) we have to use direct measurements. We plan to use information from this study to build some regressions between selected plant characteristics and biomass.

The method choosed is the weight from clipped plots. This method provides one of the most accurate measures of yield, but it is costly and laborious where production of shrubs must be determined, and also cannot be employed on permanent sample plots (*Blair*, 1959). The weight estimate method per se or combined with actual weight in double sampling is not applied, since weight estimates require extensive training periods before observers can estimate accurately (*Hutchings* and *Schmautz*, 1969) and results are better with grasses and forbs than with browse (*Wilm*, 1944).

When using the clipping method, some considerations should be attended. The choice of the plot size and shape, and the number of plots to use, is very important. According to *Reppert et al.* (1963) circular and square plots are often favored because they minimize the error of "edge effect", even if they can be less efficient than rectangular plots.

The number of plots required to sample a given area with plots of a given size must be determined statistically on the basis of sample variance, confidence level of the estimate and the accuracy of the estimate

(*Risser*, 1980). The more irregularly plants are distributed, the more plots of a given size are required to provide the same precision of the estimate (*Mueggler*, 1976). As there is no information on the variability of stands similar to those we are working with, we decided to use a pre-sampling technique to assess plot size and number. Details are given in the section "Statistical methods". The sizes of plots used in the pre-sampling technique are 1 and 2 m^2, in a nested configuration.

There are some field procedures important to insure accuracy in this method:

1 - Unbiased sample unit placement.

2 - Consistent procedures in establishing plot boundaries. In our study a plant is considered to be inside the plot if it is rooted in the plot. We think this is the more objective procedure, tending to avoid the natural tendancy to harvest more biomass than really belongs in the plot (*Van Dyne et al.* , 1963).

3 - Selection of the clipping height. Some works have been done where vegetation is clipped at ground level and in others at some arbitrary height, usually 2,5 or 5 cm (*Pieper*,1978). We selected to harvest at 5 cm because there is the advantage of not having problems including fine soil particles in our sample. The only disadvantage of this heigth would be in sampling herbage, where sometimes more than half of it can be below heigths of 2,5 or 5 cm (*Reppert et al.*1963). This is not the case, our main interested being shrub biomass.

4 - Careful plot identification, weighing, and recording.

5 - Clear understanding of species to be sampled. In our study we decided to sample only shrubs as thery are much more important in terms of biomass.

All biomass should be referred at a dry-weight basis. So, a sub-sample of the clipping will be stored in bags and dried in a forced air oven at 65°C, containing about 10-12 per cent water (*N.A.S. - N.R.C.*,1962).

These estimates of biomass will be made each year after the beginning of the experiment. The difference of the biomass estimates from year to year will give us the amount of dry matter produced during that interval. In each plot the number of plants per species will be recorded. This data can be used together with frequency to assess the distribution pattern of the different species.

Also, in each plot, each plant will measured in terms of:

- maximum diameter of the canopy
- diameter of the canopy measured at right angles to the first measurement
- height of the plant
- basal stem diameter and number of stems

We will try to use these vegetation parameters to predict biomass. Any of the relationdhips tried may produce satisfactory estimates, but must be checked for the individual area and species (*Peek*, 1981). *Rutherford* (1979) illustrates the diversity of relations used in browse estimates. Combination of predictor variables to provide a better estimate

of biomass can also be tried: *Hutchings* and *Mason* (1970) used foliage cover and basal area to estimate yields of Gambel oak (*Quercus gambelii*). *Laycock* (1970) predictes herbage yields from height and number of stems. Such kind of relations will also be tried.

4. 3 - Methods to measure fire effects on the overstory

In all plots a description of the overstory will be made in terms of species, age, density, top height, basal area, and height of lowest branches.

The field plots have a cover of *Pinus pinaster*. Age of the trees can be registered as there are precise records on the plantation year. Density will be determined by counting the number of trees of the plot and dividing it by its area. Height of 20% of the thicker trees per plot will be measured with the Blume-Leiss hypsometer and the average height (top height) recorded. The same procedure will apply for the height of lowest branches

Basal area will be determined by the *Bitterlich* method.

In each year after the burn, the plots will be examined in terms of tree mortality. Also growing of trees will be inspected in terms of ring thickness. If first impressions show some possible effects of treatments, more detailed ring analyses will be executed and explained.

Fire effects on pine regeneration will be determined by the methods explained for detecting change in vegetation, as pine seedlings are recorded in those procedures.

4. 4 - Methods to detect soil changes

Changes in soil characteristics after burning are very important to evaluate as fire is sometimes considered responsable of erosion and fertility problems.

Five composite soil samples of the upper 10 cm of the mineral soil will be collected in each plot, each 3 month. Several works (see "Effects of fire on soils") refer the upper level as the one where important changes occur. Composite samples will be used to reduce the within treatment variation.

Extraction of mesofauna from those samples will be done by the *Berlese* method modified by *Tullgren* as described by *Phillipson* (1971).

After mesofauna extraction, the dried soil samples will passe through a 2 mm sieve before subjecting them to standard chemical analyses. The soil samples will be analyzed for texture, pH_{H2O} , pH_{Kcl}, organic carbon, total nitrogen, available P and K, exchangeable Ca, Mg, K and Na, an exchangeable acidity. All the analyses will be done by the Soil Fertility Laboratory of the Instituto Universitário de Trás-os-Montes e Alto Douro.

The mechanical analysis for soil texture will be done by the sieving and sedimentation method of the *Robinson pippet* (*Silva*, 1967),after oxidation of organic matter.

The pH determinations will be done in suspensions of soil and

distilled water or soil and a potassium chloride solution 1 N (1:2,5) , using a combined glass electrode (*SCS*, 1972).

The organic matter will be computed multiplying by a constant value (1,724) the result of the organic carbon analysis done by Dichromate oxidation (*Tinsley*, 1950).

The total nitrogen contents of the soil samples will be determined in finely ground 0.5.gram portions using the method described by *Houba et al.*, (1979).

Available phosphorus and potassium will be evaluated through ammonium lactate extraction (*Riehm*, 1958 modified by *Balbino*, 1968). The quantity of phosphorus in extract will be determined spectrophotometrically by the molybdate ammonium method. Potassium in extract will be quantified by flame photometry.

Ammonium acetate will be used to extract the cations Ca, Mg, K and Na from the soil exchange (*S C S* , 1972). These extracts will be analysed for Ca and Mg levels by atomic absortion. Lathanum will be added before the analysis. K and Na in the same extracts will be determined by flame photometry.

Exchangeable acidity will be evaluated after a Barium Chloride -Triethanolamine (pH 8,0) extraction by a titration with Hidrochloridric acid (*Peech*, 1965).

4.5 - Methods for studying forage quantity and quality

– Forage quantity

According to *Pieper* (1978) forage can be defined as herbage or browse which is potential food for animals. In our study areas, browse is much more important than herbage. Therefore we are going in more detail in the analysis of the methods used for estimating available browse than herbage.

Nevertheless estimates of the herbage produced on an area will be done by clipping the herbage from sample plots, and weighing it in the field. A subsample will be dried in the air forced oven for 24 hours at 65°C. These samples will be collected at summertime, after the growing season. As standing crop tends to decline during that season (*Turner* and *Klipple*, 1952), first part of summer season was selected for sampling.

The plots used for these estimates will be the same as for shrub biomass measurements. In each plot the total weight of herbage will be registered together with an estimate of the percentage composition of each species (*Cassady*, 1959).

In the study areas forage is mainly browse. Browse can be defined as the sum total of that plant material on woody species that is potentially edible to a specified set of animals (*Rutherford*, 1979).

Commonly browse is viewed as the current annual growth of leaves and twigs (CAG, as defined by *Peek*, 1981). A better definition of browse is

the "section of current annual sprout growth between the terminal bud and the point of average browsing diameter (...)" (*Shafer*, 1963). This diameter at point of browsing (DPB) could be bigger than the diameter at proximal end of growth, the "diameter of current growth -DCG" (*Peek et al.* 1971). In that case browse can be simply defined as the parts of a branch distal to the point where branch diameter would, if air dried, equal the largest diameter observed for the stub of a browsed branch of that species (*Telfer*, 1969), including possibly wood produced in several seasons.

The last definition of browse seems the most correct. However, if we are interested in browse estimates to assess carrying capacity of a given area the definition by *Shafer* (1963) can be accepted.

So, in the shrubs collected for biomass measurements, a sub-sample will be analyzed where browse will be separed of remaining wood. This requires the previous determination of DPB, by the average of 50 measurements made in the remaining parts of twigs browsed by sheep or goats.

Then a sample of 50 twigs clipped from the terminal buds to DPB (if DPB < DGG) or to DCG will be collected. An average dry weight will be obtained. The number of samples to use can then be assessed statistically, in terms referred in "Statistical Methods". Conversion of mean twig mass to twig mass on a ground area basis (browse) is obtained by multiplying the mean twig mass of species by the mean number of twigs per stem which is in turn multiplied by the number of stems or individuals per hectare (*Telfer*, 1978; *Wolff*, 1978; cited by *Rutherford*, 1979). This

is the method choosed for browse estimation.

Correlation between browse production and other plant parameters will be tried. *Lyon* (1968) found a very strong correlation between twig production and crown volume. *Hutchings* and *Mason* (1970) estimated oak yields from foliage cover and basal area. If a good relationship of this kind is found, crown measurements will be used to browse production. In that case this method will be preferred to the previous procedure.

Browse quantity is then estimated. Quality of forage is important per se or related with treatment effects. Forage quality can be assessed by field grazing trials and/or laboratory analyses. In our case laboratory methods will be used due to the great difficulties in having grazing trials.

– Forage quality

Analyses of forage quality are made of samples composited from several shrubs of the same species. In our case 3 samples obtained for each main species are collected for each treatment and site and 4 times a year, corresponding to the four seasons.

The use of the composite samples can show some interest in terms of reducing sample variance within each treatment/site, so the effects of the burns can be more easily recognized.

There are some disadvantages in using this method: nongrazed plants, as in our plots, will be in more advanced growth stages than the plants being grazed (*Amer. Soc. Agron.*, 1952). This can make difficult

futur generalization. Also, it is obvious that a representative sample could only be obtained by letting the animal forage it (*N.A.S.- N.R.C.*, 1962). As it was not feasible to use esophageal fistulae this was not accomplished.

The dried feedstuff will be analysed for crude protein (determination of nitrogen by the Kjeldahl method), ash content and minerals. However determination of digestibility is critical and digestibility *in vitro*, will be done as described by *Barnes* and *Marten* (1979) using a modification of the method proposed by *Tilley* and *Terry* (1963).

All the analyses will be done in the Laboratory of Animal Nutrition of the I.U.T.A.D.

It would be important to have estimates of voluntary intake, but infortunately that would require the use of nonexisting techniques that should predict voluntary intake, as easily and as accurately as *in vitro* digestibility predicts *in vivo* forage digestibility (*Vöneßer et al*, 1966 as cited by *Ferreira* and *Collins*, 1982).

APPENDIX C

Approval of Program for Doctoral Degree of

Francisco Rego

(Submit one copy to the Graduate School)

RECEIVED

NOV 5 1984

GRADUATE SCHOOL

PROGRAM FOR A DOCTORAL DEGREE

FOR THE CANDIDATE

Name: FRANCISCO MANUEL CARDOSO CASTRO REGO Student I.D. # X811-73751

Degree Sought: PhD Date: 10/12/84

Major Field: FORESTRY WILDLIFE AND RANGE SCIENCES Supporting Field: _____
(If appropriate)

The required resident study has been or will be fulfilled by (how and when):

SPRING AND FALL SEMESTERS 1984 = 26 HOURS

List any non-resident study planned (where and when):

_____

Ph.D Departmental Requirements: (List any language(s) and/or other special requirements)

_____

(Ed.D) The professional experience requirement has or will be met by (where and when):

_____

I have discussed the above and the attached study plan with my major professor.

Candidate's Signature Francisco C. Rego

FOR THE COMMITTEE

The candidate took a written and/or oral qualifying examination(s) on date of _____ with the following results and recommendations (continuation of degree program, evidence of weak areas, etc.):

This program, including dissertation title and study plan, is approved:

Stephen Binkley — Major Professor — Oct 12, 1984 — Date

[illegible] — Committee Member — 24 Oct 1984 — Date

[illegible] — Committee Member — Oct 12 84 — Date

M. Hiromoto — Committee Member — 24 Oct 84 — Date

[illegible] — Departmental Administrator — 10-24-84 — Date

FOR THE GRADUATE SCHOOL

Approved by the Graduate Dean for the Graduate Council and subject to the provisions of the current Graduate Bulletin.

Date: 12/4/84 Signature: [illegible]

Distribution of copies of approved program: Major professor, candidate via major professor, department head (or Dean), Graduate School Office.

(See other side for study plan)

47

(Type one copy)

SUMMARY OF STUDY PLAN FOR A DOCTORAL DEGREE

Candidate: FRANCISCO M. C. CASTRO REGO Degree: PhD Date: 10/12/84

Major Field: FORESTRY WILDLIFE AND RANGE SCIENCES Supporting Field: _____

Dissertation Title: EFFECTS OF UNDERSTORY BURNING ON PINUS PINASTER FORESTS IN NORTHER PORTUGA

Dept.	Course No.	Brief Title	No. Semester Credits	Year	Institutio
COURSES IN THE MAJOR FIELD:		(not including Research & Dissertation Course #600)			
RANGE	454	RANGE IMPROVEMENTS	3	1984	U of I
RANGE	558	RANGE ECOLOGY: CONCEPTS	3	1984	"
RANGE	501	RANGE SEMINAR (1)	3	1984-85	"
RANGE	502	DIRECTED STUDY: RANGE MODELING	3	1984	"
RANGE	552	RANGE ECOLOGY: QUANTITATIVE	3	1985	"
RANGE	560	RANGE AUTECOLOGY	3	1985	"
FOR	526	FIRE ECOLOGY AND MANAGEMENT	3	1984	"
WLD	545	GAME RANGE ECOLOGY	3	1985	"
SOILS	502	DIRECTED STUDY. SOIL GENESIS	2	1984	"
SOILS	555	ADV. SOIL GENESIS AND CLASSIF.	3	1985	"

COURSES IN THE SUPPORTING FIELD:

_____

OTHER COURSES:		(see attached summary)			
CREDIT FOR	EQUIVALENT	OF MASTERS DEGREE	30	1978	F.F.F.
BOT	535	PLANT GEOGRAPHY	3	1984	U of I
AGE	589	WATER RESOURCES SEMINAR	1	1984	"
APST	521	MULTIVARIATE ANALYSIS	3	1984	"
APST	514	NONPARAMETRICS	3	1984	"

SUMMARY: Number of:

500-600 level credits (include doctoral research)	52 52
400 level credits	3
300 level credits (supporting & other courses only)	
MASTER'S EQUIVALENT	30
TOTAL	85 85

Doctoral Research & Dissertation

Dept.	No.	No. of Credits
RANGE	600	16

GS7/84