

# FREIBURGER WALDSCHUTZ-ABHANLUNGEN

Herausgegeben vom  
Forstzoologischen Institut  
der Albert-Ludwigs-Universität Freiburg i. Br.

**Band 4**

**Johann Georg GOLDAMMER**

**DFG-SYMPOSION „FEUERÖKOLOGIE“**

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## Vorwort

Auf Einladung der Forstwissenschaftlichen Fakultät der Universität Freiburg wurde vom 24. bis 27. Mai 1983 im Forstzoologischen Institut das zweite internationale Symposion "Feuerökologie" veranstaltet. Die neuerliche Einberufung einer solchen Tagung erschien als eine konsequente und sinnvolle Fortführung des auf dem ersten Freiburger Symposion im Jahr 1977 erfolgten Gedankenaustausches und der daraus ergangenen Anregungen.

Unter dem Eindruck der unverändert bedrohlichen Waldbrandsituation Südeuropas entstanden eine Reihe von Forschungsaktivitäten, deren Darlegung einen Schwerpunkt des Symposiums bildeten. Neben den Beiträgen, die sich mit der Ökologie des Feuers in Nadelwaldgesellschaften und dem Einsatz des kontrollierten Feuers in der Landschaftspflege beschäftigten, waren insbesondere die Einführung in die Grundlagen quantitativer Feuerökologie und den Stand der Forschung in Nordamerika von Interesse.

Die Zusammensetzung des Teilnehmerkreises ermöglichte eine Einberufung der IUFRO-Subject Group S.1.09 "Forest Fire Research", die bei dieser Gelegenheit die Zielsetzungen ihrer künftigen Arbeit im internationalen wissenschaftlichen Gedankenaustausch festlegen konnte.

Gleichzeitig trat erstmalig die innerhalb der ECE/FAO Agriculture and Timber Division neu begründete Projektgruppe "Forest Fire Prevention and Control" zusammen. Auch diese Projektgruppe, die ihre Aufgabe in der Vermittlung des Dialoges zwischen Forschung und Praxis sieht, nutzte das Forum für die Vorbereitung eines ECE-weiten Seminars für 1985.

Für die Ermöglichung und nachdrückliche Förderung dieses wissenschaftlichen Gespräches, das anlässlich dieses zweiten Freiburger Symposions auch in der Öffentlichkeit beachtenswerte Aufmerksamkeit gefunden hat, sei dem Direktor des Forstzoologischen Institutes, Herrn Prof. Dr. J. P. Vité, gedankt. Ganz besonderer Dank gilt der Deutschen Forschungsgemeinschaft, die die Durchführung dieses Symposions und die Veröffentlichung der vorliegenden Beiträge ermöglichte, ebenso dem Verband der Freunde der Universität Freiburg, der die erforderliche Auflagenhöhe durch einen Zuschuß sicherstellen konnte.

Freiburg, im November 1983

J. G. Goldammer

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## PRINCIPLES IN QUANTITATIVE FIRE ECOLOGY

Robert E. Martin and Matthias N. Diemer, U.S.A.

### INTRODUCTION

Over the years, we have had a great deal of difficulty in quantifying fires and the effect they have had on biological communities. Variability has been an important facet of these difficulties, and anyone who has attempted to measure forest fuels can testify to these difficulties. Further, the fire which will consume or modify the already variable fuels will add extra variability with either its spatial or temporal variability.

Descriptions of the effects of fires have also been distorted by the nature of the fires which were studied. Biologists often described fire effects from observations on past fires. In North America for instance, the biologist often studied the effects of large wildfires which had escaped control for many days or even weeks. One problem with these observations is that there probably were no accurate descriptions of fuel and weather conditions at the time of burning, so the observer was describing the effects of an unknown treatment. Further, since the fires often had managed to escape control for long periods of time, they were most likely burning under the more extreme fire behavior conditions. Thus, the results described would be biased toward the most severe and damaging burning conditions, and the subsequent drastic effects on vegetation, soils, nutrients and other factors. Almost never did the biologist study the effects of the fractional hectare fires which firemen were able to pounce on and stomp out at will.

Over the years, more and more attempts have been made to describe both the conditions under which fires burned and the fire itself. Descriptions would include the amount of fuels, both live and dead, present before and after the fire along with their

arrangement and moisture contents. Various attempts have been made to describe the fire itself, recording its visual and thermal properties. It is with the various measurement of fire related parameters that we will deal in this paper. We'll first discuss techniques for documenting most fires and then cover specialized techniques and problems in applying them.

### MEASUREMENTS

The order of coverage will be fire weather, fuels, flora and then the specialized measurements. In each, we'll cover generalized techniques more applicable for broad management applications and techniques which require more effort but which give more specific information. The information we draw on in the presentation comes primarily from techniques used in Canada and the United States (van WAGTENDONK et al. 1982). It should be noted that measurement of all factors except the fire itself should be made at varying times before and following the fire and preferably also on undisturbed control plots.

### FIRE

The fire itself should be documented. Generally, observations on fire are simple and require only simple equipment (ROTHMEL and DEEMING 1980). Recommended observations include:

- Flame length (slant length from middle of flame base to tip) which is proportional to fire line intensity by the equation  
$$I = 258L_f^{2.17}$$
where  $L_f$  = flame length in meters
- I = fire line intensity in kilowatts/meter of fire front
- Flame angle as the angle from horizontal to that of the flames.
- Flame height as the vertical projection of the flames.
- Rate of spread (R) in meters/hour or other appropriate units

for the flaming front.

- Residence time ( $T_r$ ) or the time flames persist at any point.
- Flame depth ( $D_f$ ) or the width at the base of the flames.

Flame depth, residence time and rate of spread are related by the equation:  $T_r = \frac{D_f}{R}$

Often these observations are made with an object of known size for comparison. My crews and I have used a vertical metal pole with metal crossarms of varying length. Objects can also be placed at known intervals on the surface for rate of spread measurements.

Fire are quite variable and the observations of its behavior give only a rough estimate of its behavior. Even then, the estimates at specific locations can be quite beneficial in assessing a fire's effects.

Photographs of burns, especially at sample points where fuels and vegetation are sampled and photographed, are very useful for visually interpreting a fire's effects and for illustration. The general use of photography for later interpretation of fire behavior usually is expensive in time, film and equipment, and does not give the perception which an observer on the site can give.

Special techniques for documenting fires are sometimes used, such as time-lapse photography to measure flame lengths and rate of spread. Electrical resistance networks with low temperature melting links have been used to indicate the fire's rate of advance. Other techniques, such as temperature measurement, are covered under special measurements.

#### WEATHER

Weather significantly alters fire behavior, and should be

measured for some time before the fire, during the fire, and often following the fire if fire effects might be dependent on subsequent weather. In some places, weather variables might be taken as part of a fire danger rating system, and supplemented as needed for proper fire documentation. Ordinarily, weather should be recorded at the beginning and completion of burning, and at half-hour intervals during burning. The weather observer should get away from the smoke and temperature effects of the fire to take the measurements. Weather observation stations on or adjacent to the burn are very helpful for obtaining pre- and post-fire weather. Belt weather kits are useful for measurements during burning and for periodic measurements before and after burning.

Weather variables of use are:

Precipitation - amount, duration, and time of precipitation, or date at which snow cover ended

Temperature - maximum, minimum, and periodic measurements during burn

Relative humidity - maximum, minimum and periodic measurements during burn

Cloudiness - at least during burn if during daylight, as insolation can affect fuel temperature and moisture content

Wind - speed and direction especially during burn

The degree of sophistication in the measurements will depend on equipment and time available. Even inexpensive equipment at or near the site will give valuable information.

#### FUELS

Fuels can be considered to be the entire biomass on an area of land. Generally, biomass fuels below the mineral soil surface do not burn and are not measured (although stumps, large roots, and buried logs frequently burn). To evaluate fuels effectively, we must consider whether they are alive or dead and whether they are

woody or herbaceous. To understand how a fire will behave in a fuel complex, we need to know several things about the fuels (from BROWN et al. 1977, with chemistry added):

- moisture content
- particle size
- quantity
- compactness
- continuity
- chemistry

Measurements taken to describe each of these properties would pretty well define the fuelbed in which a fire is burning, or has burned, since measurements should be taken before and after burning. The problem is how to measure them in ways that are not too expensive and difficult and do not disturb the fuelbed excessively before burning. We'll discuss measurement methods and how factors cover the fuel properties given.

Size of fuel particles is important in the surface area per unit volume of fuel, greatly affecting availability to burn and for heat or moisture exchange. For convenience in North America, dead fuels have been grouped in time lag classes according to their theoretical drying rate. The time lag constant of a fuel to lose 63.2 percent ( $1 - \frac{1}{e}$ ) of the difference between its moisture content at the beginning of the time period and the new equilibrium moisture content to which it is exposed (BYRAM 1963).

As an example, a fuel particle beginning at 20 percent moisture content and exposed to 10 percent equilibrium conditions would lose 6.3 percent moisture content and be at 13.7 percent moisture content in one time lag period. If the period is one hour, the fuel has a 1 hour time lag. We have grouped sizes of dead fuels into time lag classes for measurement convenience (DEEMING et al. 1977):

Timelag class	Fuel Roundwood (diameter)	Litter (depth)
1-hour		
(0-2 hours)	to 0,6 cm	to 0,6 cm
10 hour		
(2-20 hours)	0,6 to 2,5 cm	0,6 to 2,5 cm
100 hour		
(20-200 hours)	2,5 to 7,6 cm	2,5 to 10,2 cm
1000 hour		
(200-2000 hours)	7,6 to 20,3 cm	10,2 to 30,5 cm

Table 1: Time lag classes (dead fuels)

The factors listed above, except for continuity, enter strongly into the behavior of fire as predicted by ROTHERMEL's (1972) equations. Their entry into the equations are in the following forms:

Moisture content

$$M.C. \Delta = \frac{Wt_{field} - Wt_{dry}}{Wt_{dry}} \times 100$$

Particle size - by size classes, although to reduce measurement time the 1, 10, and 100-hour classes are entered as the quadratic mean diameter for the class, generally using standard QMD's given by BROWN (1974) for each species.

Quantity - tons/acre or tonnes/hectare which require conversion of volumes to mass using estimated specific gravities.

Compactness - by packing ratio, the volume of fuel in a given volume of space; this is not entered directly but comes out of the fuel quantity and depth measurements, using measured or

assumed fuel particle densities.

Continuity

- doesn't enter into spread models, as it cannot handle non-uniform fuels, it can be handled as mixtures of fuel types to some extent.

Fuels are also grouped into live or dead and woody or herbaceous.

Obtaining accurate fuel measurements has always been difficult because of their variability and diversity. Today, the dead and down fuels are usually measured by planar intersect and the latest on this method is given by BROWN et al. (1982). Litter and duff are usually measured by depth in centimeters or inches and may be related to weight by curves or equations (FFOLLIOTT et al. 1968, 1976, 1977). Grass, herbaceous, and semi-shrubs are measured by clipping or estimated from equations for cover and perhaps height (OLSON and MARTIN 1981). Shrub fuels can be estimated from basal diameter of stems (BROWN et al. 1982) or crown cover (MARTIN et al. 1981). Fuels on trees or those which will accrue from logging are often estimated from prediction equations (BROWN 1978, BROWN et al. 1977). The effects of fire on fuels can be predicted, within limits, by burning conditions. A summary of the effects of fire on fuels is given by MARTIN et al. (1979) and more recent effects in the Northwest by SANDBERG (1980) and MARTIN (1981).

FLORA

Descriptions of flora before and after fire are extremely important in assessing fire effects. Further, the flora supplies the fuels for the fire, but we'll talk about the fuels and fire later. Trees, shrubs, and herbaceous plants should be described, and different techniques are often required. Things we need to know about flora are site coverage, frequency density condition, and biomass. General sampling methods are given by MUELLER-DOMBOIS and ELLENBERG (1974).

### Site Coverage

The amount of the site covered by vegetation can be measured as canopy cover or basal cover, depending on the objectives of the measurements and time available for sampling. Usually cover is recorded by species or by groups of species according to growth habit such as overstory trees, understory trees, shrubs, semi-shrubs, and herbaceous. Crown cover of trees could be estimated using spherical densiometers, photographs, or radiation. Diameters of individual plants are often obtained by measuring the major and minor axes (diameters) and calculating the elliptical area by the equation:

$$A = \frac{\pi}{4} D_1 D_2$$

Measurement of individual crowns will give an indication of species number in addition to cover on area plots.

Usually plant cover would be measured as intercepts along a line-- the line intercept method. Each time a plant intersects the line the length of intersection is recorded by species. Since there are several layers of plant crowns, frequently one might record over 100 percent cover, and it may be important to separate intersections into strata.

The point (or point contact) method is often used by pushing 10 pins downward through a frame and recording the species of plant contacted, if any (NAS-NRC 1962). The frame may be placed for vertical or 45 degree pin angle.

The step-point method involves walking in a predetermined direction through a unit and recording what is contacted by the tip of the shoe at each of 100 paces (NAS-NRC 1962).

Estimation of cover by species within a frame such as the 20x50 cm Daubenmire frame is an excellent means of measuring cover for low vegetation (DAUBENMIRE 1959). It can also serve to indicate frequency of plants.

For wildlife habitat, structure of the vegetation is important. Methods for visual obstruction have been developed by NUDDS (1977) and ROBEL et al. (1970) to evaluate cover for various wildlife.

Photographic and charting techniques are also valuable in evaluating effects of fire on vegetation. Charting is time-consuming and used only occasionally. Photographs, however, especially when they include objects of known size, can be especially effective in evaluating response of vegetation to fire (HALL 1976). Much of our general information on vegetative changes has come from old, often casual, photographs.

#### Frequency

The frequency of a plant is used to refer to the number of times a plant shows up in samples and is a measure of the dispersion of a plant. Whatever the sampling method, the sampler merely records the presence or absence of the plant. The number and size of sampling units is important and the size should be selected so not more than 1 or 2 species should appear in every unit (CLARK and BRITTON 1981).

#### Density

Density is used to express the number of individual plants per unit area (BROWN 1954). Different methods might be used to express density (CLARK and BRITTON 1981), and methods must be described clearly. Use of frames to count number of plants originating in each is a usual sampling method.

#### Biomass

Biomass measurements usually require destructive sampling either

on each area to be sampled or by establishing biomass curves from limited sampling. Herbaceous vegetation would often be clipped at the ground surface within a quarter square meter on a burn area and oven-dried at 60 to 80°C for oven-dry weight. For shrub or tree species, estimates would usually be made from curves developed by detailed sampling of plants with a range of sizes.

#### SPECIAL TECHNIQUES

Generally, special skills and equipment are needed to measure such factors as temperature, fauna, nutrients, soils, microorganisms, smoke, physiology, insects, and diseases. We'll not discuss each of these, but we will point out problems in the field of temperature measurement.

#### Temperature

Attempts have been made, often with great inaccuracy, to measure temperatures occurring during fires. These measurements are difficult because of the ephemeral nature of the fire, the high temperatures involved, and the steep temperature gradients.

The temperature fluctuations inherent in the rapid passage of a fire front would require that any sensing element have very little heat capacity. Possibly the closest one could come to this would be a very fine thermocouple junction. Often materials which melt or change chemically have been used to indicate fire temperature. In order to observe the change, generally a substantial mass of the substance is required, thus lowering the indicated temperature because of the heat required to bring about the physical or chemical change. As the size of the indicator increases, heat loss by radiation also increases. Such devices are probably quite worthless in measuring flame temperatures, but could have some value in indicating temperatures in solid objects. When used to indicate temperatures attained in objects,

the sensor should often be kept as small as practicable and/or with physical and thermal characteristics as close as possible to the medium in which it is embedded.

Generally, these devices have the limitation of indicating only a peak temperature attained and not giving any idea of the duration of that temperature or the shape of the heat pulse. As the duration of the heat pulse shortens, under-measurement of peak temperature could also increase because of the extra heat required to bring about phase change or an endothermic chemical change.

We might consider the effectiveness of a temperature sensor by looking at the balance of heat moving to it and away from it. Since conduction, convection, and radiation are the three ways in which heat is transferred, the heat balance of an object would be:

$$Q_{K+} + Q_{C+} + Q_{R+} = Q_{K-} + Q_{C-} + Q_{R-} \quad (1)$$

where the Q's are heat fluxes

subscript K is conduction, C is convection, and R is radiation.

The + represents a heat gain in the body and a - a heat loss.

If we consider a sensor in the hottest part of a flame, then there would be no conduction to the sensor. Since the sensor would always be somewhat cooler than its flames as temperature increases, there would be no convection of heat away from it. Thus, equation (1) would reduce to:

$$Q_{C+} + Q_{R+} = Q_{K-} + Q_{R-} \quad (2)$$

Since the flames often are small, not very dense, and since the sensor is approaching the gas temperatures,  $Q_{R+}$  is generally quite a bit less than  $Q_{C+}$ . If we use small leads and expose as much of them to the same temperature as possible, then  $Q_{K-}$  is much less than  $Q_{R-}$ . Thus we have

$$Q_{C+}, Q_{R-} \gg Q_{R+}, Q_{K-}$$

The major problem we face in getting an accurate temperature indication from a sensor in a flame, then, is to estimate  $Q_{C+}$  and  $Q_{R-}$ . This can be done by making estimates of various properties of the flame, the sensor, and the surroundings, and the heat balance can be calculated as follows (MARTIN 1963):

$$h_C A_t c (T_g - T_t) = \epsilon_t A_t (T_s^4 - T_t^4)$$

where  $h_C$  = surface transfer coefficient  $\frac{\text{kJ}}{\text{m}^2 \text{sec}^\circ\text{C}}$

$A_t$  = surface area per unit length of sensor

$\epsilon_t$  = emissivity of sensor, dimensionless

$\sigma$  = Stefan-Boltzmann constant, equal to  $5.67 \times 10^{-11} \frac{\text{kJ}}{\text{m}^2 \text{k}^4 \text{sec}}$

$T_g$  = temperature of hot gases,  $^\circ\text{K}$

$T_t$  = temperature of sensor,  $^\circ\text{K}$

$T_s$  = temperature of surroundings,  $^\circ\text{K}$

We are interested in the difference in temperature between the thermometer and the hot gases, so the equation can be rearranged to give:

$$\Delta T = T_g - T_t = \frac{t}{h_C} (T_t^4 - T_s^4)$$

Calculations of errors in temperature indicators can be made using values for  $h_C$  and  $\epsilon$  from other sources. Dimensional analysis will provide estimates of  $h_C$  (McADAMS 1954), and  $\epsilon$  values can be obtained from standard tables. Using the last equation and estimated values for  $h_C$  and  $\epsilon$ , MARTIN (1963) found in headfire and backfire temperatures to be essentially the same, as would be expected.

If one wishes to improve measurements of flame temperature, then it will be important to raise the temperature at which equation (2) is in balance. Since  $Q_{C+}$  is roughly proportional to the square root of the velocity of gases flowing past an object, we would want to do this by drawing the gases or hot flames by the sensor at a high rate of speed. Also, since  $Q_{R-}$  is proportional to the difference in the fourth powers of the absolute temperatures of the sensor and the surroundings, then we could

consider raising the temperature of the surroundings. This is done by putting a series of shields around the thermocouple and drawing the flames by it faster with a vacuum. (It could also be done by reducing of the sensor.) The result of the two modifications is a shielded, aspirated thermocouple. Crude experiments comparing flame temperatures of woody cribs recorded by exposed and shielded-aspirated thermocouples indicated exposed temperatures of just under 900 °C and shielded-aspirated temperatures up to 1168 °C. This would still be less than calculated temperatures, but there was also lag time in the thermo-couple and the recorder.

Temperature measurement in solids, such as tree stems, duff, or soil can be useful, but should be done with great care. The problems are less severe, but sizable errors can result. The heat balance equation reduces to essentially a conduction problem, so that:

$$Q_{k+} = Q_{K-}$$

It might be better stated that we are interested in increasing heat conduction both to and from the surroundings and decreasing conduction along the sensor. Radiation might be a problem in porous solids, but should generally be less of a problem than the conduction errors. In soil, duff, or log temperature measurement, the leads should be parallel to the front of the heatwave, that is, along an isotherm, where there is no thermal gradient. Reduction in size of leads reduces error if there is a gradient - and there often is in field measurements. The sensor and leads should be kept small to reduce heat capacity and be in good contact with the solid, thus responding quickly to temperature changes of the body.

Temperature measurement in tree stems is difficult, because one cannot predict accurately the orientation of isotherms, and they would vary with characteristics of the fire. Further, if isotherms were predicted, locating leads along them may be very difficult. It may be easier to predict errors in temperature measurement of tree stems in fires and make corrections to

readings than to try to eliminate the errors. Accurate temperature measurements of small bodies may be very difficult. Often the heat gain or loss might be better calculated from dimensional equations (McADAMS 1954, LANGHAAR 1951) than to try to do the experimental work.

#### Other Special Measurements

Measurement of any special factors in regard to fire require other fields of expertise. We have cited temperature as one example because it is so often measured incorrectly. As with temperature, measurement of other factors should be done with the help of experts from those fields. Conversely, other scientists or practitioners dealing with measuring fuels and documenting fires should consult experts in these subjects.

#### SUMMARY

The science of wildland fire is advancing rapidly, and proper documentation of fire can help us move more rapidly and with fewer gross errors. Fuels, vegetation, weather and fire generally must be documented to give an accurate description of the fire treatment and its effects. The more compatible the documentation is among fires, areas, and continents, the more rapidly we'll be able to discern generalities, develop critical hypotheses, and test them.

As wildland fire science develops, it becomes more important that special effects on resources are measured. When special measurements are to be made, however, there is a need to have specialists from the subject disciplines involved in the planning and conduct of the fires and measurements. Without such specialists, measurements may be inaccurate, and worse, misleading.

We have presented in this paper some of the techniques used for fire documentation in North America and have attempted to typify the problems in special measurements using temperature as an example. Hopefully in the future there'll be a chance to look at fire documentation techniques used throughout the world and to arrive at some combinations of techniques which will give excellent documentation and promote intercontinental interpretation of fires and their effects.

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METHODS FOR DETERMINING THE EXTENT OF TREE DAMAGES CAUSED BY FOREST FIRES

Tytus Karlikowski, Poland

Read by Matthias Diemer, Germany

The problem of determining the extent of damages caused by forest fire turns out to be of big significance, not only from scientific point of view, but mainly from it's economical impact.

Qualification of losses caused by fire, if done immediately just after the end of fire-fighting action, may allow an effective interpretation of fire harmfulness. It concerns particularly these kinds of fires which are called "ground fire".

In such cases in pine stands only the vegetal cover and litter are being burnt. It can be said then, that no losses took place, since the stand is still alive, and the soil flora survives quite well, afterwards.

But this harmlessness is of apparent origin. As we know from the literature, the soil fauna is destroyed completely, which leads to a certain instability of the biocoenosis. Moreover, the results of investigations carried out in Poland suggest that mortality of trees from fire zone continues for several years, which consequently requires progressive cuttings with clear cutting included. This period lasts 5-6 years and is dependent on fire intensity, the season of occurrence, and even the litter moisture. So, it may be suggested, that more than once, the forest fire is the main cause of "disease-chain", because the weakened forest is being attacked by insects and fungal pests.

This is why the determination of the extent of damage to trees by high temperature just after the fire ends, plays such an important role.

In the Forest Research Institute in Warsaw the investigations have been started (1979-80) to determine the air temperature in the fire-zone, temperature in the ground, and inside the trees. On the base of consultation with specialists from the Institute of Electrical Engineering, several experiments had been carried out with application of the thermographic camera AGA 680 LW.

Thermography, as it is known, is a method for determining the field of temperature by visual means. The thermoimage (thermogram) gives the full information of all points of the area present in the field of view of the camera. On the black-and-white TV image brighter areas correspond to higher emission of thermal radiation. This emission is dependent both on temperature and emission factor. Black-and-white images can be converted to color; then each color corresponds to definite temperatures.

Besides visual presentation of temperature from the whole area tested, the next advantage of this method is the capacity of observation and measurement without disturbance.

The goal of experiments carried out by the Division of Forest Fire Protection, Forest Research Institute, using the thermographic camera AGA 680 LW was to determine the applicability of thermographic apparatus for this purpose. During the investigation different aspects of forest fire, such as temperature of soil sections and inside tree stems, temperature at the root level, detection of fire centers, etc. were evaluated.

The method of investigation consisted of an observation of a given subject using the camera mentioned above.

1. The determination of temperatures in soil sections was done by digging pits with three vertical walls and the bottom of oblique type, rising in direction to the camera. The opposite rectangular wall of approx. 50 cm of height represented the aim of tests. The soil profiles were done

during the fire was being continued and at the same time the pictures were taken also. The impact of fire suppressants on these temperatures was observed simultaneously.

2. The fields of temperature of tree stem sections were recorded directly just after the tree was fallen. The observation was made from the nearest accessible distance.
3. The determination of the field of temperature at the root-collar was performed after a few hours of fire, by digging-up the root-collar from smouldering decay and few centimeters of the soil.

Taking the results obtained as the basis, the following conclusions can be made:

1. Thanks to the visual image of soil temperature, the thermographic method appears more advantageous in comparison to traditional ones as far as measurements of temperature on various soil levels are concerned.
2. The experiments with temperature measurements of soil sections showed the significant influence of several accidental factors on soil temperature. The relationship between heat flow inside the ground and the soil structure, stone content, and the layers formation was noted too.
3. Also the significant effect of unburnt surfaces, on lower soil levels was detected. Thanks to visuality of the whole field of temperature in the soil profile, all of these causal factors can be rejected.
4. The strong soil temperature gradient just beneath the surface of decay was detected, particularly during the initial phase of fire (approx. 2 hours).
5. The possibility of visual evaluation of the tree-stem field of temperature after the fire allows prediction of the stand survivability, which is of big economical significance. The proper statistic method should be used in this case.

The application of thermographic methods for determining the fields of temperature both inside the tree and in several layers of the forest soil presented briefly in this paper, allow to consider such an apparatus as a very profitable tool, both economical, and practical.

## THE FIRE, A TOOL FOR CLEARING THE FRENCH MEDITERRANEAN FOREST ASSOCIATIONS\*

Pierre Delabrage and J. Ch. Valette, France

### 1. INTRODUCTION

Prescribed burning in wintertime has traditionally been used for limiting the undergrowth and therefore the fire development, but also improving the range quality or facilitating the chesnut gathering.

Because of rural depopulation, prescribed burning was practically abandoned and consequently brush and shrub areas expanded tremendously as "garrigues" or "maquis" respectively developed on basic (limestone) and acid parent material. In forest areas, because of weed and shrub growth, there is now a continued stratification of vegetal material from ground level to tree crown. Such conditions greatly favour the occurrence of strong fires very difficult to control.

Some vegetal associations, like "garrigues" with Quercus coccifera (this oak is in fact a shrub) may have a relative stability in spite of fires, provided their frequencies does not exceed 20-25 years. By contrast, in forest stands where shrubs have expanded under the canopies, repeated and strong fires quickly invalide the degradation and even the destruction of the forest.

Large fuel breaks are now established in order to protect the forest areas. They usually are 50 to 100 meters (or even more) wide and may be completely cleared or not (trees are left or planted). These strips, delineating the forest land in

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\* Translated by Y.BIROT

compartments, enable the fire fighters to be more efficient and therefore to limit the rate of burned areas.

These fuel breaks are usually mechanically cleared by machine or hand; then they may be maintained by combining the same mechanical techniques with other techniques such as: specific herbicides or growth inhibitors application, grazing (mostly sheep), winter burning. Concerning the last method, it is presently more realistic to think in terms of operations achieved by agencies or small companies with trained people rather than by farmers (to date rare) as in the past. This remark prints out a constraint: burning was conducted by farmers over day and night (because of better meteorological conditions). Because of social problems and costs, burning should now take place in the normal work time.

Weed and shrub control in forest is also intended to be achieved with the same techniques. In all cases, the objective is to set up or to modify the structure and the composition of vegetal formations where trees are dominant in such a manner they become less susceptible to fire. Financial evaluation of these operations must also be taken into account with respect to the patrimonial value of these forest areas.

The mediterranean Silviculture Research Station (in collaboration with other research organizations) has started investigations in this field. The goal is to find out practical methods for maintaining "clean" fuel breaks or forest stands over a long period, by combining the different techniques previously mentioned. As a finest step each technique is separately studied. Attention is paid to factors or their modalities of a given technique which make it most efficient.

Concerning the prescribed burning, the relative importance of each factor involved such as flammability, combustibility of living (shrubs, trees) or dead material (litter), slope influence is investigated. Evaluating the critical value of each factor and

its range of validity seems to be of major importance. The present paper reports some results from several research projects devoted to the factors cited above. They may contribute to a better use of fire as a cultural method.

### 1. SPECIFIC FLAMMABILITY

This parameter is assessed on a standardized sample (about 1 g) with a standardized procedure by using an epiradiator (see fig. 1). This radiator supplies a stable calorific flux of  $7 \text{ watts} \cdot \text{cm}^{-2}$ . A gas burner is used for controlling the flammability of gases produced by thermic decomposition. Flammability is measured as the timelag between the sample setting in the radiator and the flamme appearance; 100 replications are assessed at each series of measurements for each species. This provides a method for ranking the species according to their flammability. This parameter depends on several factors such as, phenological stage, water status in the soil as well as in the plant (sap pressure) or on the plant (after raining).

An example of ranking of flammability in summer time is given in fig. 2 for different species. A more accurate figure may be obtained by using a 6 steps progressive scale (0 to 5).

On limestone, white oaks (Quercus pubescens) may reach the maximum flammability (5) as soon as July and remain at the same level over the summer period until September, whereas evergreen oaks (Quercus ilex) may have a mean value of 4 with short peaks of 5 (during 10 or 20 days). For Aleppo pine (Pinus halepensis), 4 is a mean feature whereas for grasses such as Brachypodium ramosum, often dried in summer time, flammability depends on climatic events (rain, storm). For Q.coccifera, flammability may progressively increase from low value (0, 2, 3) in June to 4 in hot and dry periods.

On metamorphic bed rocks, three different heath species have a

MESURE DE L'INFLAMMABILITE

FLAMMABILITY MEASUREMENT

ENTZÜNDLICHKEITMESSEN

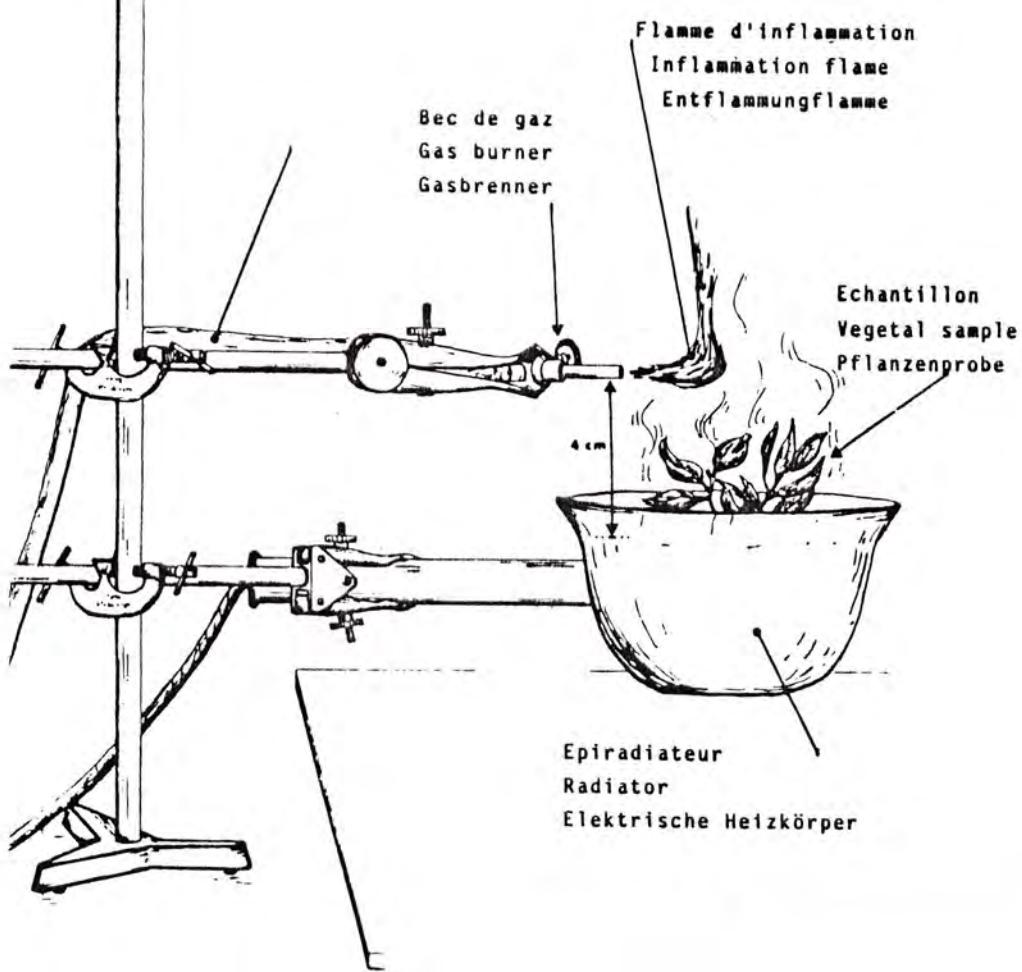


Fig.1 Epiradiator

FLAMMABILITY		
	CALCAREOUS PROVENCE	CRYSTALLINE PROVENCE
VERY FLAMMABLE	<i>Brachypodium ramosum</i> <i>Thymus vulgaris</i> <i>Ulex parviflorus</i> <i>Quercus ilex</i> <i>Quercus pubescens</i> <i>Pinus halepensis</i>	<i>Erica scoparia</i> <i>Erica arborea</i> <i>Calluna vulgaris</i> <i>Quercus suber</i> <i>Acacia dealbata</i> <i>Eucalyptus dalrympleana</i>
FAIRLY FLAMMABLE	<i>Phillyrea angustifolia</i> <i>Buxus sempervirens</i> <i>Juniperus phoenicea</i>	<i>Pinus pinaster</i>
FLAMMABLE	<i>Quercus coccifera</i> <i>Rosmarinus officinalis</i> <i>Cistus albidus</i>	<i>Cistus monspelliensis</i> <i>Cytisus triflorus</i>
NOT MUCH FLAMMABLE	<i>Cedrus atlantica</i>	<i>Arbutus unedo</i> <i>Abies cephalonica</i>

Fig.2 Specific flammabilities

COMBUSTIBILITY			
	SUMMER	AUTUMN	WINTER
<u><i>Quercus coccifera</i></u>	high	slight	null
<u><i>Ulex parviflorus</i></u>	excellent	high	slight
<u><i>Erica arborea</i></u>	excellent	slight	null
<u><i>Arbutus unedo</i></u>	slight	null	null
<u><i>Calluna vulgaris</i></u>	high	slight	null

Fig.3 Seasonal specific combustibilities

different behaviour: Erica arborea may start from 3 in early summer, then reach a plateau at 4 from mid July until mid September and finally go down to 3, whereas Erica scoparia may have a stable value of 4 over July, August and September. Arbutus unedo, less flammable, may reach 3 only during the unfavourable dry periods.

However the flammability concept is obviously limited because it does not take into account the whole individual plant structure and even less the vegetal association. It is the reason why the concept of combustibility has been developed and investigated.

## 2. COMBUSTIBILITIES

This term may be defined as the ability of a given species or vegetal association to burn. The combustibility does combine flammability and biomass variations among the different components (stems, leaves, branches) of a vegetal formation. Combustibility is reflected by parameters such as fire progression velocity, temperature levels and quantity of energy involved.

These parameters are assessed by using an experimental wind tunnel (size 1 x 8 m). For practical reasons, monospecific formations or association composed with 2 - 3 species only are studied. Fig. 3 illustrates how different species rank at different time of the year.

## 3. THE SPECIAL CASE OF DEAD MATERIAL (LITTER)

Litters and dead material have a major role in conditioning the fire occurrence, which is studied for each species with the methodology as below. Needle or leave beds are artificially made and set on a mobile frame (size 86 x 58 cm) located on a balance. A small sample is taken for evaluating the density (dry

matter/volume) and the moisture content after drying in a drying stove. Then the initial mass of the main sample is assessed. 10 ml of alcohol are used to set on fire.

Then a sery of variables are measured (see fig. 4).

a) for the flame front:

flame height ( $h$ ), length ( $l$ ), depth ( $p$ ) and tilt (angle  $\alpha$ ).

b) for the combustion:

fire propagation velocity  $V_p$ , combustion velocity ( $V_c$ ), calorific flux ( $\Phi_n$ ), maximum temperature at different levels.

Subsequently graphs are plotted (see fig. 5 and 6). Through theses graphs, some fire characteristics may be estimated, after having measured a simple variable, for example the minimum mass necessary for starting the fire. These graphs are to be completed with the slope as additional factor (down hill or up hill fires) as shown in fig. 7.

#### 4. PREScribed BURNING

The progressive development of a prescribed fire strongly depends on the quality of the dead material. The mean levels of different variables as favourable (or unfavourable) for a prescribed burning are summarized in fig. 8. This is to be related to the environmental conditions during the periods when burning is allowed; french regulations are very strict on this point.

#### 5. CONCLUSIONS

Prescribed burning seems to be a promising method in the white oak (*Q. pubescens*) zone, especially on the fuel break areas which protect old coppice stands. These fuel breaks have been cleared up by removing the shrubs and the poorest oaks. Because of a long

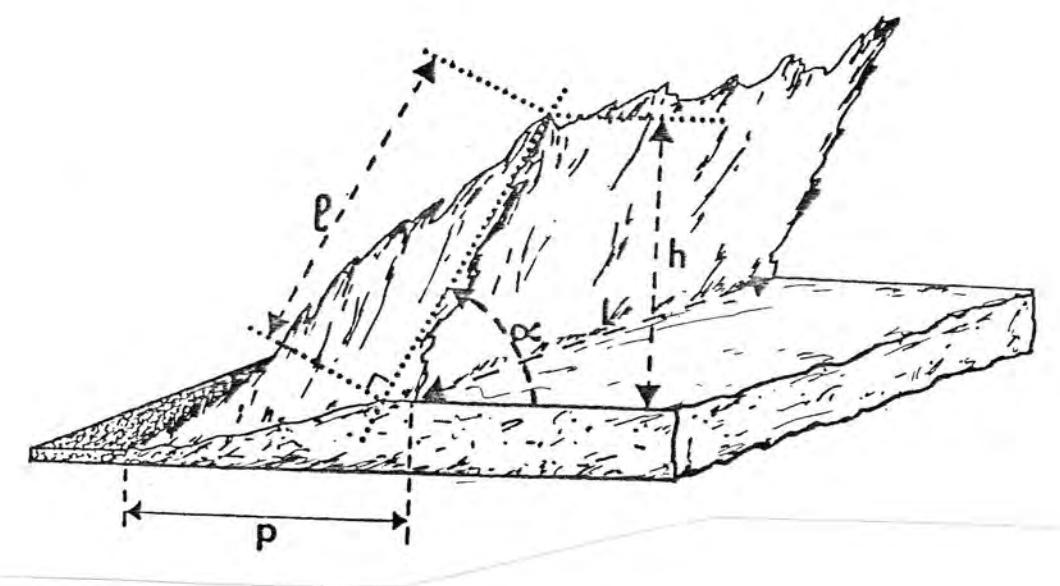


Fig.4: Perspective section of the fire front

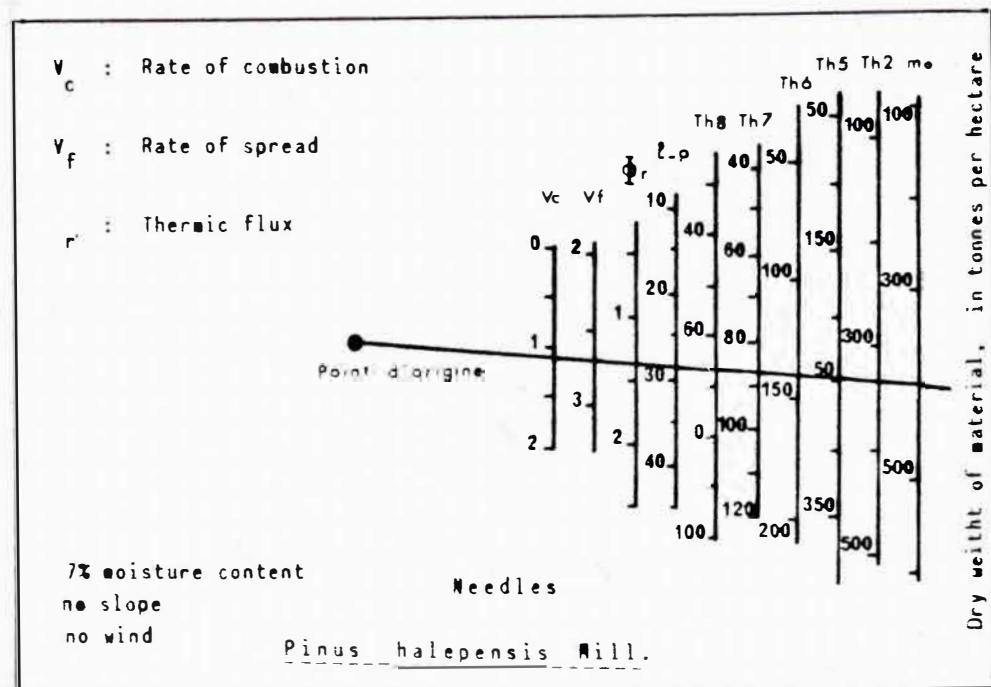


Fig.5: Burning of Aleppo pine needle litter

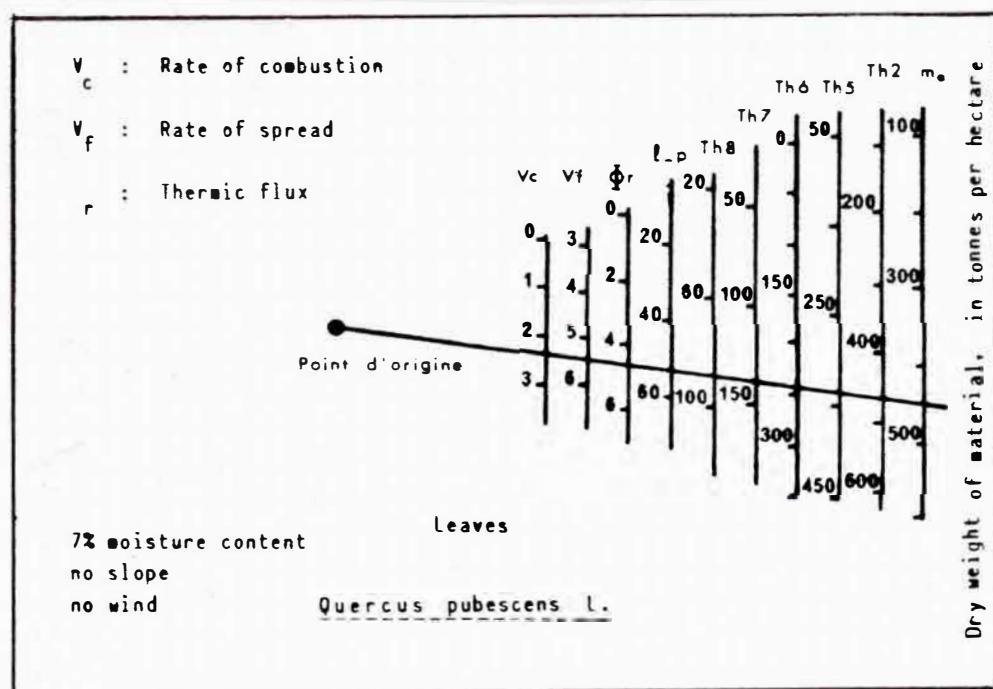


Fig.6: Burning of white oak leave litter

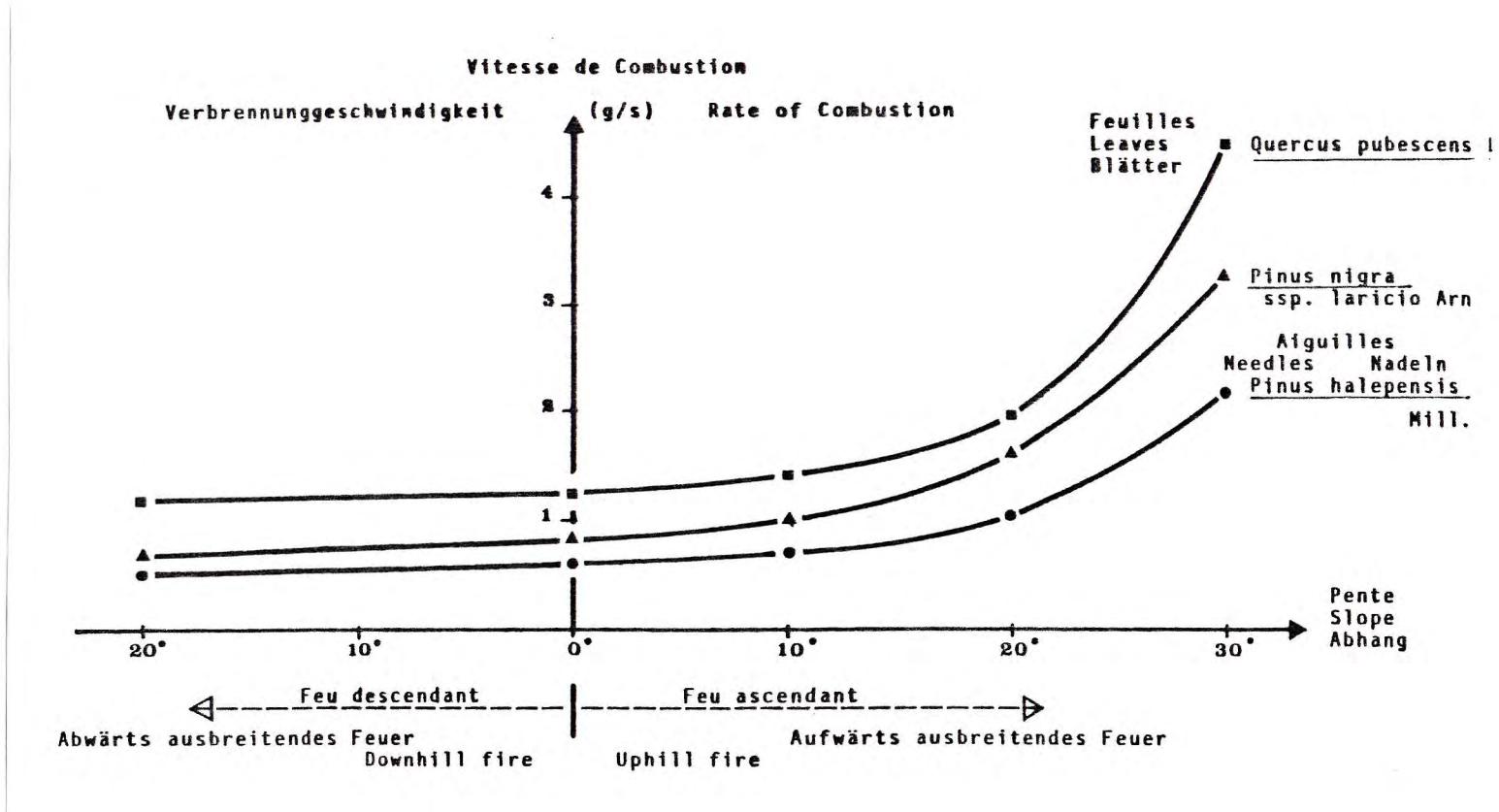


Fig.7: Sloping fire propagation of white oak leaves, Austria pine and Aleppo pine needle litter.

FACTORS

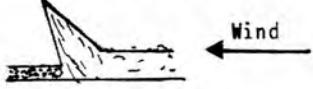
FAVOURABLE		UNFAVOURABLE
high	Weight of material	slight < 2 t/ha
< 10 % slight	Moisture content	high > 30 %
slight	Density	high
> 30° high	Air temperature	slight < 15°
< 30 % slight	Air moisture content	high > 70 %
		
Slope		Slope

Fig.8: Principal factors of litter combustion

persistence of dry foliage in white oak early burning is harmful for the coppice. Therefore it is much better to postpone the operation until March or April. Subsequently, a grass (mostly Brachypodium) expends quickly, but its growth is delayed compared with a non burned area. This favours a possible grazing.

On acid soils in Provence, where the original maritime forest (Pinus pinaster) has practically been destroyed by the pest Matsucoccus feytaudi, the needle amount on the ground is too small and the litter is unsufficient or irregularly distributed. Therefore, the fire progression is tremendously variable. Moreover, the vigorous development of shrubs make very risky the use of prescribed burning. In these conditions, fires may be harmful even for corky bank species such as cork oak (Quercus suber).

In limestone areas, keeping the fire progression under control is sometimes problematic because of the extreme flammability of Aleppo pine (P.halepensis) and even more of evergreen oak (Q.ilex) and Juniperus oxycedrus.

## EXPERIENCE AND PROSPECTS FOR PRESCRIBED FIRE IN ITALY

Giancarlo Calabri, Italy

The Italian forests cover a total area of 6.360.000 ha, about 21% of the national territory in harmony with the average cover of the European Community. They are quite poor, as concerns timber production. Most forests (about 60%) are coppices or coppices with standards; high forests are distributed almost in equal shares between conifers and broadleaved species. The total annual cut, taking into account agricultural and industrial plantations out of the forest, does not exceed 9 millions m<sup>3</sup>, that is 30% of the national needs. Timber is usually said to be the third item in red of the balance of import and export after oil and meat.

Forest lands are 60% mountainous, 34% hilly: 6% only are on the plain. Therefore their importance mainly depends on social and protection functions, in favour of recreation and tourism and against erosion, floods and landslides and pollution. Only 6% of them belong to the State or to the Regions, 34% to Communes or other public bodies, 60% to private owners.

Almost all Italian regions, because of their conditions of vegetation, climate, topography and population, have severe fire problems. Rugged terrains and dry summers and winds make forests and brushlands of the peninsula and islands (especially pine plantations and "macchia mediterranea") exposed to frequent wildfires. Summer is of course the peak season: July and August compete for the highest number of fires and forest areas burnt down. But in the northern regions and high mountains, normally the peak season occurs in winter and in early spring. During the pause of the vegetation, a layer of small branches, dead leaves and dry grass covers the soil, providing highly flammable fuels.

Fire calamity has become worse in recent decades, because of social and economic reasons. The fall in fuelwood and charcoal consumption and decrease of rural population, interested in

forest conservation and exploiting woods, have brought about fuel accumulation.

The annual cut has been reduced to a half the corresponding figure of the post-war period. Vegetation density, difficulty of access and lack of local manpower make woods more and more vulnerable. On the other hand the development of industry and tourism, the rise of living standards and traffic, and sometimes crime and violence, enhance fire causes and damages.

Only a few fires depend on natural causes, that is lightning; with the casual ones (sparks, sunbeams) they represent about 2% of all causes, on the average; the remaining 98% is ascribed to negligence, arson and doubt, sharing almost equal responsibilities. Unfortunately the occurrence of intentioned fires is rising. In 1982 about a half of the total area swept by fire was ascribed to arson, depending on nuisances, vengeance, rivalry, vandalism, protest against planning or naturalistic restrictions, and in some Regions even on the search of jobs inside the firefighting agency.

Once the building speculation had been held responsible for most fires, especially in tourist areas. As from 1975 the law prohibits any kind of building or alteration over the wooded areas swept by fire. But now in a few cases even the opposition to eventual plans is suspected of resort to fire, to bar any possibility of building. The basic national law of 1 march 1975, No 47, preceded and followed by several regional laws, has attributed responsibilities and competences to the national, regional, and local bodies. In 1977 most competences have been transferred to the Regions.

The Regions are responsible for preparing their own plans including all measures to prevent and control fires and to restore damaged areas. According to the rate of fire danger, forests have been classified into four risk classes, taking into account fire statistics, type of climate and vegetation, and

economic and social conditions. Detection and control of small fires depend on local authorities; usually fire control is led by a forest authority. Forest guard stations and mechanized brigades, depending on the Ministry of Agriculture and Forestry, have been equipped and given the main responsibilities for firefighting, with the cooperation of firemen depending on the Ministry of the Interior (responsible for events threatening building or people), of workers trained by the Regions and mountain communities, and of volunteers and other locally organized people. The Armed Forces are called for help in the gravest cases.

Forest fires situation can be resumed as follows. In the early seventies the forested areas swept by fire were over 80.000 ha per year. Since 1975 some improvement derived from the State and region all initiatives of fire protection, just in connection with mild summers. From 1975 to 1980, despite the increase of the number of fires and a fuller information from Sardinia, the yearly forested area burnt was kept around 40.000 ha; the average area of fire being 11 - 12 ha.

In 1981 the situation worsened because of severe drought and strong winds over the western Alpine regions in winter and high temperatures and increase of arson over the central and southern regions in summer. At the end of the year about 14.000 fires had spread over 230.000 ha (74.000 ha of woods and 156.000 of non-wooded areas). Sardinia gave the highest contributions (120.000 ha, 14.000 of them wooded). As a matter of fact fires don't burn forests only but spread also over agricultural lands, pastures, vineyards, uncultivated fields. On the average the forested area is only one third of the total area swept by fire. The record of Sardinia depends above all on stock-raising. Shepherds are used to burn brushlands for grazing. In the same year, at the end of August, a big fire swept about 1.700 ha (600 ha of "macchia mediterranea" and 1.100 ha of uncultivated land) across the promontory of Argentario, an important tourist resort in Tuscany. The public opinion got excited by press campaigns and polemics,

especially to support a wider use of aircraft.

Therefore, under the coordination of the Minister of civil protection, the air firefighting systems have been strengthened. At present they include military airplanes equipped to drop chemicals under pressure (1-2 Lockheed C-130 with a capacity of 12.000 litres and 2-4 Aeritalia C-222 with a capacity of 6.300 litres) and helicopters (3-4 Chinook CH-47 with sling-mounted buckets of 5.000 litres, HH3F 1.200 litres, Agusta Bell 205-600 litres), and two water-bombers Canadair CL-215 (5.500 litres) and nine light helicopters (NH-500) belonging to the Ministry of Agriculture and Forestry. In addition several regions hire light airplanes and helicopters for detection and initial attack (20 airplanes and 19 helicopters in 1982).

Last year, in central and southern Italy the summer was extraordinarily dry and hot. But firefighting activities succeeded in cutting down damages. The final yearly statistics reported less than 10.000 fires spreading over a total area of 130.000 ha (49.000 of them wooded). The decreased number of dangerous fires, despite the extraordinary drought and high temperatures is probably related with the atmospheric stability and absence of strong winds.

The prevention activities in Italy are based on a policy of total fire exclusion, aiming at controlling dangers from agriculture, industry and tourism, and at suppressing all fires as soon as possible.

On principle, forest regulations forbid any kind of fire inside the woods or at a distance less than 100 m from them. In some areas a higher distance is prescribed. Since 1975, in the peak seasons of fire, the regional authorities declare the state of severe danger. In such periods of time the law forbids to set fires, to blast mines, to use engines, stoves, incinerators producing sparks or embers, to smoke and to perform any operation which could create an immediate danger for wood.

Forest regulations exclude grazing in forest areas swept by fire as long as their regeneration is at stake. After fires affecting broadleaved species the owners were obliged to cut stumps to make regeneration easier. Such a rule has fallen into disuse because of the scarcity and cost of manpower. On the other hand the law of 1975 provides on principle the restoration of woods swept by fire at total expense of the State. But this measure is hampered by the inadequate funds.

The European Regulation No. 269/1979 in order to restore forest economy has provided for fire prevention activities in disadvantaged areas. Several Italian regions have proposed their plans, containing measures such as fuelbreaks, lookout towers, water sources and chemical retardant supplies.

Prescribed fire is not yet popular as a means of forest protection. On the whole, fire is always considered to be the worst enemy of the environment. As a matter of fact, for thousands of years fire has been used to eliminate forest and brushland for agricultural and pastoral needs. In this country the use of fire for sylviculture is almost unknown, as regards forest work traditions. Apart from piling and burning after cutting in some Regions, in edible chestnut groves, fire was used for cleaning and to make fruit gathering easier. But such practice and experience are forgotten by now for social and economic reasons. Even the burning of stubbles is carried out at present by many farmers without the care of the past and causing heavier menaces to woods.

In Italy prescribed fire can be proposed in theory for instance to reduce the heavy accumulation of fuel in "macchia mediterranea" and the undergrowth of Mediterranean pine stands at least in areas having slight slopes, to make easier regeneration, as well as to clean and maintain fuelbreaks, road side slopes and ditches. Of course its use can be more or less advantageous than other fuel reduction systems, such as mechanical, chemical or biological means. As regards biological means, despite the bad

reputation of grazing animals, it is necessary to mention that the law of 1975 has included the introduction in woods of cattle, sheep and swine, to clean the low vegetation, among the various means of fire prevention. The only fire remains ill-famed.

At any rate the first scientific experiment of prescribed fire was carried out in 1982 in Tuscany - commune of Terranova Bracciolini - by the Experimental Institute of Sylviculture. The burning block with a flat area of 1.000 m<sup>2</sup> had a stand of maritime pine 50 years old, 16 m high, average diameter = 25 cm, with an undergrowth of heather and a few calluna and juniperus. Some days before burning the brush was cut and measured, being about 19.5 tons per ha; the duff was about 21.6 tons per ha. The brush was cut to decrease the flame height and to prevent any crown scorch.

Fire was applied on the 6 April 1982, with a temperature of 17°C, air humidity 77% and a slight and variable wind, 6 days after the last rain. The average moisture of dead fuels was 28%. The prescribed burning conditions had been determined as follows: air temperature 13-25°C; air humidity 25-50%; windspeed 3-16 km/h; dead fuels moisture 6-20%.

A backfire was set from a prepared base line and advanced slowly, burning the total area in 50 minutes, with a speed of 38 m/h. All dead fuels were burnt out. The fire intensity was checked by measuring the evaporation of water from cans placed at regular intervals inside the burning block. The experiment was carried out with abundant safety measures. Twenty people with four fire trucks took part in it to exclude any danger. At last everything turned out well. No trees were scorched. A survey some months later confirmed the perfect health of the stand, as well as a satisfactory fuel reduction, that is the main purpose of prescribed fire.

This timid experience of prescribed fire in Tuscany was quite convincing from a technical point of view, but not to such a

point to propagandize a new fire policy over the country. No further initiatives have followed up to now.

As a matter of fact, several physical reasons make it difficult to spread the use of prescribed fire. Most forests and brushlands are in sloping sites, mountains and hills, and of course slope is a severe limitation. The influence of the sea and Alps and Apennines chains as well as rough topography favour microclimates and variable winds; the weather forecast is sometimes uncertain. Most forests depend on natural regeneration of various species, which could be hampered by fire. Italy is an overcrowded country. Forest estates are generally small and often cut off by built-up areas, lines of communication and other infrastructures. A reckless technician only could take the responsibility upon himself of a prescribed fire not completely safe from risk. Any escape of fire could be extremely dangerous.

On the other hand, the public opinion has been used to a policy of total fire exclusion. Fire is not considered to be a natural part of the environment. The human action in Mediterranean countries has been so intense for thousands of years to conceal natural causes of fire such as lightning. Fuel reduction is not yet a widespread necessity. Most forest areas have been threatened with destruction; have become poorer and poorer, because of the growing rural population. Forest regulations had been conceived against tillage and overgrazing, for social and economic conditions different from the present ones. However, any regulation change requires slow and complex procedures.

Nowadays forest protection is often connected with landscape, recreation and tourism. Such valuable interests exceed strict economic considerations and justify the heaviest expenses to put out fire everywhere by ground and air forces. Somewhere else forest activities are subsidized for public purposes, to protect soil from erosion or to relieve unemployment. Therefore the advantage of prescribed fire as a cheap and effective means of forest management cannot easily prevail against the alternatives

of mechanical and biological means.

At any rate, despite the strengthened forest fire services, the numbers of fires and areas swept by fire tend to increase year by year. The total fire exclusion policy is going to meet with economic restrictions sooner or later. Studies and research on prescribed fire will be useful also to improve firefighting techniques and to suggest a more effective and convenient policy of fire management.

Region	Number of fires	Area swept by fire (ha)		
		wooded	non-wooded	
Valle d'Aosta	10	10	12	22
Piemonte	163	790	390	1.180
Liguria	1.578	5.123	4.367	9.490
Lombardia	195	999	866	1.865
Trentino A.Adige	66	161	59	220
Friuli V. Giulia	277	1.470	1.322	2.792
Veneto	112	438	132	570
Emilia Romagna	92	250	78	328
Toscana	734	3.084	2.287	5.371
Marche	85	136	135	271
Umbria	125	253	248	501
Lazio	359	1.490	3.104	4.594
Molise	57	219	561	780
Abruzzo	34	129	368	497
Campania	1.427	4.839	4.963	9.802
Basilicata	241	1.335	2.198	3.533
Puglie	349	1.700	2.760	4.460
Calabria	915	6.404	5.872	12.276
Sicilia	285	7.699	4.486	12.185
Sardegna	2.453	12.303	47.416	59.719
TOTAL	9.557	48.832	81.624	130.456

Tabl. 1: Forest fires in Italy in 1982

Year	Number of fires	Area swept by fire (ha)		
		wooded	non-wooded	total area
1970	6.579	68.170	23.006	91.176
1971	5.617	82.339	18.463	100.802
1972	2.358	19.314	7.989	27.303
1973	5.681	84.438	24.400	108.838
1974	5.055	66.035	36.909	102.944
1975	4.257	31.551	23.135	54.686
1976	4.457	30.735	20.056	50.791
1977	8.878	37.708	55.031	92.739
1978	11.052	43.331	84.246	127.577
1979	10.325	39.788	73.446	113.234
1980	11.963	45.838	98.081	143.919
1981	14.503	74.287	155.563	229.850
1982	9.557	48.832	81.624	130.456
 Yearly average		51.720	53.996	105.716

Tab. 2: Forest fires in Italy from 1970 to 1982. Statistics before 1977 take only a part of fires in Sardinia into account.

Year	Natural	Casual	Negligence	Arson	Doubtful
1977	0,14	1,97	32,94	41,30	23,65
1978	0,14	2,20	33,52	32,80	31,34
1979	0,54	2,11	37,32	27,10	32,93
1980	0,11	2,14	36,25	34,11	27,39
1981	0,14	1,76	30,62	36,39	31,09
1982	0,46	1,83	33,29	37,36	27,06

Tab. 3a: Distribution of fire causes per number of fires (%)

Year	Natural	Casual	Negligence	Arson	Doubtful
1977	0,17	1,10	25,78	51,90	21,05
1978	0,09	1,04	37,22	37,51	24,14
1979	0,47	2,75	29,81	35,61	31,36
1980	0,03	1,27	30,78	46,58	21,34
1981	0,21	0,84	25,98	45,45	27,52
1982	1,44	0,74	31,69	45,84	20,29

Tab. 3b: Distribution of fire causes per total area swept by fire(%). The tables don't consider fires in Sardinia.

PRESCRIBED BURNING IN PINE STANDS FOR FIRE PREVENTION IN THE N.W.  
OF SPAIN: SOME RESULTS AND EFFECTS.

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ABSTRACT

Prescribed fire experiments are being developed in Pinus pinaster and Pinus radiata stands in the NW of Spain for wildfires hazard reduction. Total fuel loads range from 13 to 61 t/ha (5.8-27 t/acre). Fire intensities from 22 to 86 Kcal. m<sup>-1</sup>s<sup>-1</sup> (92-376 Kw.m<sup>-1</sup>) were used.

A year later, shrub biomass of the understorey was only 20% of the initial accumulation; no significant difference was detected in other components of the fuel complex. Mineral soil analysis do not show significant differences in either textural composition or nutrient contents in the 0-15 cm layer with regard to the controls. Two years later, shrub was 25% of initial amount. The other fuel components had recovered the initial loadings.

A study on edafic microflora in 0-5 cm layer did not indicate significant unfavorable effect in burned plots.

The N cycle microorganisms showed a favorable increase in burned areas. Those of the C cycle, show close similarity in both burned and control plots, and could be increased in amilolytic and hemicellulosolytic groups.

After that same interval of time, significant differences were not detected in vegetative state of trees in burned plots and the controls. Electrical resistance measurements in tree boles showed close relationship with the general vegetative state of trees and could be useful for damage predictions by fire and other agents.

## 1. INTRODUCTION

The principal forests of Galicia, situated in the N.W. of Spain, are formed by three main exotic species: Pinus pinaster Ait., Pinus radiata D. Don and Eucalyptus globulus Labill. The first two species extend over an area of some 672.000 ha of which 90% is P.pinaster.

The yield is among the largest in the country, being 6m<sup>3</sup> /ha/yr for the Monterrey pine. With these, there are populations of E.globulus (87.000 ha) which grow very well, above all within the limits of the mild oceanic climate in North and western coastal zones, adapting perfectly to the soil, generally of coarse texture, and producing the best yields: 15m<sup>3</sup>/ha/yr.

The original native forests, composed of deciduous trees, and characterized mainly by Quercus robur L. occupies, after thousands of years of exploitation, only small zones. The formation of heathland dominates the landscape, increasing each year, especially after the innumerable forest fires that lay waste the forests of this area.

Since 1968, an average of 23.500 ha burns each year in Galicia. Since that year, 30% of the woodland have been lost. Thus, forest fires have made themselves an enormous problem. The Forestry Service (ICONA) and the National Institute of Agrarian Research (INIA) have, since 1977, undertaken joint projects to do research in the most efficient preventative means. Currently, several systems are being tried out, but especially the use of prescribed burning as well as livestock to reduce the quantity of combustible material beneath the trees.

It is well known that mainly in USA, Canada and Australia, several millions of ha are periodically treated by prescribed burning for fire prevention and other management purposes. The technology of prescribed burning has been well developed in those countries. In Europe, the situation is different, and the

technique is used on a smaller and more experimental scale (LIACOS 1973, TRABAUD 1974, VEGA 1977, PITA et al. 1977, ALEXANDRIAN 1980, DELABRAZE 1981, MOREIRA DA SILVA 1982). The situation in Galicia is very different to that of SE, N and W of USA, being monospecific forests through reforestation, rather different to the latter country, well adapted to continuous fire regimes for thousands of years. The density of these Spanish forests is very great, and their phytosanitary condition is fairly precarious, frequently with large numbers of dominated and dead trees, with too little thinning and clearing done. Usually, they are young populations, so that the height of the crowns above the understorey vegetation is not great throughout of major part of their short lives, as the felling age is around 25 years. As well, the topography is normally fairly uneven, and there are high average accumulations of fuel, reaching 40-50 t/ha of dry matter.

The scope of this paper is to examine the short term effects of a series of prescribed burning experiments carried out by the Forestry Service in 1980 in some 2.000 ha of forest land, especially:

- a) To analyse the efficiency of prescribed fire to reduce fuel loading under pine canopy in the NW of Spain circumstances, and observe the fuel recovery after treatment by fire of varying intensity.
- b) To study the effect of prescribed burning on the trees, chemical composition, texture, and microbiological activity of the soil.

At present, other studies are being carried out to investigate the influence of prescribed burning on the phytosanitary state of forests treated in this fashion, examine post-treatment, insects and pathogens attacks, decomposing arthropod mesofauna in litter layers as well as the nutritional state of trees after burning, and to relate these variables with data on the fire behaviour and

with the temperatures distribution in soil during the fire.

## 2. DESCRIPTION OF STUDY AREA

The experiments were carried out in forests of P.pinaster, and P.radiata of 25-35 years of age, with average diameters of between 17 and 28 cms (d.b.h.), height 10,5 and 16 metres, and densities between 1.200 and 1.800 trees per ha distributed among various zones throughout the interior of Galicia (province of Lugo), embracing areas towards the south of the province which has a submediterranean climate with summer drought, mild winters with 1076 mm precipitation annually, up the centre of the province (Terra Cha) with 1600 mm and a more continental climate.

The vegetation of the understorey is formed of heather and gorse, typical of the order Calluna-Ulicetalia on which the reforestation of pines has been undertaken. In the centre of the region, Ulex europaeus, Ulex gallii and Chamaespartium tridentatum generally account for the greatest quantity of biomass, as well as being the most combustible. In lesser quantities, Calluna vulgaris, Erica umbellata, Erica cinerea and Daboecia cantabrica are found. In areas of high soil humidity and in waterlogged zones Rubus sp. and Erica ciliaris, among others, are found and, together with these, Quercus robur, Betula celtiberica and Salix sp. frequently live. On the other hand, Q.suber appears as the climax in the south, and under pines flourish species of clear mediterranean influence, such as Arbutus unedo, Phillyrea angustifolia, Cystus ladaniferus and Ulex sp. being rather more scarce, and mingling with Chamaespartium and Calluna.

Geological substrate varies according to the area. Towards the south shallow soils on shaly schist predominate. Towards the centre, shale and conglomerate, above all in waterlogged areas, and some stands on granodiorite.

### 3. MATERIAL AND METHODS

The burnings were undertaken in March and April. Weather conditions varied according to the zone. Between 2 and 8 days were left after the latest appreciable rain. In some places there had been three or four frosts in the preceding days. The wind in almost all the sites was light, except in one, where wind conditions were variable with a tendency to form small whirlwinds. The techniques used varied from backfiring to stripped head fire.

In these areas, burnt in 1980, eleven plots were installed of varying area ( $300-1500\text{ m}^2$ ) in zones of sufficient internal homogeneity, especially in respect to trees, fuels, topography and fire intensity, and their eleven corresponding controls.

They represented the general conditions of the different forests and the different types of fire intensities used.

On each tree, measurements were made of total height, diameter, initial height of crown, height of scorched crown and minimum and maximum height of scorched trunk.

Eight months after the experiments, soil samples were taken in 0-15 cm depth, ten samples for each plot. The following were determined in the laboratory: % organic matter (WALKLEY & BLACK), total Nitrogen % (Kjeldahl semimicro), pH (soil water relation 1: 2,5), exchangeables Ca, K and Mg, and available P (BRAY-2) as well as a mechanical analysis of soil by the international method of ROBINSON'S pipette. One year after fire, an inventory was made of total fuel present in burnt plots, and in the control ones. All vegetation and its organic residues occurring within quadrats  $1\text{ m}^2$  in size, twenty in each plot, was collected; this included living woody material, herbaceous plants, fine ( $\phi < 2.54\text{ cm}$  diameter) and coarse ( $\phi > 2.54\text{ cm}$  diameter) dead material and litter; twenty samples of the duff layer were collected after removing litter, and all material within an area of  $25 \times 25\text{ cms}$

was sampled until the depth of mineral soil.

These samples were taken from the above mentioned 1 m<sup>2</sup> quadrates, and this material was classified into five different components in the laboratory: vegetation, fine dead fuel ( $\phi < 2.54$  cms), coarse dead fuel ( $\phi > 2.54$  cms), litter and organic layer (duff). This material was dried in ovens at 105°C until constant weight. In the case of the duff, the samples were ignited in an furnace in order to make away with any fine earth adherent.

A sampling was repeated in 1982, and in following years the trend of fuel recovery will be made known.

In 1982 a study of microbiological activity in the soils was undertaken, in order to analyse effects of burning.

For this purpose, eight cores were taken from the first 5 cms of the mineral soil in aseptic conditions and averaged, from each plot. This depth was considered to be the most probable to be affected by the burning; the analyses were done throughout late spring and summer; during transport, the samples were stored in a portable refrigerator and each analysis was done simultaneously with that of a control sample. The techniques used were those of the Pasteur Institute, except for total microflora (STEVENSON and ROUATT 1953), fungi (THOM and RAPER 1954), anaerobic cellulose decomposers (EGGINS and PUHG 1961), Pectin decomposers (PATON 1959), hemicellulose decomposers (BARA et al. 1983).

In this same year, in July and August, measurements were taken of electrical resistance in trunks of every tree of both burnt and control plots. These measurements were taken in about 4 hrs at the midday, with a clear sky and without rain for at least a week. Two steel electrodes were inserted through the bark up to the xylem of the trees. The electrodes were separated by 1 cm and mounted on a prismatic wooden plaque, completely dry. Four measurements were taken from each tree at breast height, each measurement at 90° from the previous. At the same time, trees

were classified into on three types: dominant, codominant and dominated, and an visual estimate was made of the general vegetative state of the tree, using a scale of seven classes; from dead tree up to a dominant or codominant healthy one.

#### 4. RESULTS AND DISCUSSION

##### 4.1 EFFECTS ON FUELS

From the measurement of the heights of crowns scorch it is possible to determine the fireline intensity in each case (VAN WAGNER 1973). This has been the procedure to estimate that parameter in burnt plots, in preference to the flame length the whose value is more variable and more difficult to fix with precision. The intensity used varied between 22 and 90 Kcal  $m^{-1}s^{-1}$  ( $92-376 \text{ kwm}^{-1}$ ); the difference from a wild fire should be underlined, where normally between 100 up to 5 or 6.000 Kcal  $m^{-1}s^{-1}$  are generated.

In table I are shown average values, corresponding to the eleven plots, of total understorey fuel loading and its distribution into classes as well as relative proportion of each. Total values oscillate between 13 t/ha for the stands in the south and 61 t/ha for those cooler and more waterlogged areas.

From these results we can see that,

- a) The amount of combustible material which has accumulates in the P.radiata and P.pinaster stands is very considerable i. e. 37 t/ha.
- b) The duff makes up 70% of the total fuel load; excluding this, the total weight is 11 t/ha.

The amount of duff is not uniform throughout the plots. It can be seen that in the slopes on schists of the south it is scarcer

than in the cooler central areas, possibly reflecting conditions less favorable to decomposition.

TABLE I: AVERAGE FUEL LOADING (gr/m<sup>2</sup>) IN ELEVEN STANDS

COMPONENT	CONTROL	%	ONE YEAR		%	TWO YEARS		%
			AFTER FIRE			AFTER FIRE		
Phytobiomass	233 ± 61	6	40 ± 10*	2	51 ± 14*	2		
Fine elements 0.1"	280 ± 51	7	120 ± 24*	4	349 ± 87	11		
Coarse " 0.1"	136 ± 33	4	136 ± 39	5	236 ± 56	7		
Litter	486 ± 88	13	459 ± 94	16	465 ± 75	15		
Duff	2590 ± 460	70	2040 ± 339	73	2089 ± 370	65		
Total	3,731	100	2,786	100	3,196	100		

\* Significant to 5%

c) In quantity, litter is second; however, its importance is generally undervalued by foresters. But, its high flammability calls for its being taken into account.

d) Taking all the plots as a whole, only the biomass and finer elements show the fire's effect after one year, although it seems paradoxical that litter should not have played its part. The reason is that the trees have fairly low crowns, and the lower leaves were scorched by the fires. At the end of one year, when samples were taken, the amount was much the same as at the beginning, these scorched leaves then having fallen.

e) Given the great differences of the initial fuel loading among the different plots, and the different intensities with which they were burnt, an overall comparison overshadows the reality. An analysis of variance, plot by plot, reflects better the changes produced by fire.

Table II indicates the total percentages of plots which show a significant drop in fuel weight.

TABLE II: % OF PLOTS WITH SIGNIFICANT REDUCTION IN FUEL LOADING,  
BY COMPONENTS.

COMPONENT	% FIRST YEAR AFTER FIRE	% SECOND YEAR AFTER FIRE
Phytobiomass	80	100
Fine elements	60	18
Coarse elements	20	0
Litter	40	45
Duff	50	30

f) The linear correlation coefficients between fire intensity and reduction of each fuel component appears in Table III.

TABLE III: LINEAR CORRELATION COEFFICIENTS BETWEEN REDUCTION OF  
FUEL COMPONENTS AND FIRE INTENSITY.

COMPONENT	CORRELATION COEFFICIENT
Phytobiomass	0,6848**
Fine elements	0,7399***
Coarse elements	NS
Litter	NS
Duff	NS
Total	NS

\*\* Significant to 1%

\*\*\* Significant to 0.1%

NS No significant

#### 4.2 EFFECTS ON THE SOIL

Great changes in the mineral soil were not to be expected, as low fire intensities were used, and also the experiments were carried out in a season where water content in fuels and the soil was relatively high. Furthermore it should be borne in mind that there were few cases with direct exposure of the mineral soil, given the small duff reduction.

In Table IV the values of edaphic parameters are given for burnt and unburnt soil. A variance analysis and comparison of means have been carried out, and none of the variations, in the stands as a whole, are significant. However a logical tendency in a little increase of pH can be observed, as well as a small drop of the total OM and N, and a narrowing of the C/N relationship, agreeing with other findings (BOERNER and FORMAN 1982, METZ et al. 1961, SARK 1977, WELLS 1971). Slight increases in Ca, Mg, K and P concentrations are detectable eight months after the fire; these are the product of the liberation of bases of burnt vegetation and dead material, all in very small quantities, and are not statistically different to the unburned plot. Contents of clay and silt show a slight trend to drop, but neither are correlated with the slope. This is a feature of great interest, but would need to be investigated further.

TABLE IV: COMPARISON OF MEANS OF BURNED AND UNBURNED PLOTS

VARIABLE	UNBURNED PLOTS	BURNED PLOTS	SIGNIFICANCE OF DIFFERENCES
pH	4.52 ± .12	4.60 ± .09	NS
OM %	12.36 ± 2.59	10.76 ± 2.86	NS
Total N %	.393 ± .068	.336 ± .055	NS
C/N	18.4 ± 2.9	18.1 ± 2.5	NS
Ca (ppm)	71 ± 58	95 ± 76	NS
Mg (ppm)	34 ± 16	35 ± 17	NS
K (ppm)	47 ± 5	55 ± 9	NS
P (ppm)	7.2 ± 2.5	13.5 ± 9.7	NS
Clay %	17.13 ± 2.9	16.15 ± 2.6	NS
Silt %	16.11 ± 6.8	15.97 ± 6.7	NS
Sand %	67.02 ± 8.9	67.71 ± 9.3	NS

The correlations between fireline intensities and the above mentioned edaphic variations are no significant in our case. The same occurs with slope and edaphic variables. This is by no means strange, given the small differences between concentrations and that the values of intensities are, overall, small. The results appear in Table V. Note the trend of the C/N relation to increase proportionally to fire intensity, signifying perhaps a resistance to mineralisation of organic matter in proportion to the intensity of the fire. However, in wildfires, this tendency has not been confirmed (BARA and VEGA 1983) and its significance is slight. However, this relation should be studied in greater detail in the future.

The negative correlation of slopes with K could indicate a greater ability for this cation to escape by run off on inclined surfaces.

TABLE V: LINEAR CORRELATION COEFFICIENTS BETWEEN DIFFERENCES,  
FIRE INTENSITIES AND EDAPHIC PARAMETRES

DIFFERENCE	INTENSITY	SLOPE
pH <sub>2</sub> - pH <sub>1</sub>	0.2397 NS	0.3615 NS
OM <sub>1</sub> - OM <sub>2</sub>	-0.279 NS	0.0113 NS
N <sub>1</sub> - N <sub>2</sub>	0.199 NS	-0.4297 NS
(C/N) <sub>2</sub> - (C/N) <sub>1</sub>	0.6177 *S	-0.5619 *S
K <sub>2</sub> - K <sub>1</sub>	0.3452 NS	-0.5740 *S
P <sub>2</sub> - P <sub>1</sub>	0.1379 NS	0.1632 NS
Mg <sub>2</sub> - Mg <sub>1</sub>	-0.1090 NS	0.2577 NS
Ca <sub>2</sub> - Ca <sub>1</sub>	0.0250 NS	0.3523 NS
Clay <sub>1</sub> - Clay <sub>2</sub>	-0.106 NS	0.3089 NS

Suffix 1: unburned soil

Suffix 2: burned soil

\* Significant to 10%

#### 4.3 EFFECTS ON SOIL MICROBIOLOGY

As it is well known, microbiological determinations in soil present great variations, which, together with the geographical distribution of the plots, and the different fire intensities, make the study and interpretation of data very complicated. For this reason, the plots data were grouped into four burning intensities: 100 kw m<sup>-1</sup>, 163 kw m<sup>-1</sup>, 221 kw m<sup>-1</sup>, and 643 kw m<sup>-1</sup>, and the data was subjected to a variance analysis and comparison of means, which did not give significant results.

These results are given in the attached graphs, considering that the original populations in respective controls are the unit in each case.

#### Total microflora

Two years after fire, the populations are practically equal in burnings of low intensity, and slightly reduced in moderate and high intensities. BERRY (1970) did not find any changes in teluric populations after 50 years of controlled burning in summer in Louisiana. JORGENSEN AND HODGES (1970) neither found significant changes after burnings.

#### Actinomycetes

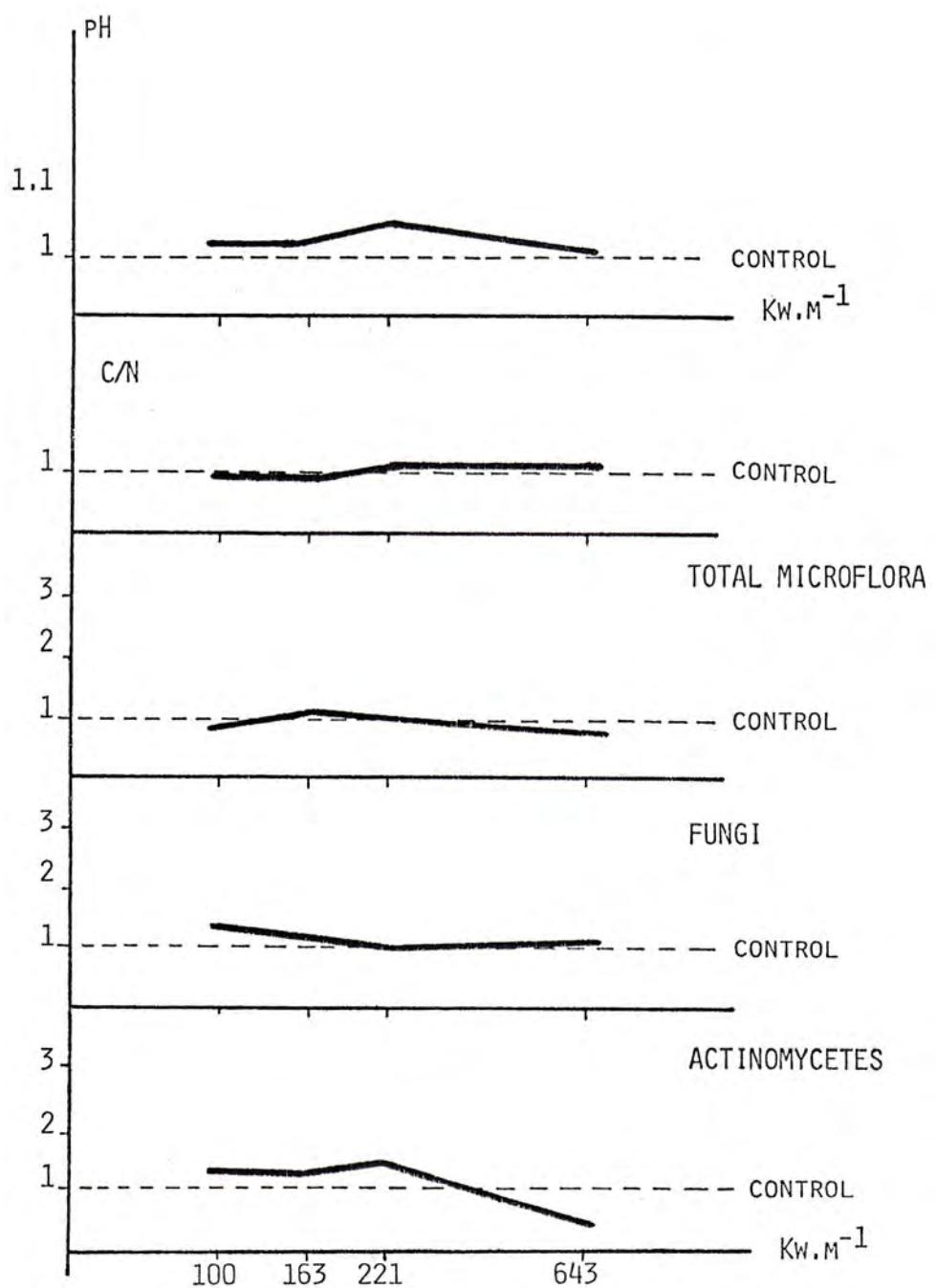
Populations were equal in the two soils. There exists a tendency to increase the percentage of actinomycetes with respect to the number of bacteria in burnt soils. This corresponds to findings in soils of this region by GIL (1982) and by WRIGHT and TARRANT (1957) in other soils. Perhaps this is due to a greater resistance this group shows with respect to heat and changes in humidity.

#### Fungi

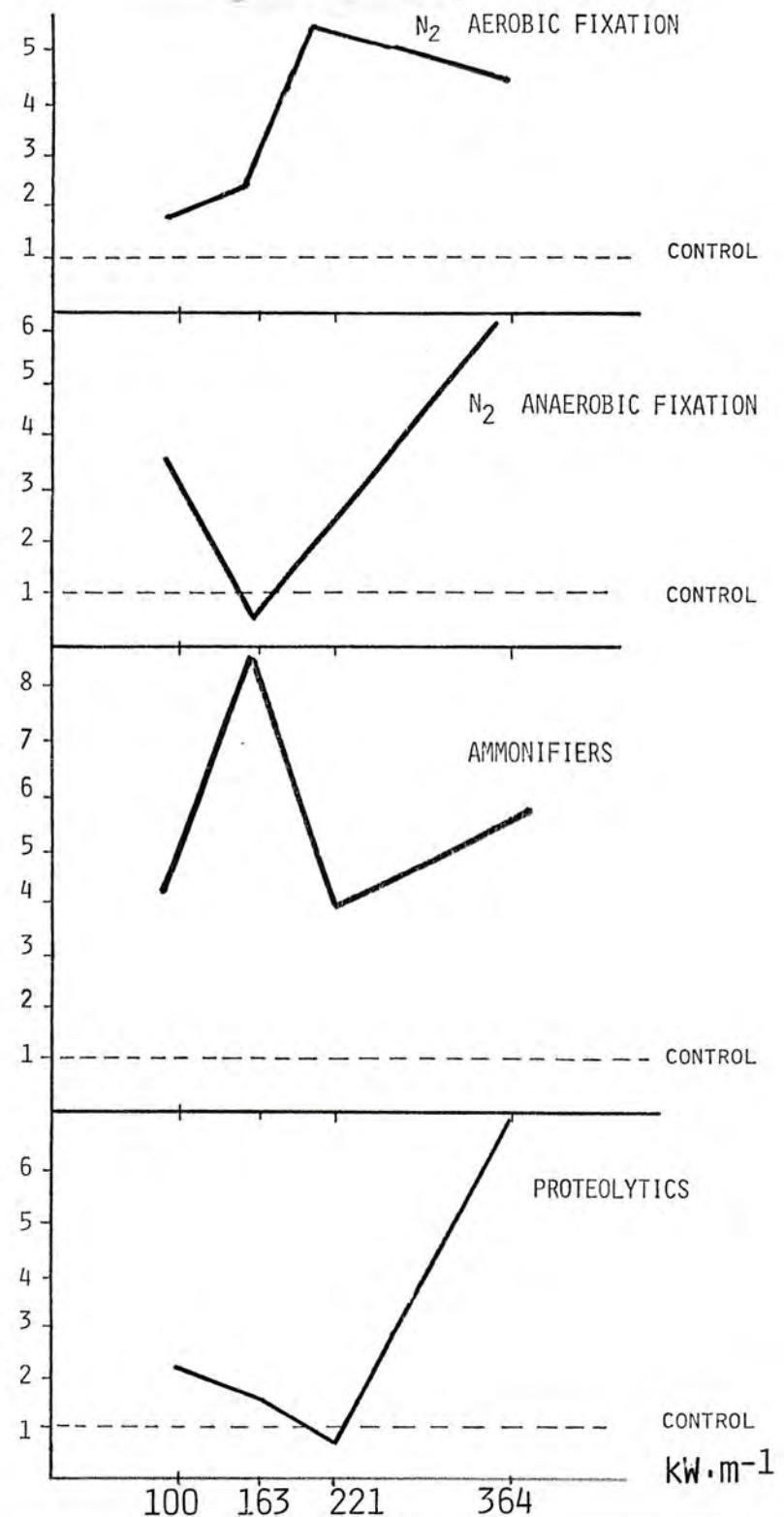
The populations are very similar. There seems to be a slight trend in decrease of fungi proportional to intensity of burning.

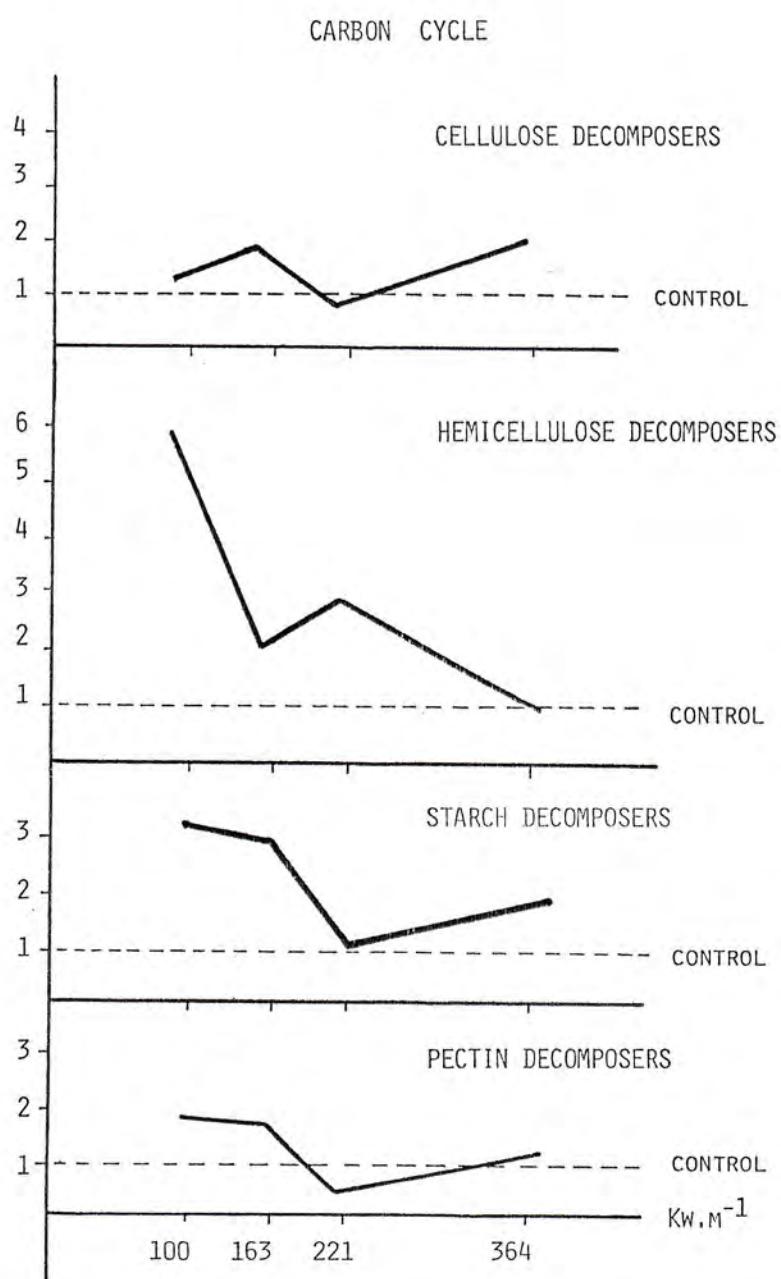
#### Nitrogen cycle

- Fixation of aerobic N<sub>2</sub>. There is always a preponderance in plots treated by prescribed burning over controls, and is accentuated from mild to moderate burnings. Looking at overall figures, the population of nitrogen fixers has tripled in burnt plots from the control.
- Anaerobic fixers: With intense burning there is a spectacular increase within this group. The relative minimal in moderate fires is not well understood. Without taking into account the fire intensity the population is three fold.



### Nitrogen Cycle





proteolytics which appear to develop better under more intense treatment and the anaerobic fixation of N<sub>2</sub>. The greatest differences are manifest in the Nitrogen cycle.

#### 4.4 EFFECTS OF FIRE ON THE TREE

In order to examine the tree evolution after prescribed burning, two procedures were carried out:

"Visu" classification of the vegetative state of trees in plots treated and in control (a). Measurement of electrical resistance of trunks of all trees (b).

a) Each tree was classified, according to its outward appearance, in one of the following types.

B: Tree in good state, dominant or co-dominant, not showing any external signs of stress or bad condition.

C-B: As above, but a tree dominated with the stand, being low and/or compressed, etc.

R: Tree belonging to dominant class, but showing some defect of vigour. The indications are varied and range from absence or decrease in growth for that year, to decolouration or yellowing in some leaves, branches, basis or top of crown, leaves abnormally pendulous, or slight defoliation of crown, etc. In other words, one or various signs that that individual is not in good condition, and referring to a tree whose survival is held in doubt.

C-R: The same as R but a dominated tree.

d: It refers to a dominant or codominant tree somewhat worse than R, and so will probably die within a short time.

C-d: The same as d, but dominated.

D: Dead tree

In Table VI appear the percentages of these types of trees in both classes of plots, burnt and control. An analysis of variance and means comparison showed that there were no significant differences in percentage of any type of tree in burned or unburned plots. According to this, one cannot deduce by outward appearance that two years after, fires have produced more dead trees, nor have altered the relative proportions of the above mentioned types.

TABLE VI: PERCENTAGES OF TYPES OF TREES IN BURNT AND UNBURNT PLOTS (SYMBOLS ARE EXPLAINED IN THE TEXT).

TYPE OF TREE	PERCENTAGE UNBURNT PLOTS	PERCENTAGE BURNT PLOTS	SIGNIFICANCE OF DIFFERENCE
B	70	66	NS
C-B	6	5	NS
R	8	12	NS
C-R	2	3	NS
d	3	4	NS
C-d	8	7	NS
D	3	3	NS

b) The measurement of electrical resistance of boles and the possibility of using the results as an indication of physiological state has attracted the attention of various authors in recent years, among them COLE and JENSEN (1980), COLE (1980), SHIGO (1974) and WARGO and SKUTT (1975).

In this case with the values of electrical resistance three channels of inquiry were opened.

1) Firstly it was decided to establish if electrical resistance discriminates among trees classified artificially by appearance. For this, each tree type was compared with the rest, making an analysis of variance and means comparison for electrical resistance values.

This data appears in Table VII. As can be seen, the system works quite well, given that of 15 comparisons, only the dominated trees of good aspect (C-B) and dominant trees with some defect of vigour (R), present electrical resistance values of great similarity. Although speaking of different trees, their physiological state is perhaps, very similar. In species needing light such as P.pinaster, being retarded in growth for any reason, and becoming dominated may be considered as in a similar vegetative state as a dominant tree in bad health.

2) Then, in order to determine if the trees of each type presented some differences according to burnt or unburnt plots, average resistance values were obtained of trees in each plot and for each type, and the averages of these were compared statistically. These measurements and the significance of the means comparison are given Table VIII.

Table VII: Comparison between mean values of electrical resistance of tree types.

TREE TYPE	RESISTANCE (kOhm)	TYPE COMPARED	RESISTANCE (kOhm)	SIGNIFICANCE OF DIFF.	TREE TYPE	RESISTANCE (kOhm)	TYPE COMPARED	RESISTANCE (kOhm)	SIGNIFICANCE OF DIFF.
B	6.75	C-B	8.32	***	C-B	8.32	C-R	8.90	***
B	6.75	R	8.31	***	C-B	8.32	d	9.70	***
B	6.75	C-R	8.90	***	C-B	8.32	C-d	9.50	***
B	6.75	d	9.70	***					
B	6.75	C-d	9.50	***					
R	8.31	C-B	8.32	NS	C-R	8.90	d	9.70	***
R	8.31	C-R	8.90	**	C-R	8.90	C-d	9.50	**
R	8.31	d	9.70	***	C-d	9.50	d	9.70	***
R	8.31	C-d	9.50	***					

\* Significant to 5%

\*\* " 1%

\*\*\* " 0.1%

TABLE VIII: COMPARISON OF ELECTRICAL RESISTENCE (K Ohm) ACCORDING TO TREE TYPES IN BURNT AND UNBURNT PLOTS.

TREE TYPE	BURNT PLOTS (K Ohm)	UNBURNT PLOTS	SIGNIF. OF DIFF.
B	6.96	6.48	NS
CB	8.6	8.4	NS
R	8.7	8.0	NS
CR	8.92	9.1	NS
d	9.8	9.6	NS
cd	9.5	9.5	NS
D	> 10	> 10	NS

3) Lastly, the electrical resistance values were grouped in intervals 4 -4.99; 5 -5.99; 6 -6.99; 7 -7.99; 8 -8.99; 9 -9.99 and >10, finding the percentages that represent, in each interval, the number of trees with respect to the total of the plot, burnt and unburnt. Then, the averages of these percentages were calculated by plot for the whole of the burnt and unburnt plots. The comparison of these percentages, in each interval, is given in Table IX.

TABLE IX: PERCENTAGES OF TREES IN BURNT AND CONTROL PLOTS IN THE INTERVALS OF ELECTRICAL RESISTENCE INDICATED.

INTERVAL OF ELECTRICAL RES.(K Ohm)	% OF TREES IN UNBURNT PLOTS	% OF TREES IN BURNT PLOTS	SIGNIFICANCE OF DIFF.
4 - 4.99	2.5	8.0	NS
5 - 5.99	17.4	17.5	NS
6 - 6.99	20.1	25.7	NS
7 - 7.99	19.4	19.3	NS
8 - 8.99	18.3	11.5	NS
9 - 9.99	12.9	11.7	NS
> 10	9.4	6.3	NS

We can conclude that:

- At the end at two years after the experiments of prescribed burning, there are no external signs of debilitation in trees in burnt plots.
- When the State of the tree is beginning to be bad, then the electric resistance increases.
- Therefore, the electrical resistance in tree boles could be used to predict damage by fire and other agents which result in a weakness in tree.

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PREScribed FIRES AND THEIR APPLICATION TO A QUERCUS COCCIFERA L.  
GARRIGUE

Louis Trabaud, France

INTRODUCTION

The study of the development of post-wildfire vegetation showed that plant communities of the French mediterranean region quickly recover, and that after about 10 years they are not much different from those which existed before fire (TRABAUD 1980, TRABAUD and LE PART 1980). To analyse more precisely and to better understand the effects of fire on plants and vegetation, it is necessary to set up experiments with prescribed burns. Only an experimentation on communities identified and studied before burning will give reliable results which can be compared with observations from plots burnt by wildfires.

By using prescribed burning it is possible: (1) to compare the post-fire floristic composition with the initial floristic composition, (2) to study the modifications induced by various fire frequencies and seasons of burning, and (3) to analyse the effect of fire on the behaviour of the species of a Quercus coccifera garrigue.

The experimentation was intended to analyse:

- a) vegetation changes as compared to the state previous to fire in order to determine the plants' degree of resistance to fire;
- b) the impact on vegetation of different frequencies of repeated burns (a burn every six years, a burn every three years, and a burn every two years);
- c) the effect on the vegetation of the burning season (either in late spring or in early autumn) to determine if the seasonal conditions influencing the changes of the phenology and

physiology of species relate to fire effects and modify the species behaviour and the vegetation equilibrium.

Thus, at the beginning the experimentation was not intended to study the application of fire to grazing purposes; it was only during the course of the experiment and at the sight of the plant modifications that the application of prescribed fires was thought.

#### EXPERIMENTAL DESIGN AND METHODS

##### Study area

The experiment has been set up on a hill 10 km north of Montpellier in a *Q.coccifera* L. (Kermes scrub oak) garrigue (*Cocciferetum* Br. Bl. 1924, subassociation *Brachypodietosum* Br. Bl. 1935; BRAUN-BLANQUET et al. 1952). This area was a long time ago cultivated then abandoned and fired several times by shepherds. The climate is mediterranean with mild winters; the annual mean temperature is about 14.4°C, and the mean annual rainfall is 1102 mm. Bedrock is hard limestone from Eocene.

##### Burning treatments

The presentation of the experimental techniques and partial results were previously published (TRABAUD 1974, 1977, 1980). Thus only a brief description will be given of the burns.

The burning seasons were chosen in relation to some mean phenological stages of the *Q.coccifera* population.

Spring: the kermes scrub-oak has started its spring growth; the first annual shoots and young leaves have already been developed, the flowers have appeared. *Q.coccifera* is then in a turgid maximally photosynthetic stage. Burns are usually lit at the end of May or beginning of June according to the meteorological

conditions.

Autumn: in early autumn, after the lignification of the young twigs when the plants seem to be at rest. Burns are set at the beginning of September.

The combination of burning frequencies and seasons gives six treatments:

- 6 P - vegetation burnt every six years in spring,
- 3 P - vegetation burnt every three years in spring,
- 2 P - vegetation burnt every two years in spring,
- 6 A - vegetation burnt every six years in autumn,
- 3 A - vegetation burnt every three years in autumn,
- 2 A - vegetation burnt every two years in autumn.

An unburnt vegetation was considered as a control: T. All these treatments have five replicates; thus there are 35 plots. Each plot has a size of 50 m<sup>2</sup> (10x5 m).

#### Vegetation analysis

A floristic list of all the taxa present in each plot is recorded every year in spring before the spring burns. Furthermore a permanent 10 m long line is located in the middle of the plots in the longest direction, observations are made every 10 cm by means of a needle. At each point the presence and the number of hits per layer for each taxon are noted. This gives an estimation of the percentage of vegetation cover and of the above-ground phytomass (GODRON 1968, DAGET and POISSONET 1971, 1974).

#### RESULTS

Frequently repeated fires alter the structure of the vegetation. Immediately after each burn there was a decrease in the number of

hits (disappearance of above-ground vegetation), then a progressive increase; this increase is slower following autumn burns (TRABAUD 1977, 1980, 1982). When burning is only every six years the vegetation of *Q.coccifera* garrigue reaches a level similar to that of the longtime unburnt garrigue within five years after prescribed fire. On the other hand, burns regularly set every two years produce a decrease in the total number of hits, for the first six years cycle. Later on the number of hits remains rather constant in equilibrium with the burn frequencies. The repetition of burning leads to a disappearance of the upper layers (above 50 cm) but it favours an increase of the amount of vegetation in lower layers (< 25 cm).

The decrease in the number of hits is mainly due to the woody plants which have fewer long sprouts bearing fewer leaves. But the number of hits from herbaceous plants is not diminished by successive fires; on the contrary it is increased and particularly with autumn burnings (TRABAUD 1980, 1982). The influence of fire on the increment of herbaceous plant mass has been recognized for a long time (AHLGREN and AHLGREN 1960, DAUBENMIRE 1968, VOGL 1974).

As sheep are grazing animals only the development through time of herbaceous plants will be considered later in this paper.

The development of the number of hits of herbaceous plants during the years of observations are presented in table 1. Four remarks can be stated.

1. In the unburnt vegetation the number of hits from herbaceous plants decreases with time. Some little differences can appear due to climatic vagaries during years, but this tendency is very clear. This is probably due to the progressive closing up of the plant cover and a more and more important encroachment by woody species.
2. In the plots burnt every six years the number of hits was

years fire regimes	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
T	111,0 ± 17,1	115,0 ± 41,0	125,6 ± 8,1	126,3 ± 4,9	117,3 ± 5,2	111,7 ± 12,0	94,0 ± 8,1	96,7 ± 21,1	74,0 ± 12,3	83,0 ± 27,9	122,3 ± 28,6	59,0 ± 15,7	55,7 ± 3,2
6P	96,3 ± 20,1	32,7 ± 11,5	85,3 ± 12,0	135,3 ± 21,8	154,7 ± 28,2	182,3 ± 43,1	154,0 ± 14,1	54,7 ± 9,9	67,7 ± 11,2	113,0 ± 8,5	125,7 ± 21,2	86,3 ± 11,9	114,7 ± 30,8
3P	58,0 ± 14,0	51,3 ± 8,0	74,7 ± 5,5	128,3 ± 12,3	45,7 ± 16,3	121,7 ± 30,8	70,3 ± 17,8	43,0 ± 17,0	47,0 ± 18,4	69,3 ± 21,3	36,0 ± 7,9	61,0 ± 20,8	62,3 ± 16,3
2P	94,7 ± 21,3	44,0 ± 5,1	76,3 ± 22,9	72,7 ± 10,7	125,3 ± 17,9	88,0 ± 15,6	79,0 ± 9,5	45,3 ± 2,7	50,3 ± 17,0	39,7 ± 6,8	61,7 ± 7,3	35,3 ± 7,3	68,0 ± 15,9
6A	92,7 ± 25,2	35,3 ± 7,9	90,0 ± 11,9	104,7 ± 28,1	152,0 ± 16,8	181,3 ± 22,6	83,7 ± 24,2	30,0 ± 2,3	92,3 ± 12,8	148,7 ± 27,8	161,7 ± 12,1	124,0 ± 18,3	147,3 ± 28,8
3A	99,3 ± 15,2	53,0 ± 12,5	98,7 ± 28,5	106,7 ± 11,7	66,3 ± 10,1	161,0 ± 8,9	85,0 ± 3,0	35,3 ± 4,7	66,3 ± 10,1	72,3 ± 6,6	49,7 ± 5,4	101,6 ± 11,7	100,3 ± 8,8
2A	111,7 ± 22,0	44,3 ± 3,5	157,0 ± 33,2	140,7 ± 34,8	214,0 ± 38,9	198,7 ± 39,5	152,0 ± 25,7	87,0 ± 8,1	139,0 ± 19,1	70,3 ± 20,6	167,3 ± 21,5	95,0 ± 12,1	138,3 ± 19,9

Table 1: Changes through time and according to fire regimes of the number of hits of herbaceous plants (means and standard errors)

burnings

increasing during the first (4-5) years following a prescribed fire, up to reach and even exceed the values of hits in the unburnt vegetation at the beginning of the experimentation, later this number of hits was decreasing.

3. When each fire frequency is compared respectively with its corresponding season of burning, the number of hits by herbaceous plants is always higher in autumn-burnt vegetation.

4. Vegetation of plots burnt every two years in autumn does always present the highest number of hits from herbaceous plants.

The ratio of the hits from herbaceous plants to the total vegetation number of hits strikingly corroborates these results. In the unburnt vegetation the proportion of the number of hits of herbaceous species compared with woody plants does not vary importantly through years (fig. 1), it does not exceed 25%, and has a tendency to decrease. At the beginning of the experiment (1969) the percentage of herbaceous plants was rather the same for all the treatments. Afterwards according to the different fire regimes there was a little change: the proportion was increased for all treatments as well at the end of the first six years cycle (1981); but when all the treatments are considered as a whole no statistical difference (analysis of variance:  $P > 0.05$ ) appears between the treatments. The comparison between only the vegetation burnt every two years in autumn and the unburnt vegetation was significant ( $P < 0.01$ ). In the plots regularly burnt every other year in autumn the proportion goes up from 20% in 1969, to 68% in 1975 and 54% in 1981, which is nearly a threefold increase, and a little more ( $\approx 3.5$ ) comparatively to the unburnt vegetation at each end of cycle.

These results are confirmed by a study of above-ground phytomass as a function of the different fire regimes. In May 1981, for each treatment seven  $1m^2$  samples were collected from each different plot. Then vegetation was handsorted, separating woody from herbaceous plants, dried, and finally weighed. Total above-

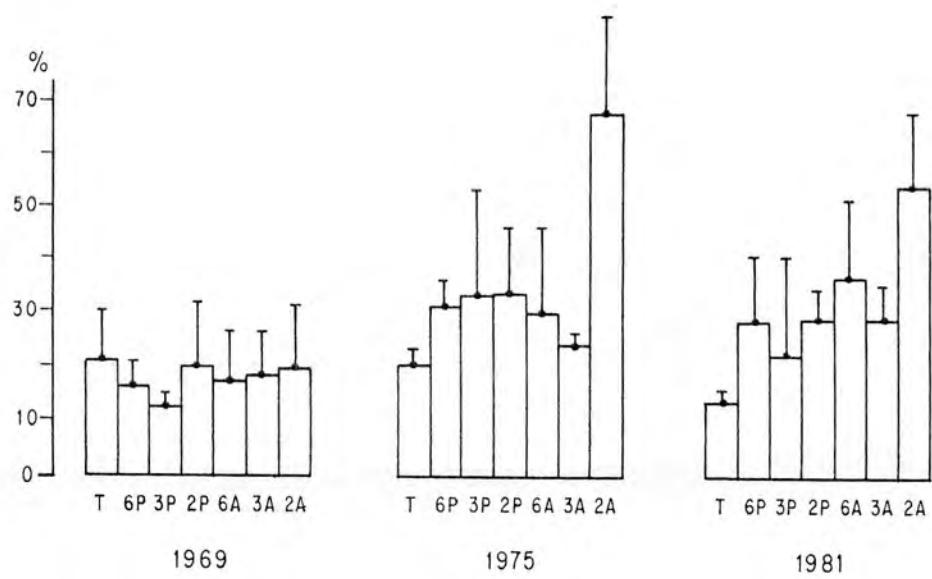


Fig.1: Changes in the ratio of hits of herbaceous plants to the total vegetation number of hits

ground phytomass of the unburnt vegetation weighed, on an average,  $28 \text{ t} \cdot \text{ha}^{-1}$  (table 2), or about a production of  $1 \text{ t} \cdot \text{ha}^{-1} \text{ yr}^{-1}$  of dry matter since the last wildfire (TRABAUD 1980, 1982). This value is similar to that already reported by LONG et al. (1967) fourteen years earlier.

Burning frequency has an effect on the amount of vegetation produced. Six years after a second burn (1981; 6P, 6A, table 2) total phytomass only represented two third of that of the unburnt vegetation. But herbaceous plants did constitute a greater proportion than in the unburnt vegetation (respectively 7.3 percent for treatment 6P; 14.7 percent for 6A; and 3.1 for T). Three years after a fourth burn the phytomass of plots burnt every three years reached one fourth of the unburnt phytomass. And the second year following a sixth fire the phytomass of vegetation burnt every two years represented only about one sixth of that of the unburnt vegetation.

In regard to the effect of season of burning the total mass of vegetation burnt in spring is respectively to each frequency always greater than that burnt in autumn (table 2). In spring-burnt vegetation the above-ground mass of woody plants is always greater than that of vegetation burnt in autumn. But, on the other hand, the mass of herbaceous plants of autumn-burnt vegetation is higher than that of spring-burnt vegetation. The most paramount change comes out from the vegetation burnt every other year in autumn (2A): herbaceous plants represent 40.4 percent of the total mass.

#### DISCUSSION AND CONCLUSION

What are the causes producing such an increase of the phytomass of herbaceous species?

The impact of fire is less severe on herbaceous than on woody plants because in the Mediterranean country the above-ground

	T	6P	6A	3P	3A	2P	2A
Mass of the woody plants g. m <sup>-2</sup>	2 702,6 (4 048,0 - 1744,0)	1 782,5 (2 634,0 - 1 111,0)	1 449,8 (2 481,0 - 325,8)	829,6 (1244,6 - 541,0)	482,0 (693,7 - 179,0)	510,1 (737,6 - 278,6)	229,3 (417,8 - 63,2)
Mass of herbaceous plants g. m <sup>-2</sup>	86,7 (204,2 - 25,4)	139,8 (326,0 - 6,9)	250,7 (596,0 - 77,3)	110,7 (333,7 - 8,6)	145,8 (325,8 - 43,1)	49,2 (109,9 - 8,0)	155,4 (411,0 - 43,9)
Total phytomass g. m <sup>-2</sup>	2 789,3 (4 102,7 - 1 924,7)	1 922,3 (2 640,9 - 1 328,5)	1 700,6 (2 703,3 - 921,8)	940,3 (1311,4 - 682,4)	627,8 (809,3 - 340,0)	559,3 (755,2 - 286,6)	384,7 (612,0 - 202,2)
Age of the vegetation	30 years after last wildfire	72 months after the 2nd burn	68 months after the 2nd burn	36 months after the 4th burn	32 months after the 4th burn	24 months after the 6th burn	20 months after the 6th burn

Table 2: Above-ground phytomass according to the fire regimes collected in May 1981 (g of dry matter per m<sup>2</sup>, means and range values).

living material of these plants is renewed each year. As hemicryptophytes or geophytes, herbaceous possess survival buds or organs buried in the ground or located at the ground surface level; each year their new shoots come out from these buds which is opposite to woody species which possess aerial living twigs and leaves persisting for several years. Thus, autumn fires eliminate only a part of the dead herbaceous material without influencing the life cycle. Furthermore and thanks to their location survival buds of herbs are protected from flame action which is not the case for woody plants.

Besides, during winter frost appears regularly in the study area and a killing necrosis due to frost appears on the tips of the smaller sprouts of the woody species coming from autumn burns, which induces a new sprouting effort mobilizing and diminishing the nutrient reserves in the root systems of woody plants.

A third factor can be the competition between the species: with spring burns woody plants (and principally *Q.coccifera*) reinvoke rapidly the burnt areas allowing very little room for herbaceous species to establish; which is not the case following autumn burns. But, it is not out of the question that these three causes, and others, react together favouring one kind of plants or the expense of the other.

Fire has been recognized for a long time to be an important factor in rangeland management (BAILEY 1978, TAINTON 1978, WRIGHT 1978; for an exhaustive bibliography on the subject). From the results of this study prescribed fire can be a valuable tool and has potentialities in the multiple use management of garrigues in this part of the French mediterranean country. However, for the best improvement the best season of burning is autumn and on a two year rotational frequency since the number of hits of herbaceous plants, as representing their phytomass is higher with this kind of fire regime. Despite the fact there is more grass in the vegetation burnt every six years in autumn (6A; table 2) than in the vegetation burnt every two years in autumn, the importance

and the density of the woody plant mass and the height ( 1 m) of the vegetation hinder the sheep to go into and to graze the grasses.

The study is still under way and continued because it is quite obvious that fire utility will depend in large measure on learning its impacts on ecosystems and learning how to use it to obtain desirable results while minimizing undesirable effects.

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THE USE OF PRESCRIBED BURNING IN THE NORTHWEST OF PORTUGAL

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1. INTRODUCTION

Fire is very important in Portugal. Wildfires burn annually large areas of the country (table I) with a rate superior to the normal afforestation capacity (SILVA 1981).

TABLE I. Areas burnt by forest fires (MARTINS 1981)

Forest and shrubland area ( $10^3$ ha)	Areas burnt ( $10^3$ ha)					
	1974	1975	1976	1977	1978	1979
2500	32	82	21	12	68	48

After the Afforestation Plan (1939) forested area increased. Pinus pinaster was the main species used. These planted pine forests are among the most flammable ecosystems in the region (TRABAUD 1981, CRUZ 1981). Domestic livestock was kept outside those forests, emigration began, and harvesting the understory of the forests for fuel or livestock "beds" by villagers decreased a lot. Excess fuel buildup began. Obviously we are dealing with an "exceptional" period of large, numerous and severe crown fires (SILVA 1983).

The major causes of wildfires in the Mediterranean Region are unknown or carelessness (SUSMEL 1973\*). Shepherds certainly contribute to wildfires when they burn the shrublands in order to improve forage availability and quality. So, it is easy to

\* Cited by LE HOUEROU (1974)

understand that causes of fire are hard to fight. Policies of fire exclusion and fire suppression were undertaken but were shown to be ineffective in many cases.

Evidence of natural underburning in Ponderosa pine forests (BISWELL 1973, HALL 1977, WRIGHT 1978, DAVIS et al. 1980) showed that fire is an ecological factor and can play an important role in pine forests. However, as this natural management of pine forests is difficult to maintain, it should be replaced by a correct artificial management, naturally by the use of prescribed fire. In Portugal, the use of this technique is making its first steps.

## 2. PREScribed BURNING

In October 1981 the Forest Services of Porto began a program for the use of prescribed fire to reduce wildfire hazard. This program was to be executed in 80.000 ha of public area, mostly occupied by pine forests (P.pinaster).

In each of the 7 Forest Administrations an emergency plan was designed in order to break the dangerous homogeneity of the forests. So, priority was given to actual fire breaks, roads and streams. Many of the fire breaks were invaded by shrubs making the operations of fire fighting difficult. So, fire breaks were burned and, 25 m for each side of the fire break, road or stream, the understory vegetation was burned.

From January to April 1982, 179 prescribed fires burned about 420 ha, corresponding to 50 effective days of work. The average expenses for each hectare burnt were 16 man-hours and 6.7 liters of fuel. The differences between Administrations were very important due to numerous factors.

From January to March 1983, 174 prescribed fires burned more than 900 ha in 40 days of effective work. The expenses decreased to

5.5 man-hours and 1.6 liters per hectare. This can be explained by a better use of the technique and more familiarity with fire. This caused some problems, and in two cases fire escaped but fortunately with minor damages.

The effectiveness of this Program in the prevention of wildfires was tested in Summer 1982. The precipitation in this Summer was 20% more than the average and, therefore, wildfires burned "only" 583 ha, about one third of the average between 1972 and 1981.

Three wildfires occurred in areas with prescribed fire. The first one didn't stop in a fire break previously burnt, but stopped in a stream where prescribed fire was executed. The second one stopped in the second fire break "cleaned" by prescribed fire. The trees near the first fire break are still alive. The third wildfire was stopped near a road where fire was executed in Spring. Pine trees near the fire breaks are still alive.

These results are not extraordinary but we think they are important, in the motivation of people involved in the program for further work.

At the same time research on fire effects on the ecosystem began, in order to have data available for the Fuel Management Plan, that should begin in October 1984, after the execution of the Emergency Plan.

### 3. RESEARCH

#### 3.1 Methods

Data are being collected for evaluating fire effects on soils and vegetation. Changes in plant communities are going to be detected by periodic surveys. First results will be available by this winter. Changes in soil chemistry and soil fauna are more rapidly evaluated. This paper intends to give first results of that

research.

### 3.1.1 Field plots

Two locations were chosen in two different ecological situations. In each of those locations two 30 x 30 m plots were established, near each other and in similar situation in terms of stand age and density, and with similar understory vegetation. One plot in each location was burnt in 1982 by the Forest Services staff.

In VIEIRA DO MINHO (altitude 775m, aspect South, 12% slope) the pine stand (P.pinaster) in the plot was 30 years old, with 700 trees per hectare, with an average d.b.h. of 20 cm and 11 m as dominant height. The understory vegetation was mostly Chamaespartium tridentatum (34% cover), with some Pteridium aquilinum (9%), Erica sp. and Calluna vulgaris (6%), Ulex sp. (3%) and grasses, mostly Agrostis sp. (4%). Granite is the parent material of the soil.

The plot was burnt in early afternoon of March, 11 (1982). The temperature range was 13-15°C and relative humidity varied from 70 to 51,5%. Fuel moisture was measured separately in twigs (45%) and litter (61%). Flame height was recorded as 60 cm. Litter was reduced significantly ( $P < 0,01$ ) from 2100 g/m<sup>2</sup> (air dried) to 773 g/m<sup>2</sup>.

In AMARANTE (altitude 375 m, aspect N, 2% slope) the forest stand (P.pinaster) was 40 years old, with 250 trees/hectare, 25 cm of average d.b.h., and 13 m as dominant height. Understory vegetation is sparse with dominance of Ericaceae (C.vulgaris, Erica cinerea, Erica umbellata). In opposition to the former, these plots were located in schistous soil.

The plot was burnt in January, 28 (1982), between 14 h 30 min and 17 h 30 min. No data were recorded for temperature, relative humidity, or fuel moisture because, at that time, material was

still lacking. Litter reduction was not significant: it varied from 1255 g/m<sup>2</sup> to 1026 g/m<sup>2</sup> (air dried). Flame height was recorded as 1.00 m.

### 3.1.2 Methods for soil and mesofauna analysis

Soil samples were collected by a metal cylinder (10 cm diameter, 10 cm height). Ten samples were collected in each date for mesofauna extraction by the BERLESE method modified by TULLGREEN as described by PHILLIPSON (1971). Three samples are collected for standard chemical analysis. Determinations of pH were done in suspensions of soil and distilled water. Organic matter is computed by multiplying the results of organic carbon analysis by 1.724. Available phosphorus and potassium are evaluated by ammonium lactate extraction.

## 3.2 Fire effects on soil characteristics

### 3.2.1 Organic matter

All authors agree that 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, DE BYLE 1976, 1981, CASTILLO 1981, TEMES 1982).

In our case, in spite of differences in organic matter between the two locations, both exhibited a significant decrease in O.M. after fire (Table 2, Fig. 1). The effects of fire in Vieira do Minho varied from time to time, almost disappearing in December and January. In Amarante there were significant differences between sampling dates.

Variation of organic matter is very important because of its consequences on other soil characteristics and in soil fauna.

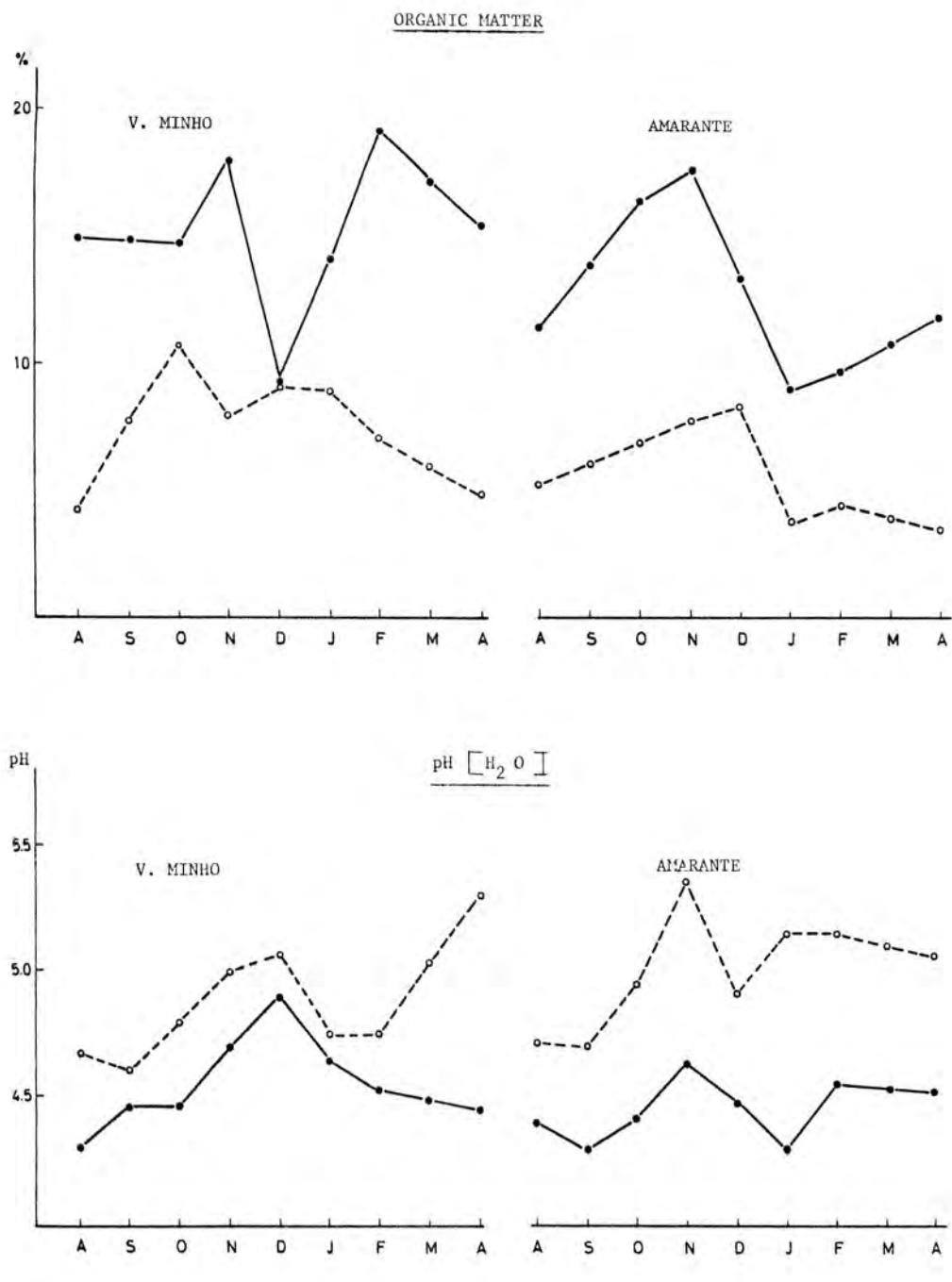


Fig.1: Comparison of burned plots (----) with control plots (—) in soil organic matter and soil pH.

TABLE 2 - Analysis of variance for organic matter

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
LOCATIONS	98.93	1	98.93	7.43 **
VIEIRA DO MINHO		13		
BURN	604.73	1	604.73	45.43 **
TIME	104.02	6	17.34	1.30 n.s.
BxT	198.34	6	33.06	2.48 *
AMARANTE		13		
BURN	568.41	1	568.41	42.71 **
TIME	232.41	6	38.74	2.91 *
BxT	39.51	6	6.59	0.49 n.s.
ERROR	745.50	56	13.31	
TOTAL	2 591.86	83		

TABLE 3 - Analysis of variance for pH [H<sub>2</sub>O]

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
LOCATIONS	0.0026	1	0.00260	0.07 n.s.
VIEIRA DO MINHO		15		
BURN	1.1408	1	1.14083	31.03 **
TIME	1.3858	7	0.19798	5.38 **
B x T	0.6392	7	0.09131	2.48 *
AMARANTE		15		
BURN	3.5752	1	3.57520	97.23 **
TIME	1.0748	7	0.15354	4.18 **
B x T	0.3931	7	0.05616	1.53 n.s.
ERROR	2.3533	64	0.03677	
TOTAL	10.5649	95		

n.s. - Not significant P > 0.05

\* - Significant P < 0.05

\*\* - Highly significant P < 0.01

### 3.2.2 Soil chemistry

Soil pH is generally increased by fire. In both locations this was clear (Table 3, Fig. 1). Also, this effect was not constant over time in Vieira do Minho. Both locations showed significant differences between sampling dates.

Available phosphorus increased very significantly in Vieira do Minho, but showed no differences in Amarante (Table 4, Fig. 2). Leaching of the duff-ash layer can account for the observed increase of available phosphorus in the top of the mineral soil (BISWELL 1973, DE BYLE 1976, TEMES 1982). As in Amarante litter was not significantly consumed, phosphorus release was not great and no significant differences in available phosphorus in soil were detected. At this location changes from time to time were found. This could be in relation with mycorrhizal activity in C.vulgaris and Erica sp., the two main species in the plots.

Available potassium decreased in both sites after burning (Table 5, Fig. 2). This highly soluble element (GIMINGHAM 1972) is very likely leached from the mineral soil. TEMES (1982) found the same in his trials. The great mobility of this element can also explain the significant variations of available potassium between sampling dates.

### 3.2.3 Soil mesofauna

The effect of fire on soil fauna has not been studied very extensively, because of its apparent lack of economic importance and the procedures involved (AHLGREN 1974). METZ and FARRIER (1971)\*, working in forest stands, refer that mites and collembolans are reduced within 24 hr after fire. They report a recovery to preburn populations in 3 to 4 years after fire.

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\* Cited by AHLGREN (1974)

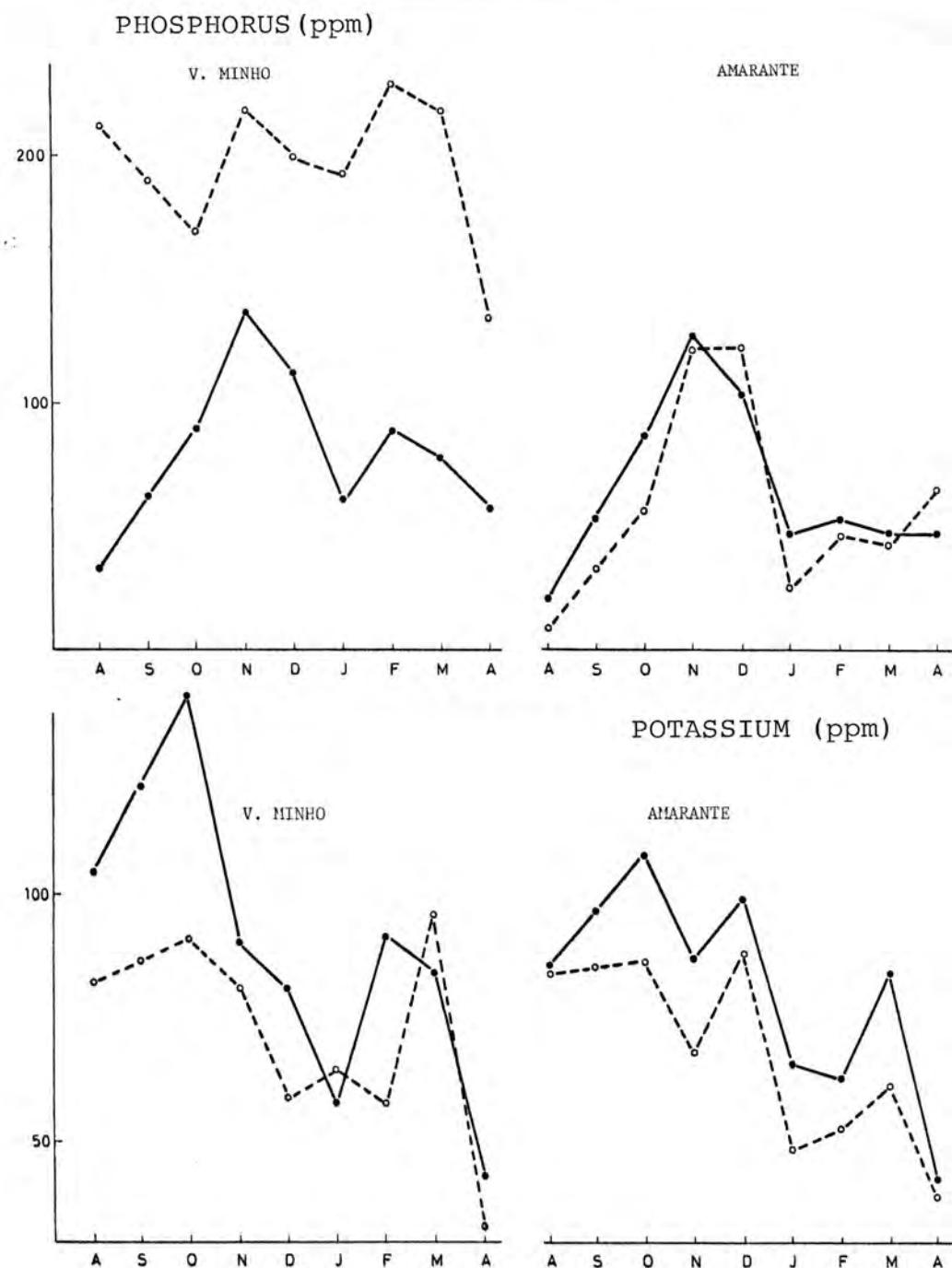


Fig.2: Comparisons of burned plots (----) with control plots (—) in phosphorus (P) and potassium (K) in soil.

TABLE 4 - Analysis of variance for phosphorus

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
LOCATIONS	16 250.010	1	16 250.010	68.73 **
VIEIRA DO MINHO		15		
BURN	17 941.333	1	17 941.333	75.88 **
TIME	3 139.250	7	448.460	1.90 n.s.
B x T	1 864.667	7	266.381	1.13 n.s.
AMARANTE		15		
BURN	35.021	1	35.021	0.15 n.s.
TIME	6 871.646	7	981.664	4.15 **
B x T	352.479	7	50.354	0.21 n.s.
ERROR	15 132.000	64	236.4375	
TOTAL	61 586.406	95		

TABLE 5 - Analysis of variance for potassium

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
LOCATIONS	1 169.010	1	1 169.010	3.23 n.s.
VIEIRA DO MINHO		15		
BURN	3 217.688	1	3 217.688	8.89 **
TIME	23 211.479	7	3 315.926	9.16 **
B x T	4 479.812	7	639.973	1.77 n.s.
AMARANTE		15		
BURN	2 133.333	1	2 133.333	5.89 *
TIME	17 313.333	7	2 473.333	6.83 **
B x T	782.667	7	111.810	0.31 n.s.
ERROR	23 163.333	64	361.927	
TOTAL	75 470.656	95		

n.s. - Not significant P > 0.05

\* - Significant P < 0.05

\*\* - Highly significant P < 0.01

In our case, counts were made grouping individuals in 4 major classes: Collembolans, Other insects, Oribatei, Other mites. Fig. 3 and 4 show the evolution of these groups in the consecutive samples. Table 6 and 7 show the analysis of variance for "Collembolans and other insects" considered together, and "Oribatei and other mites".

Some conclusions can be drawn from that data: variations from time to time were always important; mites and insects were reduced by fire in both situations; recovery to preburn levels is apparent in Amarante; in Vieira do Minho the effect of fire was not constant over time. This is in agreement with the concept that with moderate fires, "the heat of fire is apparently less important than later environmental changes in reducing insect populations" (AHLGREN 1974).

### 3.3 Fire effects on understory vegetation

No quantitative studies were done at the moment. However, it was observed that in Vieira do Minho, most C. tridentatum sprouted as some Erica sp.. Seedlings of Erica sp. and C. vulgaris were observed. In Amarante Erica sp. and C. vulgaris did not sprout, but seedlings were very abundant.

### 4. CONCLUSIONS

From this preliminary research (August 1982 - April 1983) some conclusions can be taken: effects of prescribed fire in soil chemistry are important, since pH and Phosphorus are generally considered limitant factors for plant growth, and were improved by the use of this technique. Decrease of organic matter and potassium are not alarming, because they can not be considered scarce in these situations. Soil mesofauna can recover to preburn levels one year after burning if litter is not strongly reduced. So, prescribed burning seems to be a very promising technique in

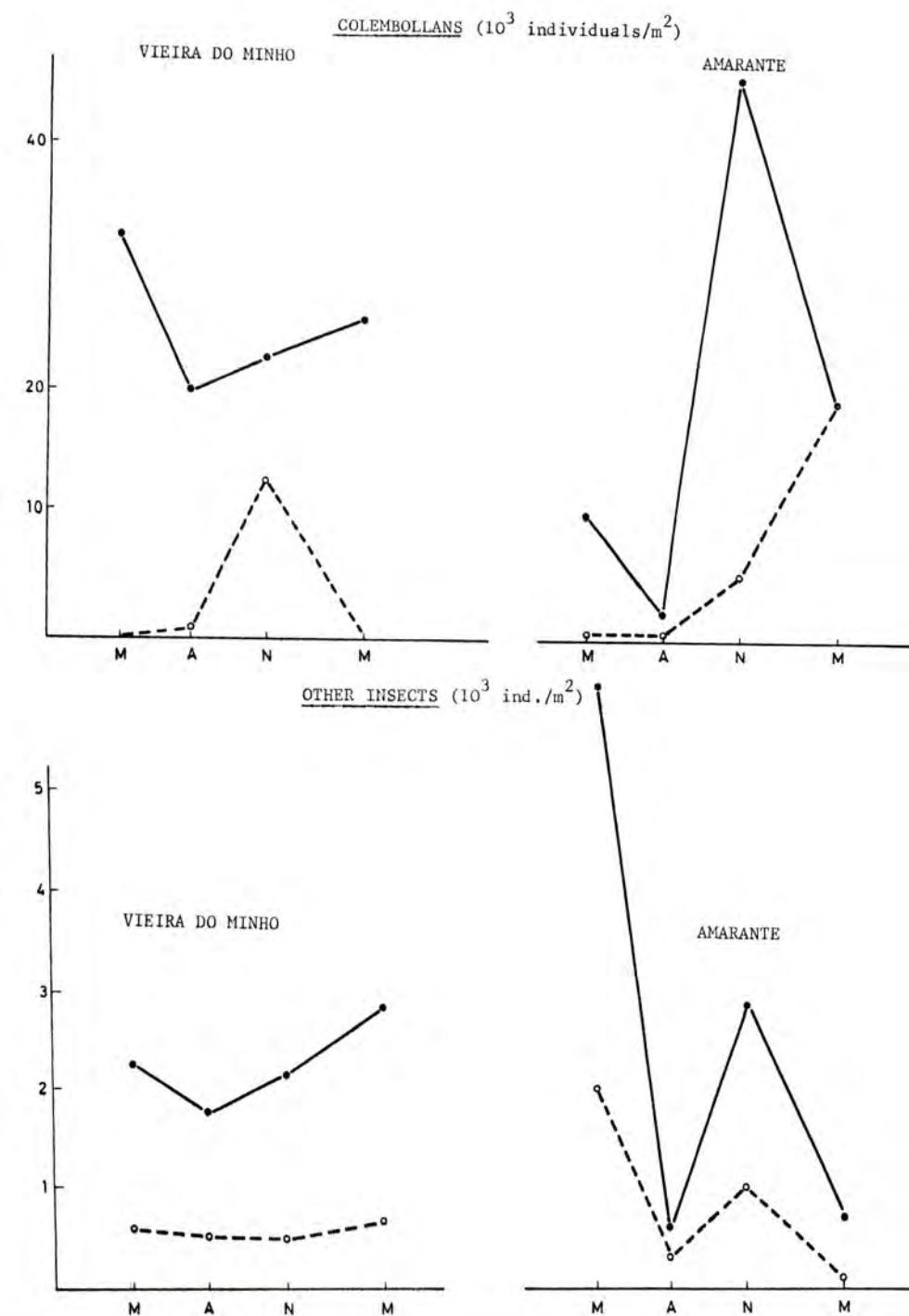


Fig.3: Comparison between burned (----) and control plots (—) for collembolans and other insects in May, August, November and March.

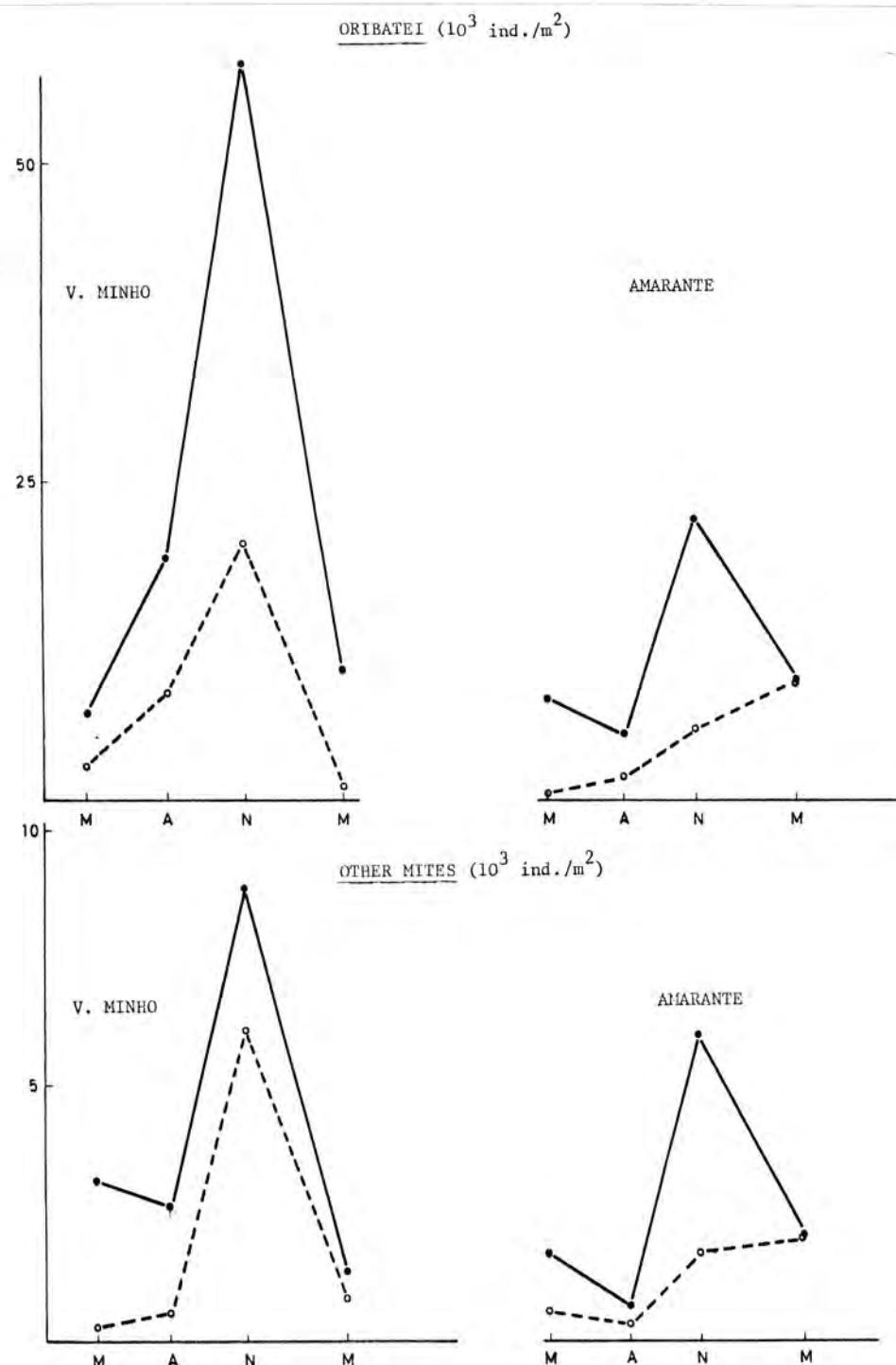


Fig.4: Comparison between burned plots (----) and control plots (—) for oribatei and other mites.

TABLE 6 - Analysis of variance for Collembolans and Other Insects (after transformation  $y = \log(x + 1)$ )

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
LOCATIONS	1.548	1	1.548	1.53 n.s.
VIEIRA DO MINHO		7		
TIME	24.425	3	8.142	8.04 **
EFFECT OF FIRE				
MAY	59.374	1	59.374	58.61 **
AUGUST	16.763	1	16.763	16.55 **
NOVEMBER	1.458	1	1.458	1.44 n.s.
MARCH	38.226	1	38.226	37.74 **
AMARANTE		7		
TIME	86.756	3	28.919	28.56 **
EFFECT OF FIRE				
MAY	12.387	1	12.387	12.23 **
AUGUST	11.280	1	11.280	11.14 **
NOVEMBER	15.017	1	15.017	14.82 **
MARCH	1.225	1	1.225	1.21 n.s.
ERROR	145.804	144	1.013	
TOTAL	414.264	159		

TABLE 7 - Analysis of variance for Oribatei and Other Mites (after transformation  $y = \log(x + 1)$ )

Source of variation	Sum of squares	Degrees of freedom	Mean square	F
LOCATIONS	4.442	1	4.442	3.96 *
VIEIRA DO MINHO		7		
TIME	88.012	3	29.337	26.15 **
EFFECT OF FIRE				
MAY	0.330	1	0.330	0.29 n.s.
AUGUST	15.435	1	15.435	13.76 **
NOVEMBER	1.557	1	1.557	1.39 n.s.
MARCH	11.056	1	11.056	9.85 **
AMARANTE		7		
TIME	35.026	3	11.675	10.41 **
EFFECT OF FIRE				
MAY	15.789	1	15.789	14.07 **
AUGUST	7.212	1	7.212	6.43 *
NOVEMBER	12.090	1	12.090	10.78 **
MARCH	0.251	1	0.251	0.22 n.s.
ERROR	161.553	144	1.122	
TOTAL	352.752	159		

n.s. - Not significant  $P > 0.05$

\* - Significant  $P < 0.05$

\*\* - Highly significant  $P < 0.01$

Portuguese Forestry: reduction of fire hazard seems effective and environmental consequences are not alarming (and, in some aspects, even beneficial). However, questions are, at this point, more than the answers. The need of further research is obvious. Also, continuation of this work is necessary for a longer period, in order to assess optimal periodicity for prescribed fire in these regions. With the execution of the 3.000 hectares of the Emergency Plan, and with the results on the ecological effects of prescribed fire, the Fuel Management Program will have conditions for a confident start.

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FIRE PROPAGATION RISK IN A FOREST PARK  
(Parque Florestal de Monsanto)

Carlos Souto Cruz, Portugal

SUMMARY

The use of controlled fires at the Monsanto Park (Lisbon) as a prevention fire measure has been restrict so far due to the lack of precise information in Portugal about the propagation risks envolved.

This lack of data regarding such kind of natural risk determined an analysis and interpretation procedure using only the available data about fires that occurred in this area.

The impossibility of using the automatic treatment of existing data in order to obtain useful basic elements for forest works in the spring of 1983, led us to adopt a previous analysis of the data in order to obtain the following elements:

- a) A fire propagation potencial risk gradient (concerning only the geocoenosis characteristics)
- b) A fire propagation biotic risk gradient (concerning only the vegetation characteristics)

1. PREVIOUS CONSIDERATIONS

Forest fires are facts with rather important repercussions in Portugal.

Their number and the area burnt are conditioning factors to the use of territory and to the preventive measures to be adopted in

the forest management to face this natural risk.\*

Due to the reduced number of studies on this subject, almost all the territorial planning adopted up to now in Portugal omitted the fire risks as a basic data or considered them only on qualitative terms.

Fires in a forest environment depend upon the following factors:

- a) the soil and meteorological conditions when fires occurs (soil moisture, air humidity, temperatures and wind velocity)
- b) land morphology (slopes, exposure)
- c) characteristics and amount of fuel
- d) liable elements for the fire conflagration and control (specially the human ones)

However, the meteorological factors at the fire conflagration moment and during it are not taken into account in the territorial planning.

Exception to the above occurs in the analysis process where different meteorological conditions strongly disguise the relative importance of the permanent factors.

The importance of such factors lies mainly in the forest management setting up of fire meteorological risk (VELEZ 1981, DELABRAZE 1982) or instantaneous fire risk (DIAS 1958).

Instead of this, the micro or meso-climatic characteristics in average terms for the critical period appear as the main factors.

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\* In this paper the english word RISK corresponds directly to the portuguese word RISCO, whose sense is similar to HAZARD in american fire terminology.

As a way of framing the fire problem from the territorial planning point of view (CRUZ 1981) it is important to define the fire risk under the following aspects:

- in conflagration terms, that could be defined by the number of fires
- in propagation terms, that could be defined by the average dimensions of each individual burned area.
- in burning terms, that could be defined by the total area burnt, that is the result of the previous ones.

The risk of fire can also be envisaged according to the risk conditioning factors, namely:

- a) potential fire risk, which corresponds to the occurring probability of fires due only to climatic, edaphic, hydric and orographic factors.
- b) biotic fire risk, which corresponds to the occurring probability of fires due only to biocoenosis characteristics (total biomass, cover density, tree cover, stratification type, fuel combustibility and understory moisture).
- c) natural fire risk, which corresponds to the occurring probability of fires due to the biogeocoenosis characteristics. It corresponds therefore to the data related with both the potential and biotic fire risks.
- d) real fire risk, which corresponds to the occurring probability of fire based not only in the natural risk but also in factors of antropic origin (deliberate or careless setting of fires, accessibility and fire control and prevention measures).

However, the knowledge of the different kinds of risks have different impacts.

So, the potential fire risk concerns mainly the long term territorial planning studies (due to the fact that only the geocoenosis factors are not considered as potentially variable).

The natural fire risk concerns mainly the medium and short term territorial planning, where it is a environmental element conditioning the different human uses. Also the knowledge of this factor and its cartographical reproduction may become a useful element in the fire control measures.

The real fire risk is a basic element to the study and analysis of the different kinds of risk, as it corresponds to what really happens. As an element easily to obtain "a posteriori" it could be used directly as a first approach to the fire risk, specially for the definition of the critical areas with this kind of natural risk.

Fig. 1 shows a theoretical integration of the different kinds of fire risks considered with the corresponding determinative elements.

## 2. OBJECTIVES

Concerning the problem of prevention and control of forest fires, the Municipality of Lisbon (CÂMARA MUNICIPAL DE LISBOA) defined a investigation programme on the following phases:

- a) gathering and selection of data concerning forest fires.
- b) setting up of correlations among the number and the average burnt area of each fire and the following factors:
  - type and density of vegetation
  - hydric factors
  - physiographic factors
  - meteorological factors
  - human factors
- c) drawing in cartographical terms of the conflagration and propagation fire risks based in the correlations defined on the previous phase.
- d) adoption of measures for territorial planning and forest management as a way to prevent and control the forest fires.

in terms of:

- conflagration

- propagation

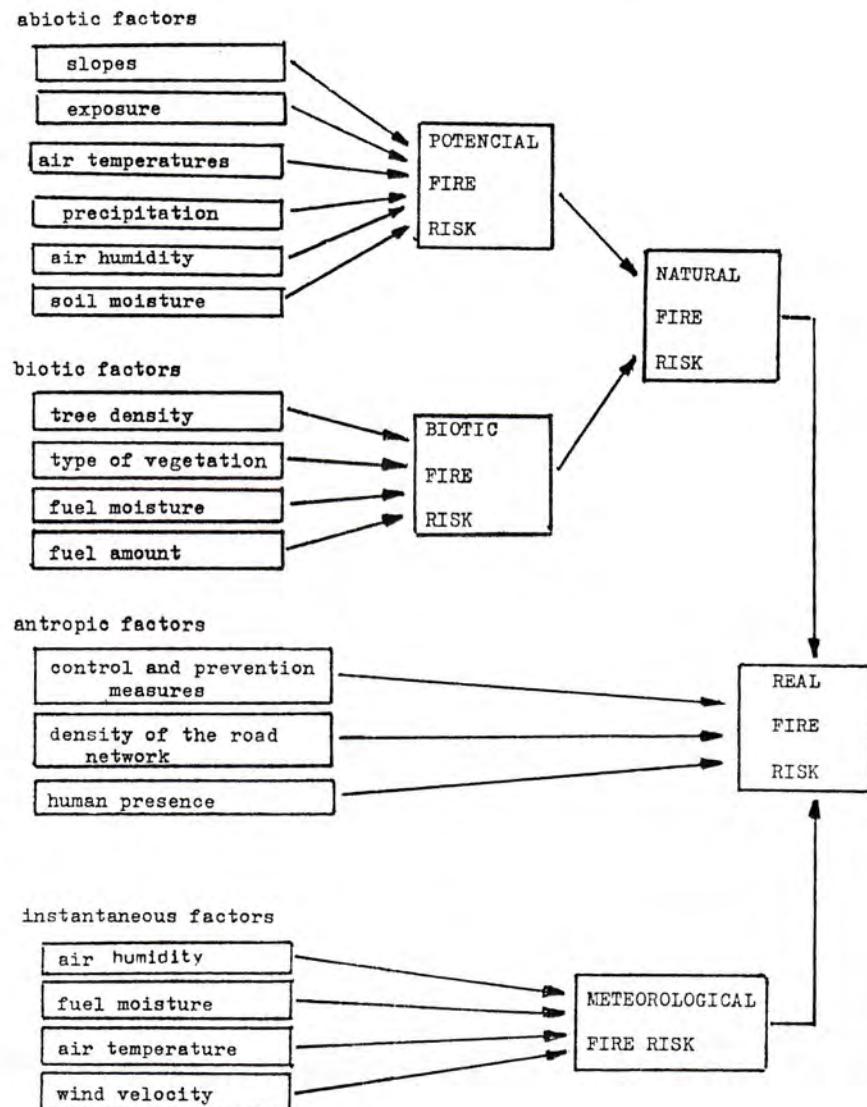


Fig.1: Fire risk integrated factors

THE PARQUE FLORESTAL DE MONSANTO was choosen as a study area. Those 1.000 ha forest park stays inside a urban area (Lisbon) and has a high diversity in ecological terms. There occurs an high frequency of fires (with a average of 80 fires per year) quite well reported about data (time, place, burnt area, number of attained trees and burned ones).

In this process the data concerning the number and average burnt area correspond to the real fire risk. The elimination or the settlement of the antropic factors make possible the definition of the natural fire risk, which can be devided in fuel parameters (biotic fire risk) and environment parameters (potential fire risk).

Controlled burning is used at the MONSANTO forest park as a fire prevention measure. The knowledge of different propagation fire risks on this park may help the forest technicians in the area management.

The delay of the informatic process envisaged, obliged us, in order to obtain useful elements for the works in the spring of 1983, to define the propagation risk only with the following elements:

- a) Potential propagation fire risk
- b) Biotic propagation fire risk

These two elements are complementary once its integration defines theoretically the natural propagation fire risk.

But such integration is not valid in the present case as the first element (potential risk) is determinated by a qualitative aggregation of the environmental factors and the second (biotic risk) established by a previous analysis without correction with any environmental factors (including the instantaneous ones).

### 3. POTENTIAL PROPAGATION FIRE RISK

Cartographically represented in fig. 2 it was based on a methodological proposal included in the Ecological Cartography Project from the European Economical Communittee (E.E.C.) (KNOBLICH 1980).

The proposed method (AQUATER 1980) concerns the identification of the threatened areas by the wild fires.

Different versions adopted for Portugal has been used in several territorial planning studies (ROXO 1981, KNOBLICH 1982).

In the present case the method concerns the aggregation of the main permanent environment factors that determine the fire propagation risk: Emberger's pluviothermic quotient, insolation intensity, soil moisture in the summer and slopes.

#### 3.1 EMBERGER'S PLUVIOTHERMIC QUOTIENT

$$\text{Determined through the formula } Q_2 = \frac{2,000 P}{(M+m+546.7) (M-m)}$$

where P (average annual precipitation)

M (average maximum temperature in summer)

m (average minimum temperature in winter)

The basic climatic data has been previously corrected. \*

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\* J. de Pina Manique e Albuquerque has developed in Portugal several studies concerning the values of P M and m, established at sea level and afterwards corrected with an altitude gradient.

The Q2 values (Emberger's pluviothermic quotient) were reorganized on a 9 degrees gradient with the following correspondence:

Q2 between 150 and 155 .....	degree 9
155 and 160 .....	8
160 and 164 .....	7
164 and 168 .....	6
168 and 172 .....	5
172 and 176 .....	4
176 and 180 .....	3
180 and 185 .....	2
185 and 190 .....	1

### 3.2 INSOLATION INTENSITY

Cartographically established through integration of elements obtained in physiographic analysis (slopes and exposure). The number of insolation hours (BARTORELLI, 1967) is gathered and translated in a 9 degrees gradient with the following correspondence:

below 1,600 hrs/year .....	degree 1
between 1,600 and 1,800 hrs/year ....	2
1,800 and 2,000 hrs/year ....	3
2,000 and 2,100 hrs/year ....	4
2,100 and 2,200 hrs/year ....	5
2,200 and 2,300 hrs/year ....	6
2,300 and 2,400 hrs/year ....	7
2,400 and 2,500 hrs/year ....	8
above 2,500 hrs/year ....	9

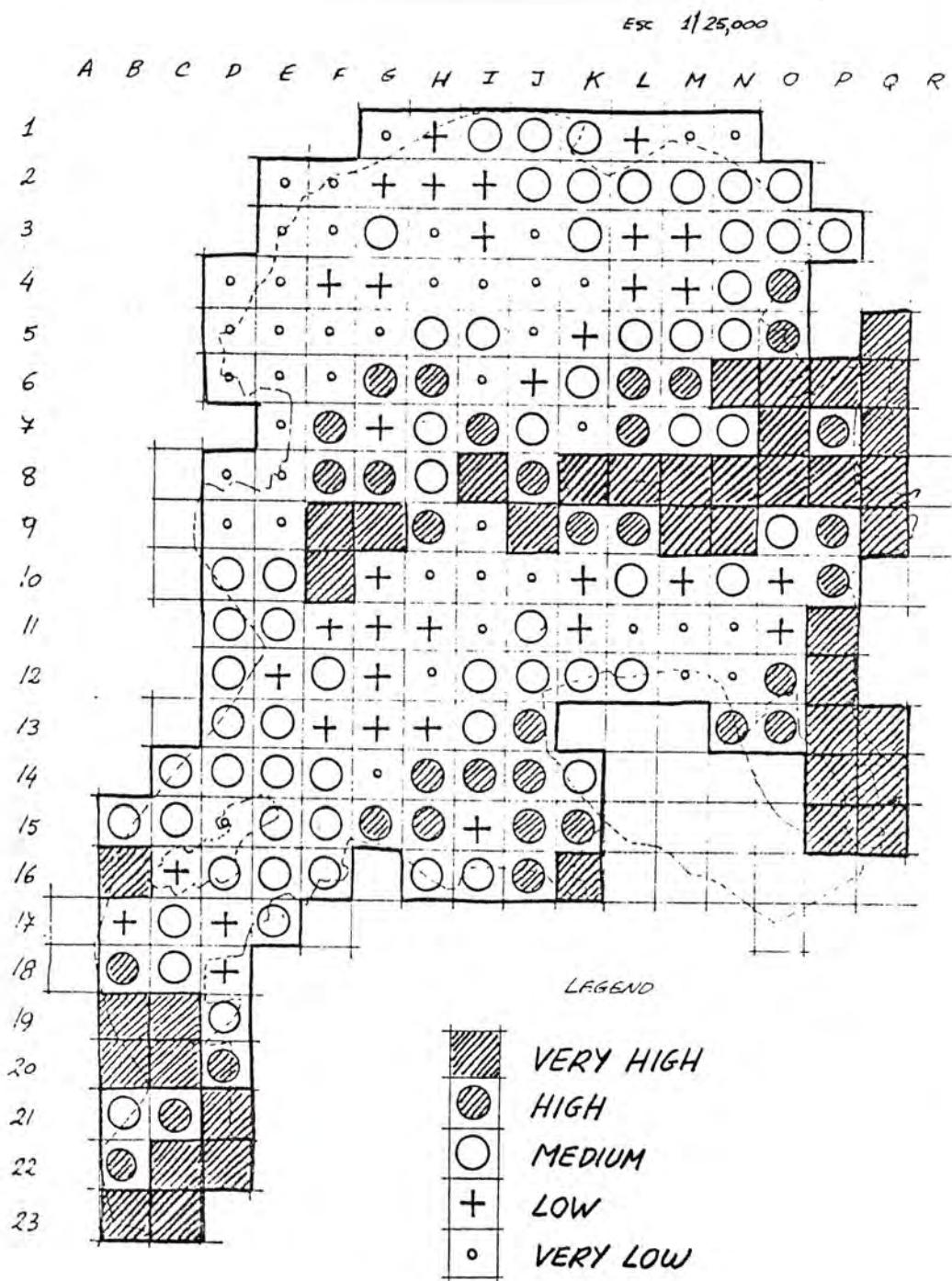


Fig.2: Potential propagation fire risk

### 3.3 SOIL MOISTURE IN THE SUMMER

Established from the physic and hydric substratum characteristics in the following gradient:

soils with high water-table .....	degree 2
silty-loam soils .....	5
sandy soils and limestone .....	8

### 3.4 SLOPES

These physiographic factor has been used through the following gradient:

slopes below 5% .....	degree 2
between 5 and 10% .....	4
10 and 20% .....	6
above 20% .....	8

### 3.5 INTEGRATION SCHEME

The values obtained from the different factors have been added and latter on reduced to a 5 degrees universe.

Such process makes possible the establishment of different potential propagation fire risks through the area under study.

## 4. BIOTIC FIRE PROPAGATION RISK

This element is only an approach, as it was established through a very limited analysis of the basic existing data.

Several important factors have not been used in the analysis as follows:

- a) physiographical factors that have been included in a different element.
- b) meteorological factors, such as temperature, air humidity, soil moisture and wind velocity occurring at the moment of deflagration and fire spreading.
- c) human factors, mainly on the aspects of detection and fire control. These factors have been considered of smaller importance than the previous ones due to the existence of a dense road network (with a total length of 120 km), a firemen head-quarter in the centre of the park, forest guards houses, military and private installations along the park.

The conclusions concerning the biotic risk in such conditions have a rather limited importance, however, it could be used as a first approach to the problem.

#### 4.1 USED BASIC DATA

The MONSANTO forest park constitutes an emergent relief with 1.060 ha of total area, presents an altitudinal variation between 30 and 200 meters and has a rather diverse vegetation.

The reforestation began in 1936 and has been concluded 30 years later.

The existing data about wild fires in the park concerns mainly the time, local (in a 6.25 ha reference reticulate), burnt area, type of vegetation attained and quantity of dead trees.

Although the fire records started from 1950, only after 1964\* they have been considered as reliable.

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\* 1965 has not complete data, so they have been not used.

The basic data, referred in short on TABLES 1 and 2 pointed out to:

- a) A total of 1.126 wild fire occurred (with a average of 70.4 fires per year during the period). With a minimum in 1969 (40 fires) and a maximum in 1976 (125 fires).
- b) The maximum of fires occurs in August (25.8%) and July (23.3%), following by June (11.8%) and September (11.6%). In October occurs 3% of the fires and in May 1.4%. In the other months (November to April) only 1.7% of the fires occur.
- c) The average burnt area per fire during the period considered is 2.345 sq.m., with a minimum in 1976 (1.191 sq.m.) and a maximum in 1980 (4.163 sq.m.)
- d) The majority of the fires has been of low intensity and slow-spreading. The flame rarely attained 2 m in lenght (the average lies between 0.5 and 1 m).
- e) Different types of vegetation reveal a different susceptibility to the fires.
- f) A rather importance of wild fires in Monsanto park. In 16 years the fires spreading through 295 hectars (almost 30% of all area).

From the existing data it was selected to analytic treatment only those concerning the average burnt area per fire, density and type of vegetation. All the data has been reported to the referred reticulate used in these park as the fire reference element.

The selected data are shown in figures 3, 4 and 5 per gradient or presence/absence of data.

#### 4.2 DATA TREATMENT

The original study project pointed out as a basic methodology the setting up of correlations between the burnt area and the type of vegetation, density of tree cover, Emberger's pluviothermic

	burnt area	number of fires	burnt average area (sq m)
1964	60 985	44	1 386
1965	-	-	-
1966	237 856	59	4 031
1967	73 932	52	1 422
1968	139 894	82	1 706
1969	95 400	40	2 385
1970	181 891	86	2 115
1971	120 683	65	1 857
1972	182 636	59	3 096
1973	191 939	87	2 206
1974	260 232	96	2 711
1975	251 923	124	2 032
1976	148 907	125	1 191
1977	163 470	67	2 440
1978	343 255	95	3 613
1979	341 295	114	2 994
1980	266 430	64	4 163
TOTAL	2952 108	1259	
Annual average	184 507	78,7	2 345

Table 1: Fire statistics

	occupied area (A)	burnt area (B)	$\frac{100 \times B}{A} \%$	number of fires
mixed stands	163,2	409,4	39,9	452
carvalhal ( <i>Quercus</i> sp)	35,7	134,7	26,5	121
acacial ( <i>Acacia</i> sp)	8,8	31,0	28,4	34
pinhal manso ( <i>Pinus pinea</i> )	112,5	498,1	22,6	489
eucaliptal ( <i>Eucalyptus</i> sp)	60,8	281,6	21,6	264
pinhal de alepo ( <i>Pinus halepensis</i> )	24,2	126,3	19,2	108
cupressal ( <i>Cupressus</i> sp)	34,2	276,5	12,4	201
olival ( <i>Olea europaea</i> )	4,1	37,2	11,0	36

Table 2: Fire data referred to the type of vegetation

The total occupied area exceeds the global area under study. The different types of vegetation include both the pure stands and the mixed ones.

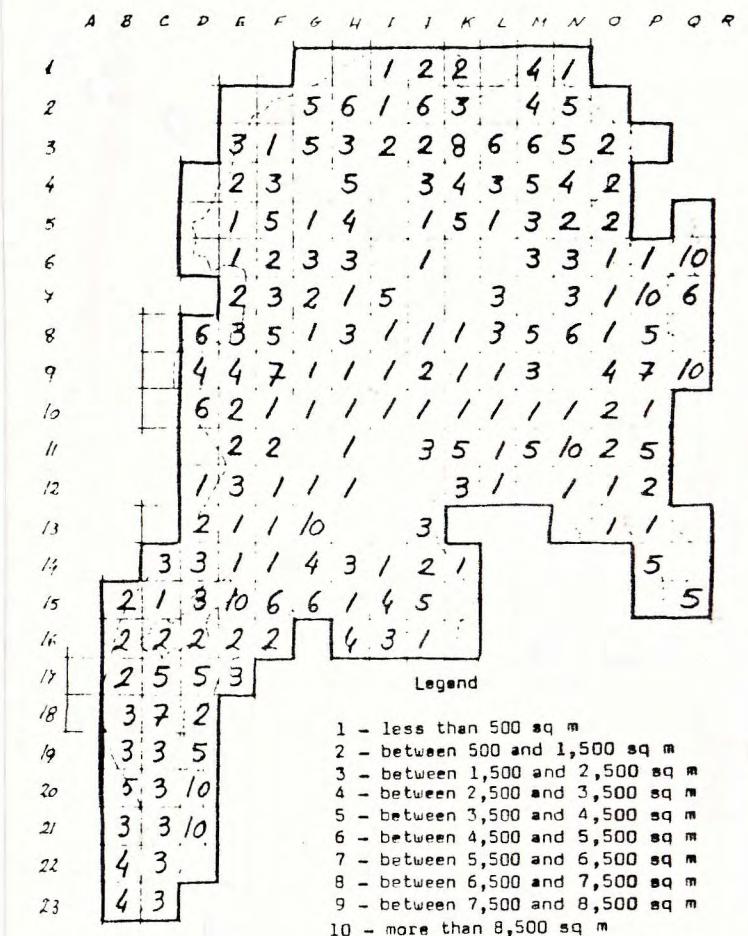


Fig.3: Average burnt area

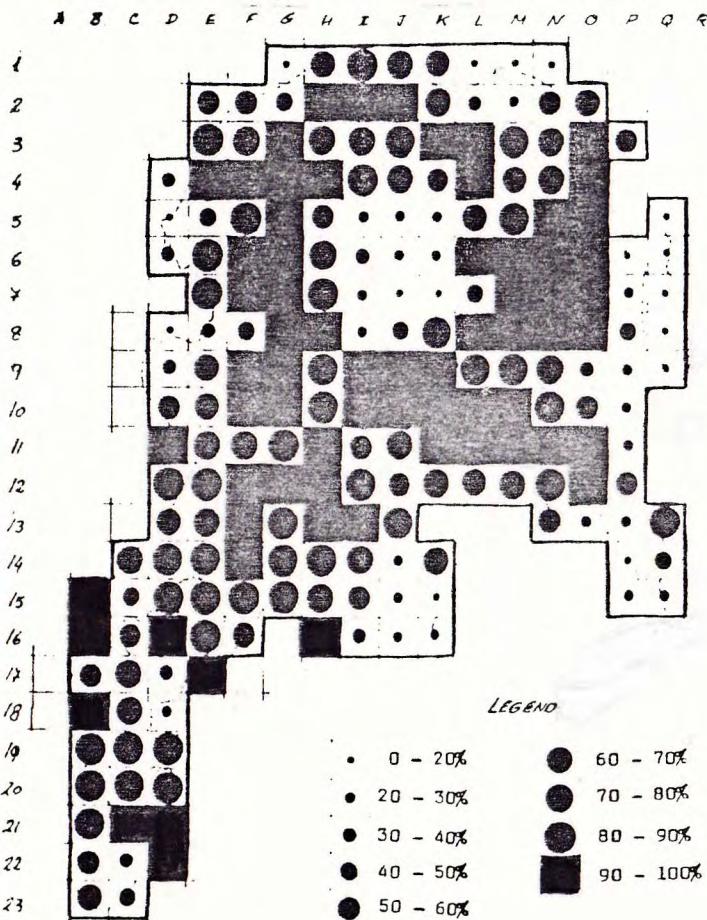


Fig.4: Tree cover density

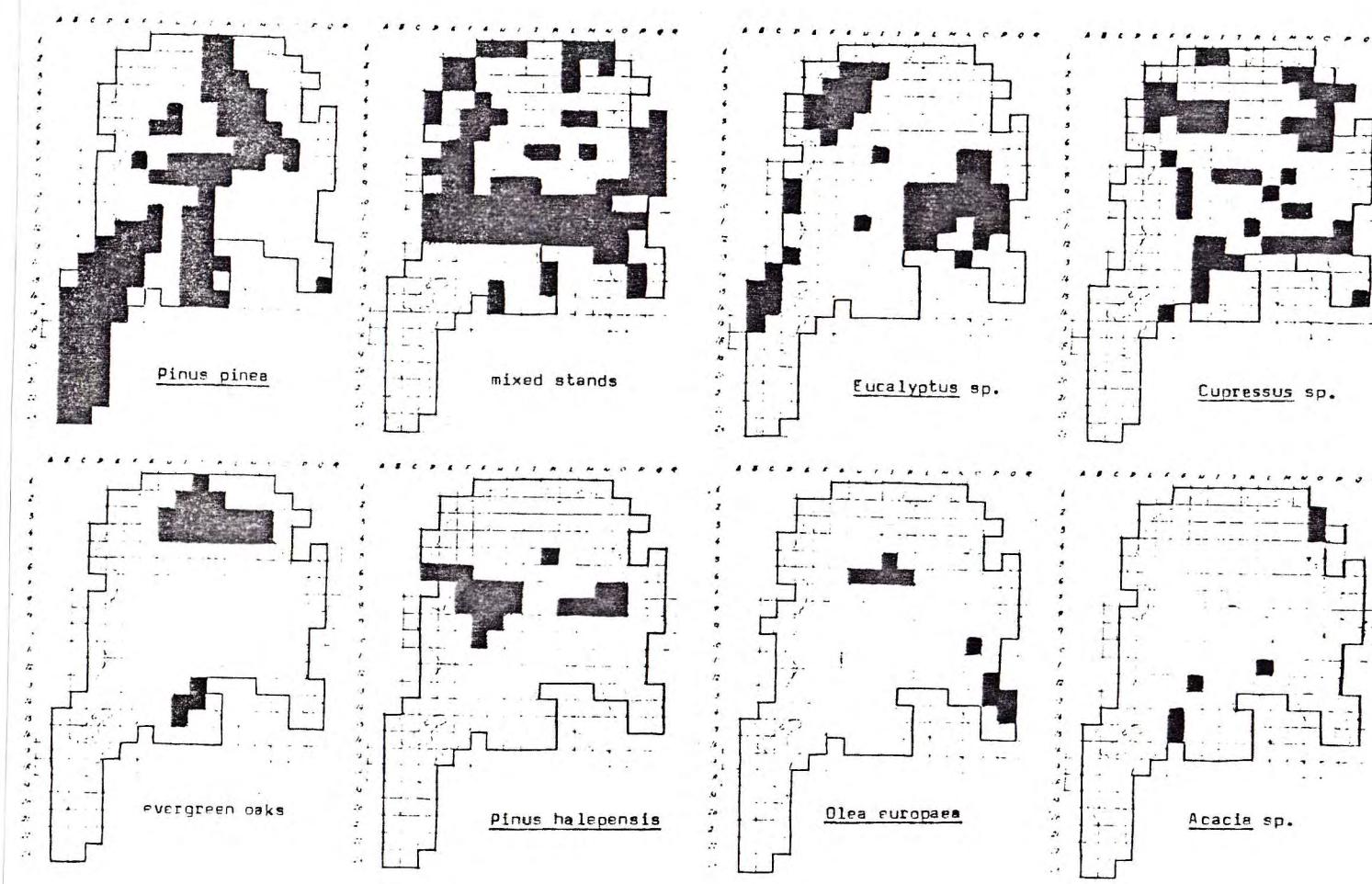


Fig.5: Vegetation types

quotient, average soil moisture in summer, insolation hours, slopes and meteorological conditions at the moment the fires start (temperature, air humidity, wind velocity and time elapsed after last rain).

As it was mentioned before, this kind of analysis that normally implies the automatic treatment of available data, was not interely completed.

In this phase, the analysis was limited to the determination of a probability risk gradient of fire propagation based only in the type of vegetation and the tree cover density. The remain factors related to the fire propagation were not taken into account.

The vegetation types considered are the followings:

ACACIAL - tree cover: dominance of Acacia melanoxylon, Acacia cyanophila, Acacia longifolia, or Acacia pycnantha and occasionally Acacia cyclops  
understory: mainly composed by Acacia sp. regeneration

CARVALHAL - tree cover: dominance of evergreen sclerophytic Quercus species, mainly of Quercus suber (cork oak), and Quercus rotundifolia (iberian holm oak). Locally also occurs Quercus faginea, Quercus robur and Fraxinus angustifolia subsp. angustifolia  
understory: a very dense one that includes not only the dominant species regeneration but also Phillyrea latifolia, Viburnum tinus, Arbutus unedo, Rhamnus alaternus, Quercus coccifera, Juniperus phoenicea, Olea europaea var. sylvestris (Zambujeiro) and Pittosporum undulatum

CUPRESSAL - tree cover: dominance of Cupressus sp., mainly of Cupressus lusitanica but also of Cupressus macrocarpa and Cupressus sempervirens  
understory: almost absent with practically no shrubs

EUCALIPTAL - tree cover: dominance of Eucalyptus sp., mainly of Eucalyptus camaldulensis or Eucalyptus cornuta. Locally occurs also Eucalyptus botryoides, Eucalyptus saligna, Eucalyptus sideroxylon, etc.  
understory: is rather diversified and always present, it includes Rubus ulmifolius, Lonicera etrusca, Prunus spinosa subsp insistitoides, Ulmus minor, Acacia longifolia, etc.

OLIVAL - tree cover: dominance of Olea europaea var. europaea (olive tree)  
understory: with strong antropic characteristics (agriculture or grazing)

PINHAL DE ALEPO - tree cover: dominance of Pinus halepensis  
understory: with an intense regeneration of the dominant pine species. Includes also Arbutus unedo, Phillyrea latifolia, Quercus coccifera, Rhamnus alaternus, Rhamnus lycioides subsp. oleoides, Olea europaea var. sylvestris

PINHAL MANSO - tree cover: dominance of Pinus pinea (umbrella pine)  
understory: a very diversified one, from scarcely herbs to very dense formations with Quercus rotundifolia, Phillyrea latifolia, Rhamnus alaternus, Juniperus phoenicea, etc.

MIXED STANDS - This kind of vegetation referred the remain vegetal cover, usually very diversified and with a strong number of dominant species. The more frequent species in the tree cover are: Quercus faginea, Quercus robur, Quercus pyrenaica, Gleditchia triacanthus, Ulmus minor, Celtis australis, Populus alba, Populus nigra, Fraxinus angustifolia, Fraxinus americana, Cercis siliquastrum, Ailanthus altissima, Acer negundo,

Ceratonia siliqua, Olea europaea, Schinus terebenthifolia, Albizia lophanta, Pittosporum undulatum, Acacia dealbata, Acacia decurrens, Acacia retinoides, Acacia Karoo, Acacia pycnantha, Acacia melanoxylon, Eucalyptus sp., Cupressus sp., Pinus canariensis, Pinus pinea, Pinus halepensis and Platycladus orientalis

The average burnt area of the different types of vegetation is shown in TABLE 3 in function of tree cover density. The pure stands and the mixed ones are presented separately.

Through regression analysis we tried to determine the evolution trends of the average burnt area on the different types of vegetation whose linear regressions are represented in FIG. 6.

The correlation coefficients (*r*) and the regression coefficients (*B*) of those regressions are shown in TABLE 4.

#### 4.3 CONCLUSIONS

Based on the correlations between burnt area and the different vegetation types and tree cover densities, it is possible to conclude in a first approach the following:

- a) in global terms there is a inverse correlation between the average burnt area and the tree cover density, mainly for low cover densities (the average burnt area varies from 10.900 sq.m., 7.300 sq.m. and 5.900 sq.m. for tree cover densities below 20%, 30% and 40% respectively). For tree cover density over 70% the average burnt area present a trend to stabilize at 2000 sq.m..
- b) on Quercus sp. and Acacia sp. stands occurs a direct correlation between the average burnt area and the tree cover density.

The fact may be related with the high pluri-stratification of

vegetation types	tree cover density								correlation coefficient (r)	regression coefficient (B)
	0 to 20%	20% to 30%	30% to 40%	40% to 50%	50% to 60%	60% to 70%	70% to 80%	80% to 90%		
pure <u>Acacia</u> sp.	-	-	-	-	0	-	-	3200	-	+ 0,16
mixed <u>Acacia</u> sp.	-	-	-	-	0	-	-	4600	800	-
<u>Acacia</u> sp.	-	-	-	-	-	-	-	3600	800	-
pure <u>Quercus</u> sp.	-	-	-	-	-	2300	4900	-	1,00	+ 0,05
mixed <u>Quercus</u> sp.	-	1300	-	-	3500	1900	1800	4300	2900	+ 0,26
<u>Quercus</u> sp.	-	1300	-	-	3500	2000	3200	4300	3000	-
pure <u>Cupressus</u> sp.	-	-	-	-	-	-	-	1100	1500	+ 0,03
mixed <u>Cupressus</u> sp.	-	2800	-	-	-	-	-	1200	1600	-
<u>Cupressus</u> sp.	-	2800	-	-	500	1900	500	3100	1200	-
pure <u>Eucalyptus</u> sp.	-	-	-	-	500	1900	500	3100	1200	-
mixed <u>Eucalyptus</u> sp.	-	3000	-	-	4000	-	-	2000	3100	-
<u>Eucalyptus</u> sp.	-	3000	-	-	4000	2200	1000	1700	1000	-
pure olive tree stands	-	-	-	-	4000	2200	1000	1700	1300	-
mixed olive tree stands	-	-	-	-	4000	2200	1000	1700	1300	-
olive tree stands	-	-	-	-	4000	2200	1000	1700	1300	-
pure <u>Pinus pinea</u>	-	-	-	-	-	-	-	-	-	-
mixed <u>Pinus pinea</u>	-	-	-	-	-	-	-	-	-	-
<u>Pinus pinea</u>	-	-	-	-	-	-	-	-	-	-
pure <u>Pinus halepensis</u>	-	-	-	-	-	-	-	-	-	-
mixed <u>Pinus halepensis</u>	-	-	-	-	-	-	-	-	-	-
<u>Pinus halepensis</u>	-	-	-	-	-	-	-	-	-	-
mixed stands	-	2500	0	-	4400	-	-	-	-	-
total stands	-	6800	2500	4300	4400	-	-	500	1900	-
10900	4300	2600	3100	2300	2300	1500	1000	2200	2800	0,21
10900	4300	2600	3100	2300	2300	900	2000	2000	2500	0,55

(a) calculated for tree cover density over 20%

note: (-) such type vegetation does not exist  
 (o) does not occurred fires in this type of vegetation

Table 3: Average burnt area (sq m)

Table 4: Linear regressions (weighted)

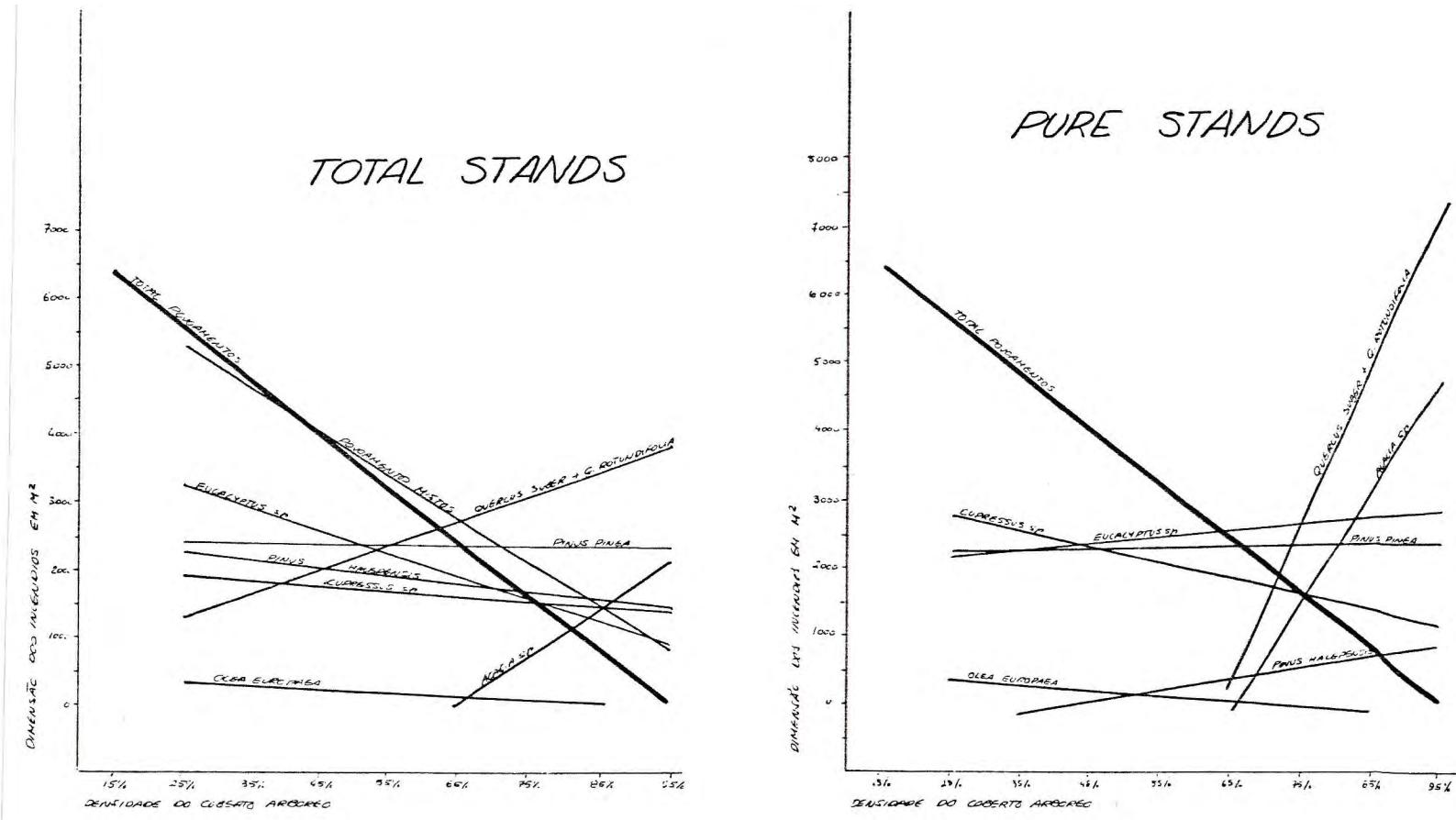


Fig.6: Linear regressions

these stands and the fuel continuity. Both result from the low growing rate of the evergreen oaks and the low height of the existing Acacia species.

- c) the mixed stands, the Cupressus sp. stands and the Olive tree stands present a inverse correlation between the average burnt area and the tree cover density. This fact is apparently based on the low understory density of the Cupressus stands (due to a low luminosity) and Olive tree stands (due to traditional agriculture uses), whereas in the mixed stands this effect is probably due to several different factors (mainly to the highly interspecific competition and the discontinuous stratification)
- d) in the pine stands (of Pinus pinea and Pinus halepensis) and in the Eucalyptus sp. stands the correlations between the average burnt area and the tree cover density are not very well defined:
  - in the pure stands the correlation is a direct one, although not very accentuated.
  - in the mixed stands the correlation is a inverse one.With the existing data it is difficult to find a correct explanation.
- e) in the different vegetation types the average burnt area increases in the following order: Olea europaea stands - Cupressus sp. stands - Pinus halepensis stands - mixed stands - Eucalyptus sp. stands - Pinus pinea stands - Acacia sp. stands - evergreen Quercus sp. stands

#### 4.4 FIRE PROPAGATION RISK AND CORRESPONDING INDICES

The above conclusions open the possibility to define a variation in the probability of the fire propagation risk depending upon the vegetation type and tree cover density.

Such probability may be represented by a qualitative gradient directed correlated with the average burnt area. It may vary between degree 1 (minimum) and degree 5 (maximum).

TABLE 5 shows the results in accordance with the above gradients.

In the case of MONSANTO park and taking into account the different vegetations types and considering always the highest value of fire gradient, the biotic risk of fire propagation may be charted as follows (Fig. 7):

maximum risk - presence of vegetation with degree 5

medium risk - presence of vegetation with degree 4

minimum risk - presence of vegetation with degree 3, 2 or 1

Vegetation type	% of tree cover									
	0	20	30	40	50	60	70	80	90	
	-	-	-	-	-	-	-	-	-	-
	20	30	40	50	60	70	80	90	100	
<u>Quercus</u> sp.	4	4	4	4	4	4	4	5	5	5
<u>Pinus pinea</u>	4	4	4	4	4	4	4	4	4	4
<u>Eucalyptus</u> sp.	4	4	4	4	4	4	4	4	4	4
<u>Acacia</u> sp.	4	4	4	4	3	3	4	4	4	4
average	5	4	4	4	4	3	3	3	3	3
mixed stands	5	4	4	4	4	3	3	2	2	2
<u>Cupressus</u> sp.	4	4	4	4	3	3	2	2	2	2
<u>Pinus halepensis</u>	4	4	4	4	3	2	2	2	2	2
Olive trees	4	4	4	4	3	2	1	1		

Table 5: Average burnt area gradient

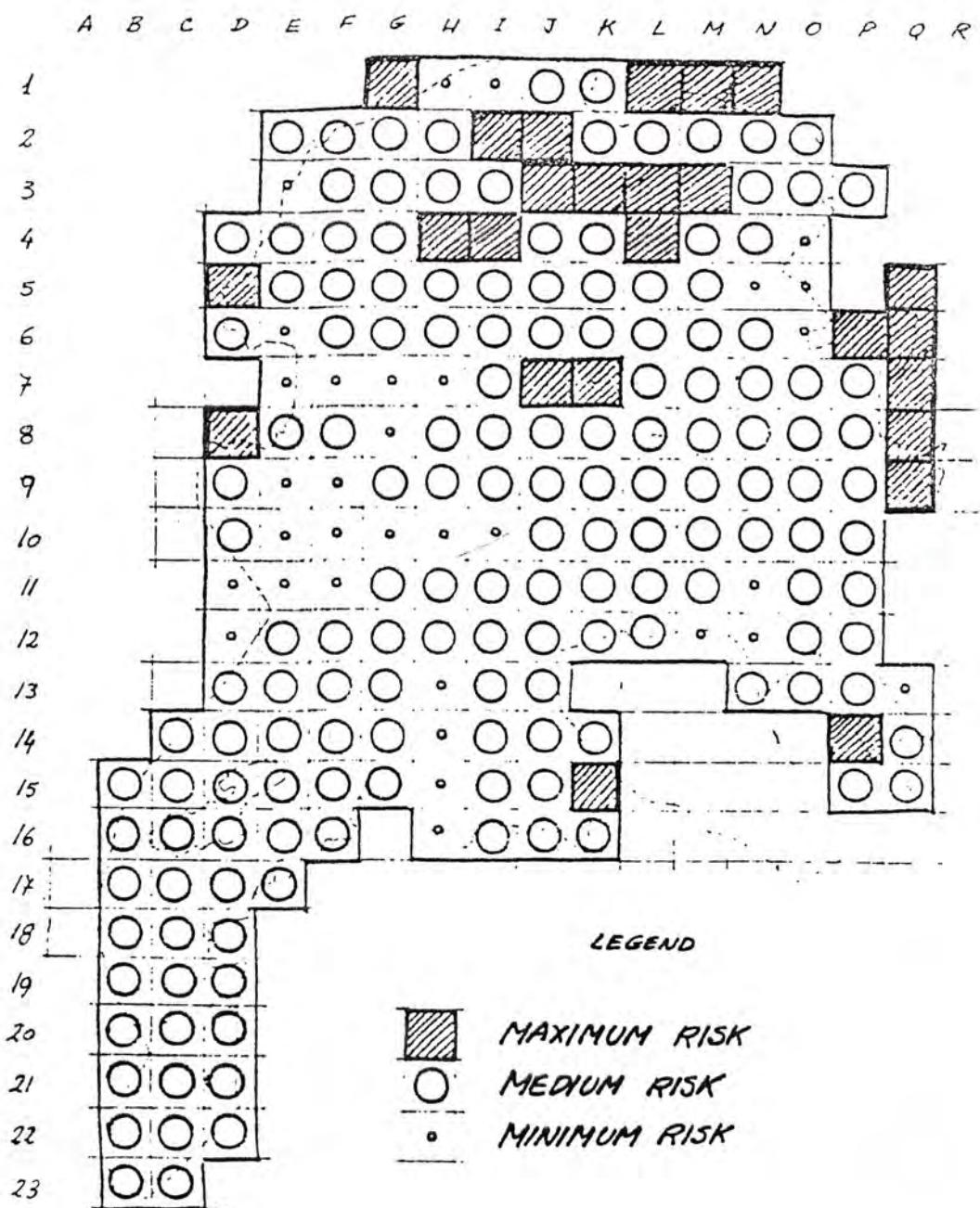


Fig.7: Biotic propagation fire risk

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## KONTROLIERTES BRENNEN IM WESTEN DER VEREINIGTEN STAATEN VON AMERIKA

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### Einleitung

Feuer ist ein wichtiger Bestandteil vieler naturnaher Ökosysteme der Welt (PYNE 1982). Die Periodik des Auftretens von Feuer ist abhängig von der Vegetation, dem "Feuerwetter" (meteorologische Bedingungen, unter denen hohe Brandgefahr herrscht) und den sich daraus ergebenden Unterschieden im Verhalten des Feuers und dessen Auswirkung auf die Vegetation (MARTIN 1982a). Kenntnis über das Vorkommen und Auswirkungen von Bränden werden als Grundlage zur Anwendung des Feuers als Bewirtschaftungsmethode benutzt. In diesem Beitrag sollen die historische Rolle von Feuer im westlichen Nordamerika und die sich daraus ergebenden derzeitigen und zukünftigen Anwendungen des kontrollierten Brennens behandelt werden.

### Historisches Vorkommen von Bränden (Feuergeschichte)

Feuer wurden alltäglich von den Europäern beobachtet, die Nordamerika durchquerten. Berichte über das Auftreten von Bränden kamen von Forschern, Trappern und Siedlern aus dem Flachland des Mittleren Westens und den Rocky Mountains, bis hin zur Pazifikküste. Diese Feuer wurden hauptsächlich von Blitzschlag und Indianern verursacht, aber oftmals trugen auch Siedler dazu bei.

Den von Indianern verursachten Bränden wird in jüngerer Zeit stärkeres Interesse entgegengebracht. Niemand zweifelt an der Tatsache, daß Indianer Brände legten, wobei es umstritten ist, ob dies vorsätzlich oder unbeabsichtigt geschah, um bestimmte Ziele

zu erreichen. Jahrelange Untersuchungen über die Anwendung von Feuer durch amerikanische Ureinwohner veranlaßten STEWART (1963) zu der Feststellung, daß die "Eingeborenen in allen Vegetationstypen brannten, die dazu geeignet waren". Manche Forscher vermuten, daß der Besitz von Pferden die Indianer zum großräumigen Brennen veranlaßte; diese Vermutungen stimmen aber nicht mit Untersuchungen aus dem Nordwesten der USA überein.

Seit einer halben Million Jahren ist der Mensch in der Lage, das Feuer zu nutzen und zu beherrschen, aber erst während den letzten 10 - 20.000 Jahren lernte er es zu erzeugen (STEWART 1963). Dennoch war die Entzündung von Feuern für die Indianer relativ problematisch, und sie ließen daher ihre Lagerfeuer brennen oder benutzten langsam brennende Vorrichtungen, um den mühsamen Prozess der Feuerentfachung zu vermeiden. Beide Gewohnheiten waren Ursache für weiträumige Brände.

Die Indianer benutzten Feuer offensichtlich zur Jagd, zum Sammeln von Insekten und zur Erhaltung geeignet scheinender Vegetationstypen, wie z.B. offener Flächen um ihre Lagerplätze zum Schutz gegen Feinde. Im Mittleren Westen wurden Feuer wahrscheinlich gelegt, um den Bison in Fallen zu treiben, während in der "Intermountain"-Region die Hänge am Fuß entzündet wurden um Wild, das vor Rauch und Flammen flüchtete, abzuschießen. In Nordkalifornien wurde die Rauchentwicklung von qualmenden Feuern zum Sammeln der Larven von Coloradia pandora genutzt und Grasbrände wurden gelegt, um Heuschrecken in Gruben zu treiben (BODENHEIMER 1951). Diese Insekten wurden getrocknet, in Pulver zerrieben und als Protein Zusatz zur Nahrung genutzt. Ungeachtet der tatsächlichen Zwecke erweiterten die Indianer in den Landschaften des Westens das Vorkommen von Bränden.

Aufgrund des Auftretens von Gewittern in diesen Gebieten war das Feuer jedoch bereits ein wichtiger Bestandteil der Natur. Dokumente aus der Gegenwart deuten darauf hin, daß durch Blitzschlag bis zu 100 Brände/1 mio ha verursacht werden (SCHROEDER and BUCK 1970). In den meisten Gebieten des westlichen

Landesinnern, außer auf feuchten Standorten, auf denen die Douglasie (Pseudotsuga menziesii) dominiert, werden jährlich mindestens 25 Brände/1 mio ha durch Gewitter verursacht. Die große Anzahl durch Blitzschlag entstandener Feuer ist auf die lange sommerliche Trockenperiode mit geringer Luftfeuchtigkeit zurückzuführen. Krautartige Pflanzenteile verholzen, das Brennmaterial trocknet aus, und aufgrund der Tatsache, daß der Niederschlag verdunstet, bevor der Boden erreicht wird, erhöht sich die Brandgefahr.

Die Anpassungsformen vieler Pflanzen im westlichen Nordamerika deuten auf eine Evolution in einem "Feuerklima" hin, d.h. unter klimatischen Bedingungen, in denen der Zeitraum zwischen den Bränden relativ unterschiedlich, aber dennoch vorteilhaft für bestimmte Pflanzen sein kann. Am offensichtlichsten ist dies bei Baumarten, die resistent gegen das Feuer sind, mit Ausnahme von Kronenfeuern. Die starke Borke der Ponderosa-Kiefer (Pinus ponderosa), der Lärche (Larix occidentalis), der Sequoia-Arten (Sequoia sempervirens, S.gigantea) und Douglasie (P.menziesii) sind völlig widerstandsfähig gegen Bodenfeuer, obwohl sie im Sämlingsstadium recht anfällig sind. Die Sämlinge der Ponderosa-Kiefer werden, aufgrund des kräftigen Astwuchses und der langen Nadeln, die die Knospen schützen, als erste dieser Arten resistent. Andere Arten entwickeln "serotine" Zapfen, in denen keimfähige Samen über lange Zeit hinweg erhalten werden. Diese Anpassung ist besonders an folgenden Kiefernarten ausgebildet: Pinus contorta, P.attenuata, P.muricata, P.radiata, sowie dem Mammutbaum (S.gigantea). Weitere Pflanzen haben "harte" Samen, die bis zu 200 Jahre lang keimfähig im Boden ruhen können. Diese Eigenschaft ist in verschiedenen Arten der Gattungen Ceanothus spp. und Arctostaphylos spp. und verschiedenen Schmetterlingsblütlern (Leguminosae) vorhanden (GRATKOWSKI 1962, MARTIN et al. 1975a)."Leichte" Samen sind eine weitere Strategie die, wie z.B. bei Populus spp., die Besiedlung entfernter Brandflächen ermöglicht. Letztlich ist die Fähigkeit vieler Pflanzen erwähnenswert, sich mittels Stockausschlägen und Proventivknospen vegetativ zu vermehren, was bei der

Wiederbesiedlung offener Flächen große Vorteile mit sich bringt. Ein einmaliges Beispiel einer Kombination von "leichten" Samen und Stockausschlägen sind die Millionen ha von Pappelbeständen (hauptsächlich Populus tremuloides und P.grandidentata) in den Staaten entlang den Großen Seen, die in den letzten 80 Jahren nach Abholzung oder Waldbränden entstanden sind. Die historische Bedeutung des Feuers in Nordamerika ist umfassend dokumentiert (ALEXANDER 1979, 1980; STOKES and DIETRICH 1980; MASTROGIUSSEPPE et al. 1983). Die unterschiedliche Beschaffung von Daten und deren Auswertung erschwert jedoch direkte Vergleiche. Die Resultate können zur Erstellung eines allgemeinen Verhältnisses zwischen dem Feuerintervall und klimatischen Gegebenheiten herangezogen werden (MARTIN 1982).

Das historisch nachgewiesene Auftreten von Feuern auf einem bestimmten Standort und dessen Vegetation liefert eine ökologische Grundlage für die Anwendung des kontrollierten Feuers. Das unberechenbare Verhalten und Vorkommen von Waldbränden würde, sofern unkontrolliert, viele der natürlichen Reize unseres Landschaftsbildes beeinträchtigen. Demzufolge wird das Feuer so eingesetzt, um bei weitestgehender Reduzierung der Umweltbelastung die forstwirtschaftlichen Erträge zu erhöhen. Die Verfolgung der Idee, das Feuer aus den Grenzwirtschaftswäldern fernzuhalten, resultierte in überbestockten Beständen, erhöhtem Schädlingsbefall, katastrophalen Brandbedingungen und in erheblich reduzierter Primärproduktion unserer Weide- und Feuchtgebiete. Mit dieser Taktik haben wir versucht, natürliche Prozesse auszuschalten, anstatt sie durch wohlüberlegte Anwendung des Feuers nachzuahmen.

#### Planung des kontrollierten Brennens

Die Anwendung des Feuers als Bewirtschaftungsmaßnahme hängt von den Zielen und der Konzeption der jeweiligen Organisation ab (MARTIN 1978). Wenn innerhalb einer Verwaltung das Feuer als Management-Methode nicht vorgesehen ist, dann findet diese

Nutzung auch nicht statt. Dieser Zustand herrschte in einem großen Teil der Vereinigten Staaten mehr als drei Jahrzehnte lang.

Falls die Anwendung von Feuer möglich ist, muß sie aus der gesamten Bewirtschaftungskonzeption hervorgehen. Diese Entscheidung sollte auf den folgenden Kriterien basieren:

1. Ein bestimmtes Gebiet wird mit Feuer behandelt, um eine erwünschte Nutzungsform zu erreichen.
2. Das kontrollierte Brennen ist aus ökonomischer und ökologischer Sicht die am besten geeignete Maßnahme der Behandlung eines Bestandes.

Oftmals sind jedoch mehrere Methoden notwendig, um bestimmte Zielsetzungen zu erreichen, und in diesem Fall würde Feuer in Kombination mit mechanischen, chemischen und biologischen Mitteln angewandt; dabei müssen die verschiedenen Methoden aufeinander abgestimmt werden.

Beim Einsatz des kontrollierten Brennens sind verschiedene Planungsschritte notwendig. In privaten Organisationen muß dieses Verfahren nicht formell sein, vorausgesetzt, daß Erfahrungen über das Verhalten und die Auswirkungen eines Feuers vorhanden sind. In den meisten staatlichen Behörden wurde dieser Prozess inzwischen formalisiert, um die Erfolgschancen zu erhöhen und eine Basis für spätere Auswertungen zu bilden. Es ist in vielen Fällen möglich, Zeit- und Kosteneinsparungen zu erzielen, wenn mehrere Projekte koordiniert werden.

Die meisten Feuer werden im Idealfall von Expertengruppen, aus Fachleuten verschiedener Disziplinen bestehend, geplant bzw. deren Anregungen berücksichtigt. Obwohl sich die aus diesem Vorgang ergebenden Änderungen nachteilig auf die ursprüngliche Zielsetzung auswirken können, wird dadurch oft die Verwirklichung eines Oberzieles auf rationelle Weise ermöglicht. Der Feuerökologe muß sich z.B. mit einer verminderten Reduzierung des brennbaren Materials zufrieden geben, fördert aber damit Entwicklungen aus forstwirtschaftlicher, jagdwirtschaftlicher

oder Standorts-bezogener Sicht, die oftmals den Wert der ursprünglichen Zielsetzung übersteigen. In den verschiedenen Organisationen wird der Planungsvorgang unterschiedlich gehandhabt, enthält aber prinzipiell in jedem Fall dieselben logischen Schritte (MOBLEY et al. 1977, GOLDAMMER 1978, MARTIN and DELL 1978, FISCHER 1978). Der Umfang einer derartigen Planung wird in der Regel auf ein einseitiges Formular mit einer Karte als Grundlage reduziert. Sie enthält folgende Einzelheiten:

1. Standortsbeschreibung:

Die Beschreibung des zu brennenden Standorts ist der erste Schritt in der Planung. Die zu erfassenden Daten beinhalten brennbares Material, Vegetation, Böden, Topographie, Gewässer und Beweidung bzw. Äsung durch Wild und Vieh. Diese Inventarisierung kann unter Umständen zur Modifizierung von Bestandesabgrenzungen führen, um homogenere oder auch vielfältigere Brandflächen zu gestalten, wobei unterschiedliche Lagen, Vegetation, Brennmaterialanhäufungen und andere Faktoren gegebenenfalls eine gesonderte Anwendung des Feuers zu bestimmter Zeit und unter speziellen Bedingungen erfordern.

2. Zielsetzung:

Die zu erreichen Ziele sind auf den jeweiligen Fall hin konzipiert und berücksichtigen die generellen Bewirtschaftungspläne und standörtlichen Gegebenheiten. Diese Vorstellungen sollten klar und quantitativ dargestellt werden, um Mißverständnisse und Fehleinschätzungen zu vermeiden, sowie eine Bewertung des Branderfolgs zu ermöglichen. Solche Zielsetzungen beinhalten z.B.:

- Reduktion des Brennmaterials der 100-Stunden-Zeitverzugsklasse ( $\varnothing$  2,5 - 7,6 cm) 10t/ha \*
- 90% der Humusschicht auf dem Standort zu belassen

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\* S.a. Beitrag von MARTIN und DIEMER

- 70% der Bäume mit einem Durchmesser unter 7 cm abzutöten
- Kronen bis zu 6 m Höhe zu versengen

### 3. Brennplan und -vorschrift:

Der Brennplan enthält die Voraussetzungen und Richtlinien zur Anwendung des Feuers, die auf Erkenntnissen der obigen Kategorien (1,2) basieren. Mehrere quantitative Hilfsmittel stehen zur Verfügung, um eine gewünschte und gleichzeitig realistische Vorschrift anzusteuern. Das Feuerverhalten kann anhand der Gleichungen von ROTHERMEL (1972), durch Nomogramme (ALBINI 1976), Computern oder Taschenrechnern, wie dem Texas Instruments TI 59 oder Hewlett-Packard HP-41C, berechnet werden. VAN WAGNERS Gleichungen (1973) oder die graphischen Darstellungen von ALBINI (1976) ermöglichen eine Vorhersage über die Höhe der Versengung der Baumkronen. Bei der Verfassung der Brennvorschrift ist die Kenntnis der vielfältigen Auswirkungen des Feuers auf die Ressourcen hilfreich. Dazu können zusammenfassende Darstellungen herangezogen werden (LOTAN et al. 1981, LYON et al. 1978, MARTIN et al. 1979, SANDBERG et al. 1979, TIEDEMANN et al. 1979, WELLS et al. 1979). Der durch das Feuer verzehrte Anteil des Brennmaterials kann über den Feuchtigkeitsgehalt anhand von Gleichungen prognostiziert werden (SHEARER 1976, NORUM 1977, SANDBERG 1980, MARTIN 1981). Diese quantitativen Hilfsmittel sind bei der Erstellung des Brennplans äußerst nützlich. Die Genauigkeit der Brenn-Vorschrift und deren Ausführung erfordert jedoch Erfahrung. Insgesamt basieren viele Brennpläne im Wesentlichen auf Erfahrungen, die bei anderen Bränden unter ähnlichen Bedingungen gemacht wurden.

Bei der erfolgreichen Anwendung des kontrollierten Brennens tragen viele Faktoren bei, u.a. Topographie, Wetterbedingungen, Brennmaterial, Jahres- bzw. Tageszeit, Entwicklungsphase der Vegetation, Bodenbeschaffenheit und Anwendungsweise des Feuers. Im Gegensatz zur (Schad-) Waldbrandbekämpfung ist es beim verordneten Brennen möglich, alle diese Faktoren zu berücksichtigen oder gegebenenfalls zu modifizieren. Obwohl die

Topographie eines Gebietes unveränderlich ist, kann man die Auswirkungen eines Feuers durch die Anordnung der Brennflächen nach geographischen Gesichtspunkten optimieren. Deswegen ist es notwendig, daß der Feuerökologe bei Entscheidungen über die Abgrenzung und Bewirtschaftung von Flächen zu forstlichen, weide-, jagdwirtschaftlichen oder anderen Nutzungsarten beteiligt wird.

Das brennbare Material wird durch die Vegetation eines jeweiligen Standortes charakterisiert und kann vor dem Brennen auf verschiedene Weise, vor allem der Anordnung, manipuliert werden. Weiterhin sind bestimmte Anforderungen an den Zeitpunkt und die Wetterbedingungen zu stellen, da Jahres- und Tageszeit von charakteristischen klimatischen Verhältnissen geprägt werden, die einen bedeutenden Einfluß auf den Zustand der Vegetation und das Brennmaterial haben. Die Brenntechnik ist in der angelsächsischen und auch in der deutschen Literatur ausgiebig behandelt worden (MOBLEY et al. 1977, MARTIN & DELL 1978, GOLDAMMER 1978). Für die Entzündung kommen dabei verschiedene Methoden und Geräte unterschiedlicher Wirkungsweise in Betracht:

Die Brennfackel oder Feuerkanne (drip torch) ist aufgrund ihrer vielseitigen und einfachen Handhabung am weitesten verbreitet. Fackeln, die in der Hand gehalten werden (road flares, Warnleuchtkörper), entzünden Brennstoffe äußerst langsam, aber sind leicht und kompakt. Flammenwerfer (Rückenspritze) mit Propan oder Diesel sind geeignet, um das Brennmaterial über eine Entfernung von 6-8 m in Brand zu setzen. Nachteilig wirkt sich jedoch die kompliziertere Bauweise und der relativ hohe Kraftstoffverbrauch aus. Elektronische Zündungsmethoden, wie z.B. mit Sprengschnur und Benzin-Gel ermöglichen eine gleichzeitige Entzündung großer Flächen. Diese Methode ist jedoch mit mehreren Nachteilen verbunden: Erstens erfordert die Verdrahtung einen großen Zeitaufwand und zweitens muß das präparierte Gelände bewacht werden, um eine verfrühte Zündung zu vermeiden. Mit Kaliumpermanganat und Äthylenglycol gefüllte Hülsen, die in Australien zur großflächigen Entzündung mit Flugzeugen entwickelt worden sind, wurden inzwischen in den USA zum Einsatz von

Hub schraubern aus umkonstruiert. Außerdem gibt es die "helitorch", eine große, unter dem Hub schrauber hängende Brennfackel, dessen Anwendung sich vor allem in steilen oder großflächigen Lagen bewährt hat und zunehmend verbreitete Anwendung findet.

#### 4. Logistik

Der nächste Schritt im Planungsvorgang beinhaltet logistische Überlegungen zur Vorbereitung, Ausführung des Brennens und anfallenden Nachlöscharbeiten ("mop-up"). Hierin werden die notwendigen Arbeitskräfte, Ausrüstungsgegenstände und Versorgungsmaterial aufgeführt.

#### 5. Öffentlichkeitsarbeit und Genehmigungen

Heute werden zur Durchführung des kontrollierten Brennens eine Reihe von Mitteilungen und Genehmigungen benötigt. Sowohl private Grundbesitzer, als auch Körperschaften des öffentlichen Rechts müssen Genehmigungen einholen, um den gängigen Bestimmungen über Luftverschmutzung zu entsprechen. Hierbei sind vor allem die erwartete Rauchentwicklung und die Wetterbedingungen, die das Feuer verhalten wesentlich beeinflussen, von Bedeutung. Benachrichtigung der Öffentlichkeit über Rundfunk, Fernsehen oder Zeitungen, bietet dem Feuerökologen außerdem noch die Möglichkeit, die Gründe und Vorteile des kontrollierten Brennens zu publizieren. In der Regel werden zudem noch zuständige Polizei- und Feuerwehrstationen benachrichtigt, um Anrufe von der Bevölkerung entgegenzunehmen.

#### 6. Auswertung und Bericht

Die Beschreibung und Auswertung des Brandgeschehens sind wichtige, aber oftmals übergangene Bestandteile des kontrollierten Brennens. In letzter Zeit wurde dieser Schritt in den Planungsprozess eingegliedert und ermöglicht einen "Feedback", um eventuelle Mißstände zu beseitigen und die Wirksamkeit zu verbessern. Die Beschreibung sollte u.a. die allgemeinen Bedingungen während des Brandes, das Verhalten des Feuers und dessen Auswirkungen über mehrere Planungs-Perioden

hinweg beinhalten.

### Die Ausführung des Brennens

Ein erfolgreich durchgeföhrter Brand erfordert umsichtiges und vorsichtiges Vorgehen aller Beteiligten. Nachdem die im Brennplan vorgeschriebenen Bedingungen erfüllt worden sind und sich das Personal vollständig versammelt hat, müssen die neuesten Wettervorhersagen ausgewertet werden, da ein unvermuteter Wetterumschwung sich verheerend auswirken kann. Beobachter in Feuerwachtürmen sollten informiert werden, um sofort über Veränderungen berichten zu können. Das Personal sollte über Zielsetzung, Inhalt des Brennplans und ihr Verhalten bei außergewöhnlichen Situationen informiert werden. Schließlich sollte ein Testfeuer entzündet werden, gewöhnlich in einer Ecke der zu behandelnden Fläche und mit repräsentativem Brennmaterial. Das Verhalten dieses Testfeuers ermöglicht es dem Verantwortlichen, eine Entscheidung über die Gewährleistung der Zielsetzung zu fällen.

### Anwendungsbereiche des kontrollierten Brennens

Feuer wird im Westen der Vereinigten Staaten prinzipiell als Bewirtschaftungsmaßnahme anerkannt. Die Anwendungsbereiche sind bei verschiedenen Nutzungsarten bereits festgelegt, in anderen Fällen jedoch nur experimenteller Natur oder erst im Stadium der Vorbereitung.

### Standortvorbereitung

Die häufigste Nutzungsmaßnahme des kontrollierten Brennens im Westen der USA dient der Bodenvorbereitung. Hunderttausende Hektar abgeholtzer Waldflächen werden als Vorbereitung zur Aufforstung abgebrannt (MARTIN et al. 1975). Allgemein wird diese

Methode hauptsächlich nur auf Kahlschlägen, aber auch vereinzelt im Schirmschlag-, Überhälter- und Plenterbetrieb eingesetzt. Weiterhin besteht die Möglichkeit der Reduzierung von Brennmaterial, der Verminderung der Konkurrenz durch Sträucher oder unerwünschter Baumarten und der Freilegung des Mineralbodens. Bei der Aufforstung mit Feuer behandelten Flächen verbessern sich die Arbeitsbedingungen sowohl bei manuellen als auch bei maschinellen Pflanzenmethoden erheblich (MARTIN 1977).

Generell wird ein Feuer mit hoher Intensität bevorzugt, um Rauch mittels Konvektionsströmung rasch in großen Höhen abzuführen. Demzufolge werden, abhängig von Lage, Wind und anderen Faktoren Streifen-Lauffeuer oder Ringfeuer eingesetzt. Falls Schutz des Mineralbodens notwendig ist, muß ein Großteil der Humusschicht nach dem Brand erhalten bleiben. Dieser Bedingung kann man dadurch nachkommen, indem man im Brennplan festlegt, nur unter Bedingungen mit hoher Bodenfeuchte zu brennen (SHEARER 1976, NORUM 1977, SANDBERG 1980).

Eine neuartige Methode der Bodenvorbereitung vor dem Einschlag wird in Gebieten erprobt, in denen Konkurrenz durch Straucharten eine erfolgreiche Aufforstung verhindert (MARTIN 1982b). Diese Anwendungsweise basiert auf der Tatsache, daß die Straucharten im dichten Baumbestand oftmals schwach und gestreift sind. Ein Bodenfeuer vor dem Einschlag tötet viele Sträucher ab, die sich in lichten Beständen durch Stockausschläge vermehren würden. Zudem wird die Anzahl keimfähiger Samen in Streu- und Humusschicht reduziert. Es scheint, daß zwei Feuer notwendig sind um die Konkurrenzfähigkeit der Sträucher nachhaltig zu beeinträchtigen, zumal das erste Feuer unter gemäßigten Brennverhältnissen hauptsächlich der Reduzierung des Brennmaterials dient. Der zweite Brenndurchgang wird durchgeführt, wenn die Streu- bzw. Humusschicht relativ trocken ist, um dem Wurzelstock der Sträucher größere Hitze zuzuführen und mehr Samen zu vernichten. Vorversuche in Oregon waren vielversprechend, aber weitere Untersuchungen sind notwendig, um die Zweckmäßigkeit dieser Methode zu dokumentieren.

### Verminderung der Schadfeuergefahr

Jeder Einsatz des kontrollierten Brennens vermindert, zumindest vorübergehend, die Brandgefahr (MARTIN et al. 1979). Da das Vorkommen von Bränden auf unseren Forst- und Weideflächen aus wirtschaftlichen und klimatischen Gründen nicht zu verhindern ist, kann durch die Verringerung brennbaren Materials die Entzündung und Ausbreitung eines Schadfeuers effektiv reduziert werden. Die Anhäufung des Brennmaterials ist ein natürlicher Prozess, der jedoch durch menschliche Eingriffe nachhaltig beeinflußt werden kann. Leicht entzündbares, abgestorbenes Holz auf der Bodendecke, Kräuter, Sträucher sowie niedere Baumkronen ermöglichen das Entstehen von bestandsvernichtenden Waldbränden. Diese Verhältnisse werden zudem durch Schlagraum von Durchforstungen oder Hieben zuerst als "red slash" mit leicht entzündbaren Nadeln und später als weniger entzündbarem, aber dennoch gefährlichen "gray slash" geschaffen. Aus diesem Grunde wird das kontrollierte Brennen verstärkt zur Reduzierung natürlicher und anthropogener Anhäufungen von Brennmaterial eingesetzt.

Die beste Anwendungsmöglichkeit besteht in Beständen der Ponderosa-Kiefer, die durch ihre Feuerfrequenz und -resistenz optimal an Bodenfeuer angepaßt sind. Im allgemeinen werden Bestände mit einem Stammdurchmesser von 7,6 cm (BHD) und größer behandelt, doch kann das kontrollierte Brennen auch in jüngeren Beständen mit mäßigen Baumschäden erfolgreich durchgeführt werden. Weiterhin werden auch junge Bestände mit Lärchen, Douglasien oder resistenten Kiefern durch Bodenfeuer behandelt. Die Anwendung von Feuer ist jedoch beim Vorhandensein von feuerempfindlichen Baumarten, wie z.B. Tannen, Fichten und Kiefern mit dünner Borke, dringend abzuraten. Bei dieser Anwendungsweise werden im Brennplan Feuer mit geringer bis mäßiger Intensität festgelegt. Oft ist es ausreichend, nur das Brennmaterial bis zu einem Durchmesser von 2,5 cm (Zeitverzugsklasse 1-10 Stunden) zu beseitigen, um extreme Temperaturrentwicklung innerhalb des Bestands zu vermeiden.

Niedrige Lufttemperaturen und mäßige Winde sind zum Schutze junger Bestände absolut notwendig. Einige Monate nach dem Einschlag, wenn sich die Nadeln im Schlagraum rot färben, ist der Brennstoffkomplex in vielen Fällen zu entzündlich, um eine erfolgreiche Durchführung des "kontrollierten" Brennens zu gewährleisten. In diesem Fall muß die Behandlung auf mindestens zwei Jahre hinaus verschoben werden, bis der Schlagraum verdichtet werden kann oder die Nadeln abfallen. Während dieser Zeit sind der gelichtete Bestand sowie angrenzende Wald- oder Weideflächen extrem schadfeuergefährdet. Versuche von GOLDAMMER (1983) in subtropischen Kiefernaufforstungen Südamerikas haben allerdings gezeigt, daß bei Beachtung bestimmter Feuchtigkeitsverhältnisse die hochentzündlichen Nadeln ("flash fuels") aus den Durchforstungsabfällen ohne eine Gefährdung für den stehenden Bestand herausgebrannt werden können.

#### Beeinflussung der Konkurrenz

Der auf die Zielbestockung wirkende Konkurrenzdruck durch die Begleitvegetation kann in verschiedenen Phasen des Bestandeswachstums beeinflußt werden (BARRETT 1973, 1982; OLIVER 1979). Die Untersuchungen von BARRETT zeigen, daß der Zuwachs der Ponderosa-Kiefer bei einem mittleren Baumabstand von 8 m etwa doppelt so groß ist, wenn die aus Ceanothus velutinus, Arctostaphylos patula und Purshia tridentata bestehende Buschvegetation unterdrückt wird, als dies bei ungehinderter Konkurrenz der Fall ist. Bei einem mittleren Baumabstand von 5,7 m betrug dieser Zuwachsvorsprung immer noch das 1,6-fache. Auch wenn diese Untersuchungen mit mechanischen und chemischen Behandlungsmaßnahmen durchgeführt wurden, sollten die Ergebnisse auch auf das Feuer übertragbar sein. Feuer könnte dabei entweder eine noch stärkere Auswirkung haben, da die Nährelemente besser verfügbar gemacht werden, oder auch geringere, wenn der Gesamt-Stickstoffvorrat reduziert wird oder Wurzeln, Stamm oder Krone beschädigt werden.

Ein Teil der unerwünschten Vegetation kann durchaus die gleiche Art sein, wobei das Feuer dann zur Läuterung eingesetzt würde. Es ist zwar nicht zu erwarten, daß eine Feuer-Läuterung oder -Durchforstung den gewünschten Standraum bewirkt, immerhin lassen sich aber dadurch die Kosten eines derartigen waldbaulichen Eingriffes senken.

#### Beschleunigung der Astreinigung

Die heutzutage angewendeten weiten Pflanzabstände beschleunigen zwar das Wachstum, sie haben aber auch die Bildung starker Äste zur Folge. Kontrolliertes Feuer würde diese Äste zwar nicht verbrennen, kann sie aber frühzeitig, wenn der Baum noch jung ist, abtöten, so daß dann schneller und mehr astfreies Holz gebildet wird.

#### Artenzusammensetzung

Auf Standorten, auf denen die Zielbestockung aus feuerresistenten Baumarten besteht, kann das Feuer diese fördern und dabei gleichzeitig die konkurrierenden Baumarten eliminieren. Das kann aus verschiedenen Gründen wünschenswert sein, wie z.B. aus standortsspezifischen, ästhetischen oder anderen Gründen des Forstschutzes (Insekten-, Schadfeuer-Gefahr). Es kann aber auch bedeuten, daß es möglich ist, in einem ungleichaltrigen Bestand eine lichtbedürftige und feuerresistente Baumart zu erhalten, die normalerweise die Rolle einer Schattbaumart übernehmen würde.

#### Weideland

Feuer hat die Tendenz, die ökologische Sukzession von Buschformationen zurück in das Gras-Kraut-Stadium zu versetzen, wobei das verfügbare Äsungsangebot für Vieh auf eine Dauer von mehreren Jahren vervielfacht werden kann. Wo Weideland durch

übermäßige Nutzung beeinträchtigt worden ist, sollte es direkt nach dem Brennen frisch eingesät und so lange von Vieh freigehalten werden, bis es in der Lage ist, den erneuten Beweidungsdruck zu verkraften. In vielen Gegenden schlagen die heimischen Grasarten, die durch Sträucher unterdrückt wurden, nach Feuer und ohne weitere Behandlung wieder aus. In baumbestandenem Weideland, das einen wichtigen Bestandteil der insgesamt verfügbaren Fläche ausmachen kann, kann kontrolliertes Brennen das Futterangebot wesentlich erhöhen, sei es durch Wurzelausschlag oder vorhandene Samen oder zusätzlich eingebrachtes Saatgut (HALL 1976). Bei Aussaat muß allerdings beachtet werden, daß eventuell neu eingeführte Arten nicht zu einem Hindernis für eine spätere Naturverjüngung des Bestandes sind. Die in der entsprechenden Bestandesphase durchgeführte Waldweide kann wiederum erheblich zur Verminderung konkurrierender Vegetation und damit zur Wachstumsverbesserung beitragen.

#### Habitate von Wildtierarten

Die Feueranwendung im Westen der Vereinigten Staaten dient zum größten Teil zur Verbesserung von Wildhabitaten, auch wenn dies in der Küstenebene des Südostens bereits sehr viel weiter entwickelt worden ist. Auftreten oder Anwendung von Feuer ändert die Struktur eines Ökosystems, wobei, allgemein ausgedrückt, die Habitatvoraussetzungen für die einen Arten verbessert und für andere verschlechtert werden. Bei sorgfältiger Einbeziehung wildbiologischer Aspekte sollte für das Wild insgesamt ein Nutzen erreichbar sein. Für viele Fälle bedarf es aber noch weiterer Kenntnisse und Informationen, um die Auswirkungen des Feuers auf die nicht jagdbaren Wildarten bewerten zu können. Die Zusammenhänge zwischen den Auswirkungen des Feuers auf Wildtierarten und die Konsequenzen auf die Bestandesverjüngung dürfen von den Forstleuten dabei nicht übersehen werden.

Monokulturwirtschaft hat oft eine Verminderung des Artenspektrums

von Wildarten zur Folge, mosaikartige Struktur der Vegetation hingegen bewirkt Randstufen ("edges") und erhöht Anzahl und Diversität der Arten (THOMAS 1978). Untersuchungen haben beispielsweise gezeigt, daß kontrolliertes Brennen eine Anzahl von Vogelarten fördern (TIAGWAD et al. 1982) und Kleinsäugerpopulationen (FRENZEL et al. 1979) und Jagdwildarten (LYON et al. 1978) beeinflussen kann. Wichtig ist vor allem eine klare Zielsetzung und Brennvorschrift, um ein gefordertes Vegetationsmosaik zu erhalten. Hierbei kann auch die Wirkungsrichtung des Feuers mit einbezogen werden, den Samenfall oder das Ausschlagen von Verbißpflanzen von Schalenwild zu verbessern (MARTIN and DRIVER 1983).

#### Insekten und Pilzkrankheiten

Die Wechselbeziehungen zwischen Insekten- Pilzkrankheiten- Feuer können einen der interessantesten Aspekte der Ökosystemforschung sein. Entsprechende Grundlagenforschung wird derzeit betrieben, wobei bislang lediglich die direkten Auswirkungen der drei Parameter auf die jeweiligen anderen beiden bekannt sind. Mehrere Hypothesen wurden bereits aufgeworfen, ohne daß sie näher untersucht oder bestätigt werden konnten (MARTIN et al. 1976, PARAMETER 1977, GEISZLER et al. 1980, MITCHELL and MARTIN 1980, MARTIN and MITCHELL 1980). Einige Untersuchungen haben sich mit den Auswirkungen des Feuers auf Insekten und andere Krankheiten befaßt. Im Südosten haben FROELICH und DELL (1967) und FROELICH et al. (1978) die Möglichkeiten untersucht, mit Hilfe von Feuer die durch Fomes annosus verursachte Wurzelfäule in Kiefern zu bekämpfen und konnten dabei einen leichten Rückgang der Befallserscheinungen nach dem Brennen feststellen. REAVES et al. (1983) haben die Beeinträchtigung des Wachstumes und der Rhizomorphen von Armillaria mellea unter Laborbedingungen aufgezeigt.

Die Erforschung dieser Wechselwirkungen genießt hohe Priorität, wobei die konventionellen Bekämpfungsmethoden nicht vergessen

werden sollten. Sollten die direkten Auswirkungen des Feuers nicht erfolgversprechend sein, müssen die indirekten Einflüsse mit in Betracht gezogen werden, die eine Ökosystemveränderung zur Folge haben, auf die ein Organismus sensibel reagiert.

### Wasser

Kontrolliertes Brennen zur Erhöhung der (Trink-)Wassergewinnung wird selten angewendet, obwohl es prinzipiell möglich ist (HIBBERT 1983, LEAF 1975), besonders dort, wo der jährliche Niederschlag 400 mm übersteigt. Zwingende Gründe, wie Hangstabilität oder Erosion, können das Ausmaß der Feueranwendung zur Erhöhung der Wassererträge begrenzen. Untersuchungen über die unterschiedlichen Auswirkungen des Feuers auf Wasserertrag und -qualität sind für die meisten Ökosysteme nicht bekannt und Mittel für langfristige Untersuchungen auch nicht vorhanden.

### Erholungswirksamkeit und Landschaftsbild

Feuer wird in der Regel als nachteilig für Erholung und ästhetischen Eindruck der Landschaft beurteilt, wobei sicherlich in der Regel nur an die kurzfristige Wirkung bestimmter Brände gedacht wird. Das Brennen in Waldbeständen ist sicherlich dazu geeignet, die Sicherheit und Begehbarkeit durch die Verminderung von insektenbefallenen und totem Holz und auch hinderlichem Unterstand zu verbessern und die Luftzirkulation zu erhöhen. Landschafts- und Waldbilder können zu einer parkartigen Form zurückverwandelt werden, wie sie sich den frühen Siedlern und Waldbesuchern dargestellt haben. Hierzu wird das Feuer, häufig auch durch manuelle Arbeiten ergänzt, in den Mammutbaumwäldern (Sequoiadendron giganteum) der Sierra Nevada oder auch in den Ponderosa-Kiefernwäldern im Crater Lake National Park eingesetzt. In diesem Zusammenhang wird das Feuer auch im Sinne einer Wiederherstellung des "natürlichen" oder "historischen" Zustandes von Naturparks eingesetzt.

SUMMARY

Prescribed fire is being used more and for a wider variety of uses than ever before in Western United States. As more is learned about the ecology of fire and fire manipulation, we should see more use of fire even though constraints, particularly from smoke production are tightened.

Fire can be used in many aspects of timber, fuel, wildlife, insect, disease, range, water, and recreation management. The extent of fire use, and its effectiveness, will depend on the ingenuity and skill of both the researcher and manager.

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## RECENT DROUGHTS AND FOREST FIRES

Ricardo Vélez Muñoz, Spain

### 1. Introduction

Ecological studies on the forest fire, when moved by bodies in charge of fire fighting, undoubtedly have a purpose going beyond the study itself. The idea, of course, is to get to know the phenomenon of wildfires better, how they occur, how they develop and what effects they have. Nevertheless, the aim of this knowledge is to lay the foundations for fire prevention policies and techniques or for limiting damage occurring when fires break out.

For some years now, we European foresters find ourselves with the doctrinal trends arriving from North America which do not just advocate the simple prevention of fire but the management thereof. Fire is a dynamic balancing factor conditioning wildland vegetation, its forms and associations. Fire must therefore be controlled, sometimes suppressing it and others prescribing it in order to obtain the type of vegetation required. There should also exist a forestry and reforestation policy, one of whose bases is the recognition that fire may exist in wildland for bad and, at times, for good.

It is curious to listen to the comments at specialist meetings of veteran foresters when they are presented with the possibility of prescribed fire, on occasions followed by goat grazing, which are ideas running against those they have maintained and defended almost axiomatically for many decades.

The truth is that forest fires constitute such a frequent phenomenon in Mediterranean countries since far remote times that they are now one further element in the configuration of the ecosystems of south European countries and fire must be inexorably considered in a forest conservation policy.

It is naive to believe that a forest, whether natural or artificial, is going to remain the same for ever by simply preventing any human intervention.

Static equilibrium does not exist in ecosystems. On the contrary, there exist permanent processes of evolution and succession, at times slow and gradual, at others accelerated and irregular. It is difficult for models endeavouring to reproduce the course of change processes to accurately predict the system's situation at a future time. It is highly likely that the process will not be linear, that it will jump, that it will seem to be governed by chance rather than logic. Nevertheless, there are observations which are repeated. Ecosystems have a biological inertia to change and can resist strong environmental actions without intense alterations. Sometimes they even need time for the process to be maintained. For instance, conifer forests remain productive on the long term only if once a century fire frees the nutrients that have been accumulating on the forest floor or if man introduces a system of logging and destroying slash which has the same effect.

This capacity for taking in actions of change and bringing them into the ecosystem's evolution process is naturally limited. If the frequency of these actions or their intensity are excessive, the change may be an irreversible leap leading to another ecosystem model. Repeated fire transforms the forest into brushland and the latter into grassland. Evolution models, however, provide for a slow reconstruction of the original system. It is the theory of climax successions, from the rock to the hardwood stand. Unfortunately, irreversibility would seem to occur at times, as in desertification processes, where the meteorological component may prevent unwise changes or changes not thought out by man from being rescued by Nature's own vigour.

In fact, at the present time we are faced with situations where the danger of irreversibility is very high. Large, frequent forest fires linked with irregularity of precipitations may

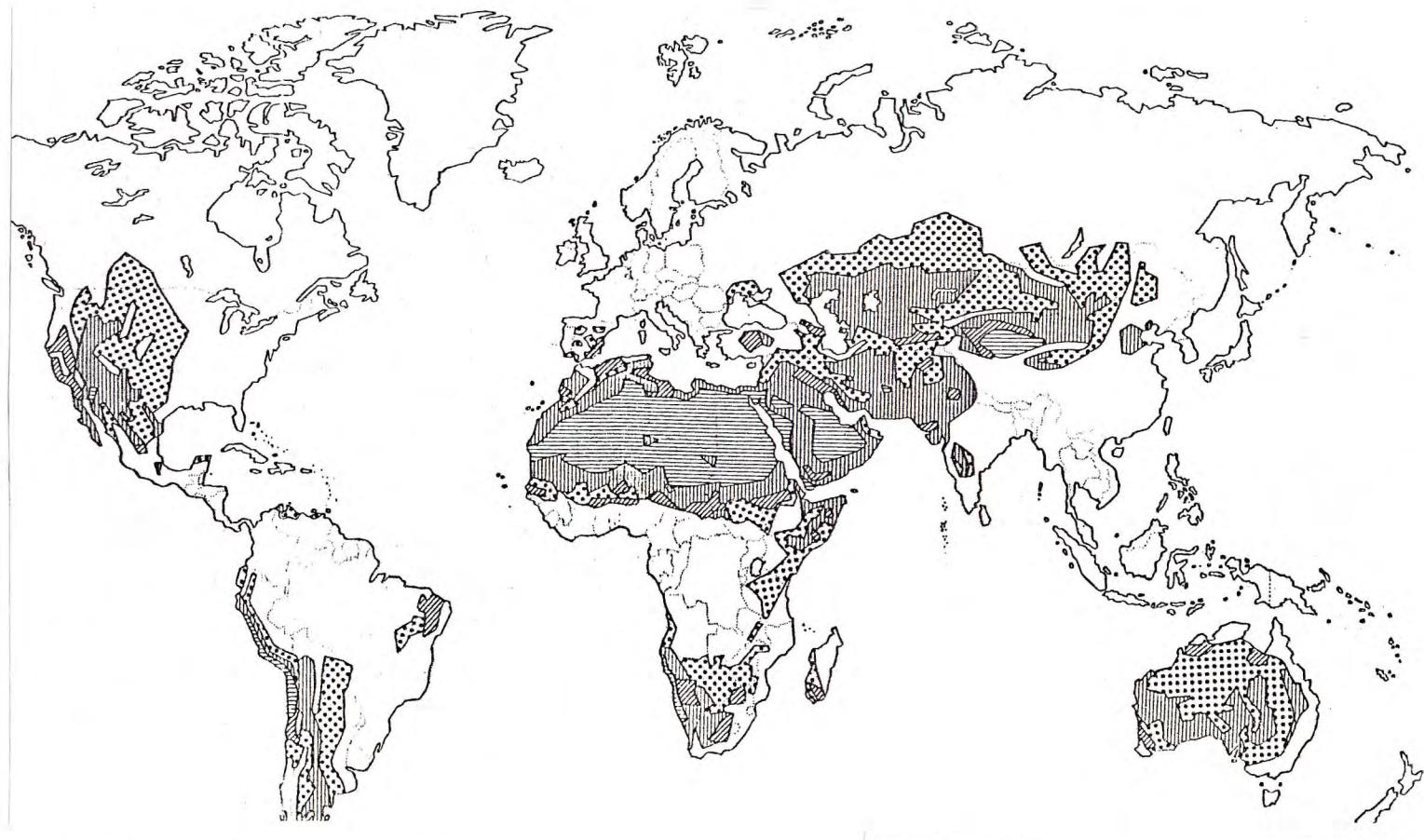
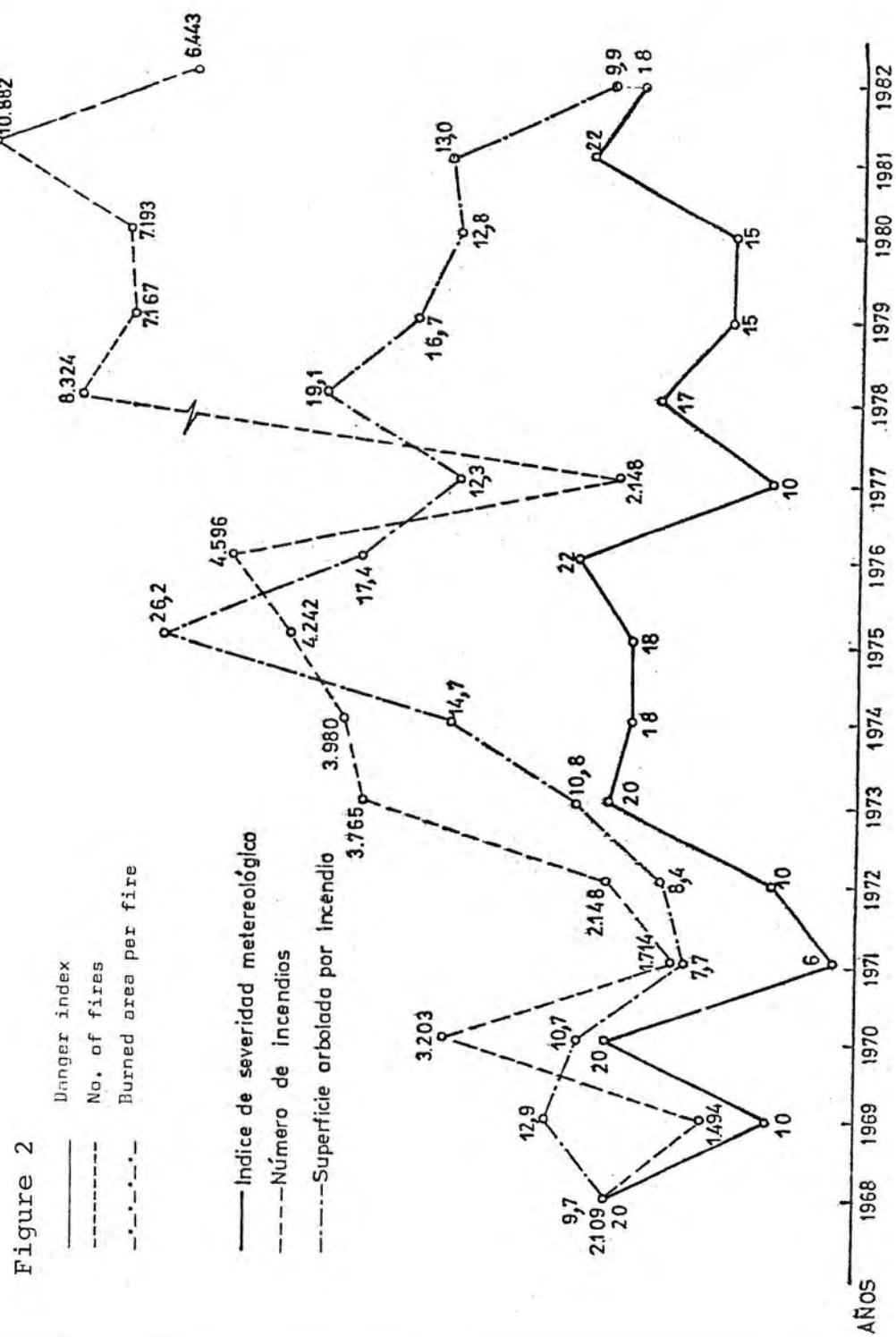
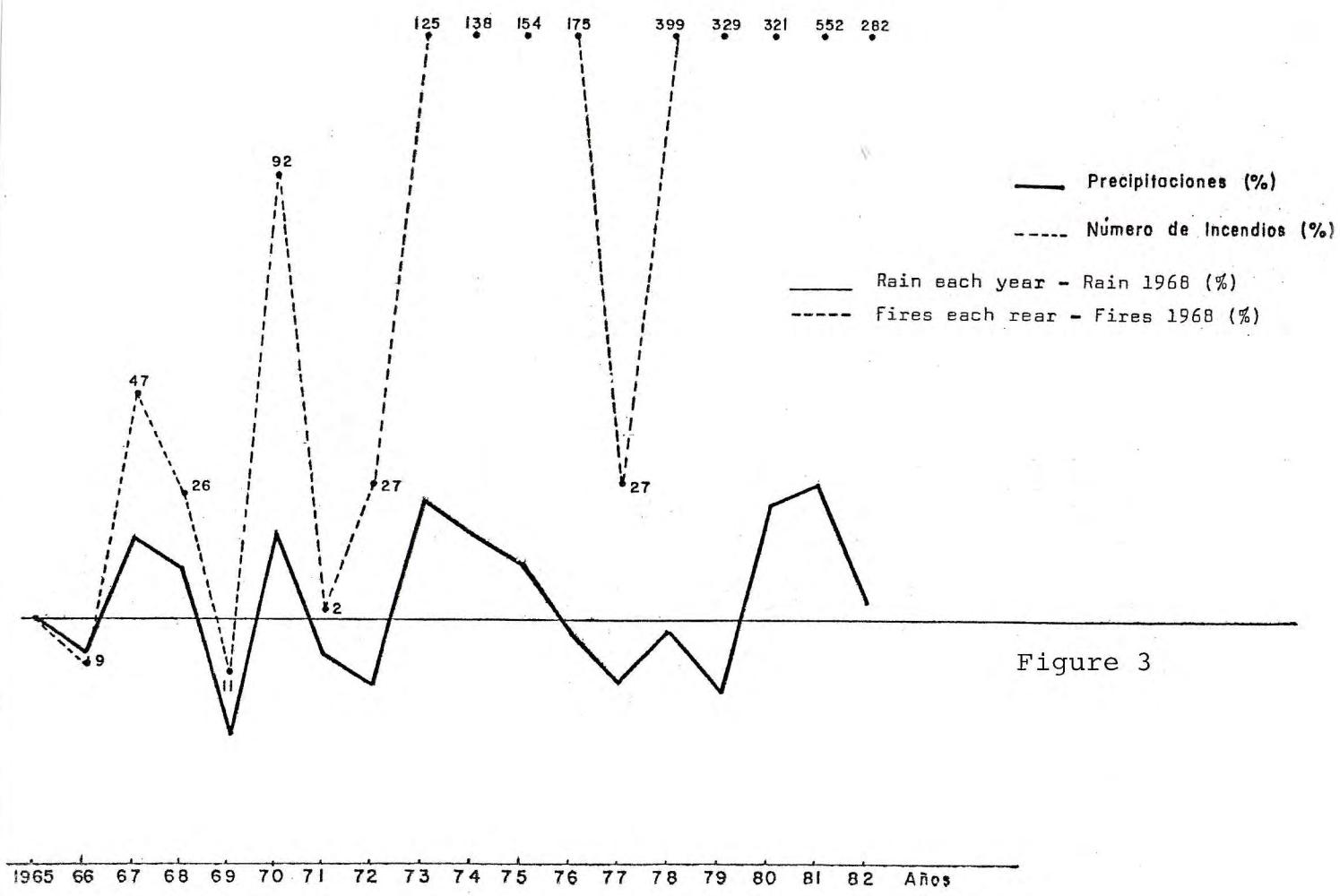


Fig.1: Desertification risk (PNUMA)

- Very high
  - High
  - Moderate
- Deserts





aggravate the risk of desertification, at least locally (Fig. 1).

## 2. Drought in Spain

Man is the agent unleashing 95% of fires either in economic activities (for example, shepherds and farmers who use it to clear the ground) or in recreational activities (hikers and wildland visitors) or in warlike activities (manoeuvres and even wars themselves). However, these activities have to be undertaken in a meteorological environment favouring the fire's development.

One of the current lines of research on fire ecology in Spain refers, in fact, to the correlation between the weather and the starting, spread and effects of fires.

Over the last few years in Spain, a meteorological situation has occurred noticeably influencing all human activity. This is a prolonged drought, apparently more persistent than at other times.

To analyse the influence of drought on forest fire phenomena a start can be made on the diagnosis (VELEZ 1981) made on the situation in the Mediterranean basin, applying the system of fire danger determining used in Spain (VELEZ 1982) with a macroscopic perspective. The system leads to a High to Very High basic danger index calculated from a High to Very High Flammability of the forest fuels, a High to Serious Causality and a growing fire risk or frequency. The fire weather danger rating is High to Extreme for 60 to 120 days a year. The composition of the Basic and weather ratings give a resulting High effective Danger of a permanent nature aggravated during 120 days a year.

The last few years' figures (ICONA 1983) reveal that in fact the number of fires and average area per fire tend to be on the increase (Fig. 2), and that large fires are becoming a more and

more frequent threat (Table 1).

In the light of this diagnosis, to what extent is drought an important or decisive component in forest fire phenomena?

It is estimated that drought exists (GARCIA DE PEDRAZA 1983) when the rainfall collected is less than 60% of the monthly normal or 75% of the annual normal in a region. The problem is aggravated, as the same author states, when the scarcity of rainfall is joined by its untimeless, because it does not rain when it is required to spread over large areas and persist for many months. Figure 3 represents the deviations of atmospheric precipitations since 1965 for the whole of Spain (PEINADO 1983) in percentages compared to the average for the period from 1947-1979.

Two prolonged dry periods appear therein, from 1973 to 1975 and from 1980 to 1982.

The deviations in the number of fires in percentages compared to 1965, the precipitations in which were the same as the average for the period mentioned, are shown in the same figure. A certain parallelism can be observed between both curves. It can be seen particularly that the periods of prolonged drought coincide with high upward jumps in the number of fires. However, the drought curve shows fluctuations not appearing in the number of fires curve, the growing trend of which is clearly and highly accelerated.

In addition, anomalies appear, like that in 1976, 1978 and 1979 which were wet, overall, yet the number of fires strongly increased.

The explanation for these discrepancies must be sought, on the one hand, in the untimeliness of the rains and, on the other, in human action which, for reasons not fully explained, has "shot up" over the last few years.

As important as the intensity of precipitations is their

distribution in time and space. That is why it is necessary to find out how each year's dry periods have come about.

Dry, prolonged summers create suitable conditions of humidity in the vegetation for a small amount of heat to be the origin of large conflagration.

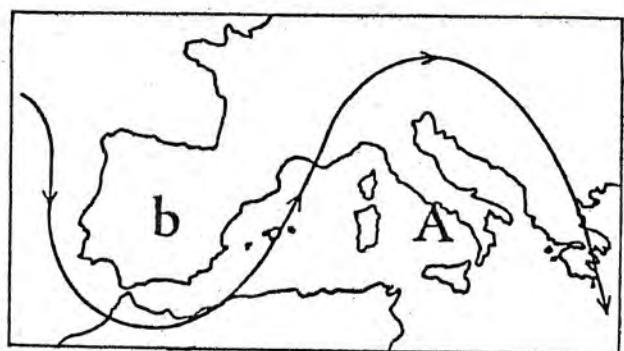
However, summers are not always the same from one year to the next; neither are their characteristics even over the whole Mediterranean basin. According to GARCIA PEDRAZA (1980), the eastern Mediterranean's weather is generally at odds with the Iberian Peninsula's (Fig. 4).

During the two year period 1976-1977, summer brought stormy weather and squalls to Mediterranean Spain and the south of France whilst the drought was intense and long in Italy and Greece.

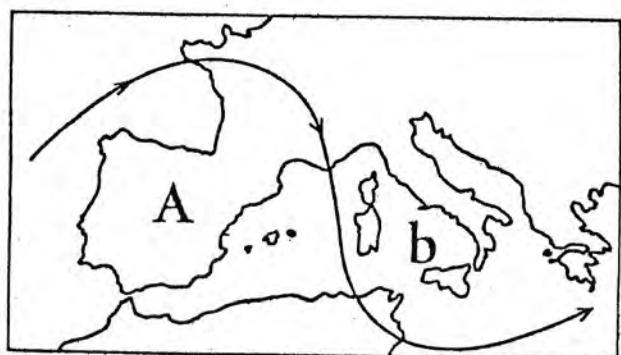
On the contrary, in 1978 and 1979, the dry weather commenced very early in the western Mediterranean, with storms appearing in Italy and Greece. That is to say, whilst high pressure established itself over the Iberian Peninsula, to the east of the Mediterranean, the weather's instability relieved the drought.

On the other hand, in the three year period from 1980 to 1982, conditions have been abnormal and a much more homogeneous weather state has occurred over the whole of the northern Mediterranean. Low pressures followed the parallels, eluding the European peninsulas and giving rise to extraordinarily prolonged dry periods during which fire danger conditions grew to limits never before recorded.

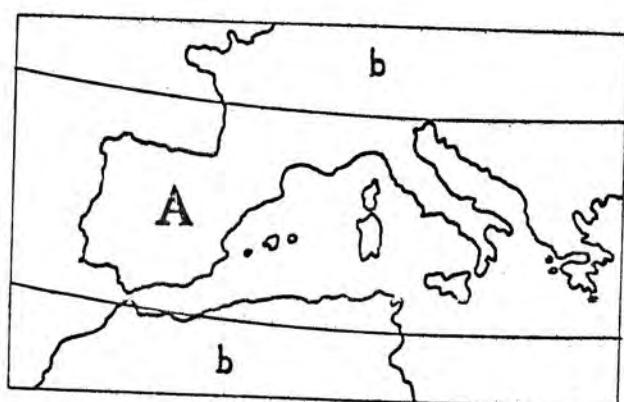
With reference to Spain, in 1980, the danger season, coinciding with the dry period, began in Andalusia in June. It then became general over the whole country, except the north, where the month of July was relatively wet and cool. August turned out to be typically dry, and very hot, and extended intensely and unusually



1976 - 1977



1978 - 1979



1980 - 1982

Figure 4

into September and October. There was a high windstorm in the latter month around the 12th, which heightened the danger extraordinarily over the whole Mediterranean area.

Autumn was fairly dry, just like winter of 1981, which also heightened the danger, particularly in Galicia and Cantabria where the south wind blew on many days.

The months of April and May, 1981 were, however, very rainy and relieved the situation. Nevertheless, an intense heatwave occurred from June 6 to 22, more accentuated in Extremadura, the Central Region and Andalusia but also reaching the Douro, Galicia and Cantabria. Danger was specially intense in Andalusia and Extremadura where the thermometer reached 43°C.

It cooled at the beginning of July but the heat and drought returned with the dry weather extending up to November and the danger season persisting until that month. November 1981 was the driest of the century with an almost total absence of precipitations. Before the rains came in December, there were high gales in Catalonia, creating a situation of extreme danger.

1982 was more irregular. Winter and spring continued dry. The March-April dryness in Galicia and Cantabria was particularly noted, producing an intense danger season in those areas. The beginning of summer was wet in these regions, however, whilst an intense heatwave castigated Catalonia, the Ebro basin and Central Region, reaching 43°C in Logrono and Lérida. Danger was therefore extremely high in those regions during the first half of July, but dropped later on. In Galicia, the hot weather returned in the middle of August and a further danger season commenced until the end of September when the storms came.

The intense downpours in Valencia and Catalonia in October ended the drought and the ground's water deficit. Danger also was over.

Even though dry weather is fundamental for fires to start, wind

is the decisive factor for them to spread. The summer land breezes of the "foehn" type have a high speed and drying strength. These are the "Tramontana" of Catalonia, the "Poniente" of Valencia and the "Levante" of the Straights. They all make the atmospheric humidity drop below 30 percent and, in addition, contribute towards propagating fires, moving firebrands over long distances. In Spain there is another dangerous wind also, that which blows from the south at the end of winter in the Bay of Biscay and causes numerous fires at a quiet time for the actual Mediterranean basin itself.

Over the three year period from 1980 to 1982, the wind likewise aggravated the danger at certain times.

In 1980, the windstorm in the Mediterranean in the middle of October favoured the advent of over 700 fires in one week, which covered more than 7.000 ha in Catalonia and Valencia, causing five deaths. The south wind storm in Asturias in April had likewise caused high losses.

In 1981, the south wind was also an occasion of danger in Asturias in February and March. In December, the extremely high gales preceding the rains spread fires over extensive areas.

On the other hand, 1982 was not particularly a windy year. Only in the second week in July was there a hot south wind in Catalonia and the south of France, causing a fearful wave of fires. Likewise, in the middle of August, a gust of wind in the Sierra de la Almijara (Granada) caused a fire to advance 3 kms. in one hour, turning it into the major forest disaster of the year.

### 3. Forest fires in Spain during the period from 1980 to 1982

A summary of the foregoing four year period is included as a background to the period under consideration.

In 1976 few fires occurred in Mediterranean Spain. If the national total was high, this was due to fires in Galicia, favoured by the extreme drought that affected the Atlantic region and also parched central Europe. The number of fires in France increased for this same reason and forest fires had to be fought even in Germany. On the other hand, the number remained stationary in the French Mediterranean departments.

The following year, the number of fires in Spain and France dropped considerably because of the rainy summer but, on the other hand, they rose enormously in Italy and Greece because of the prolonged drought. A large fire on the island of Evvia occurred in Greece, affecting over 11.000 hectares of pine stands and crossing the island from side to side.

The situation was reversed in 1978. The total number of fires doubled in Spain and tripled in France for the Mediterranean departments. The high number was maintained in Italy due to the high fire incidence of the island of Cerdina located more to the west. The number descended in Greece thanks to the relatively wet summer.

Very high figures were reached again in Spain and the south of France in 1979, whilst the danger index dropped in the east of the Mediterranean.

The data for the three year period from 1980 to 1982 appear in Table 2.

### 3.1 1980

There were 7.193 fires during this year, practically the same figure as in 1979, which devastated 265.954 ha in all. This is an area slightly less than that affected the previous year.

By regions, the fire incidence occurred as follows:

Region	Number of fires			Forested surface (ha)			Non forested surface (ha)		
	1980	1981	1982	1980	1981	1982	1980	1981	1982
Galicia.....	1.974	5.086	2.394	10.356	54.620	16.212	14.258	62.818	20.053
Cantábrico....	965	1.052	803	13.178	13.072	12.174	9.729	12.546	8.865
Ebro.....	271	363	195	6.848	3.709	2.875	5.361	7.915	2.592
Nordeste.....	813	794	632	17.853	16.736	11.375	8.851	5.219	7.068
Duero.....	1.120	1.143	929	8.265	8.172	5.743	43.668	22.010	20.865
Centro.....	383	548	263	3.670	8.547	2.007	10.318	5.795	6.811
Levante.....	468	734	395	13.165	12.705	5.827	15.236	19.264	8.185
Extremadura...	326	301	158	7.251	6.873	1.068	27.883	6.421	1.952
Andalucía.....	837	778	629	10.684	14.007	6.542	37.233	13.768	11.323
Canarias.....	36	83	45	1.232	3.226	36	914	1.013	47
Total.....	7.193	10.882	6.443	92.503	141.666	63.879	173.451	156.769	78.804

Table 2: Forest fires in Spain in the period from 1980 to 1982.

- Galicia: The danger season was delayed until well into the summer which, together with the prevention measure adopted, enabled the damage to be reduced to less than one third of that which occurred the previous year.
- Cantabria: The dry March-April period caused by the south wind raised the danger index a lot in Asturias and Santander, with very high damage.
- Ebro: The dry weather even affected high mountain areas and large fires occurred in Huesca, like that of Aineto, Sabinanigo and Trillo (August 2 - 15) which affected 4.060 ha of pine stands.
- Northeast: With a fire incidence similar to 1979's, damage was greater because of the drought. The following can be quoted: several fires in Gerri de la Sal (Lerida) at the beginning of August affecting 1.400 ha of forest; the Roquetas and Mas de Barberans (Tarragona) fire at the end of August affecting 3.400 ha; the fires from October 6 to 12 with a strong gale spreading over 7.000 ha in Tarragona and over 6.000 ha in Barcelona.
- Douro: The number of fires grew considerably (30% more than in 1979) as a result of the longer duration of the danger season because of the drought and winds, especially in the Tietar and Alberche valleys in Avila where a fire of 2.100 ha occurred (July 28 to 29).
- Central Region: The insufficiency of the spring rains and a very dry July with temperatures higher than normal increased the danger and several strong fires occurred in the area of San Martin de Valdeiglesias (Madrid) at the end of July.
- Levante: Fires continued being frequent due to the drought, although they did not cause damage as serious as that in 1979. Nevertheless, there was a fire covering 6.079 ha in Requena -

Loriguilla (Valencia) from August 15 to 19. The October gales also favoured the spreading of numerous fires in Alicante and Castellon.

- Extremadura: The drought was intense over all areas, even the high mountains with the number of fires increasing by 50% and the area affected by fire doubling in comparison with 1979 .
- Andalusia: The pressing heat of July increased danger particularly in Seville, Cadiz and Cordoba. From July 13 to 16, a fire affected 3.845 ha in Aznalcollar (Seville). There were 12 fires affecting over 500 ha each in Cadiz.
- Canary Isles: The area affected by fire doubled in comparison with 1979.

### 3.2 1981

During this year, 10.882 fires occurred, the maximum up to now, covering 298.436 ha.

The fire incidence by regions was as follows:

- Galicia: The dry weather starting in June caused the danger season to begin two months earlier than usual, and the fire incidence and area affected grew enormously. Damage even reached the north of the region, where rainfall is a maximum in normal years, but with a fairly prolonged dry period this year. Completely out of character, 28 fires covering over 500 ha each occurred.
- Cantabria: With a very dry winter and a summer also extremely dry in Asturias, damage was again very high.
- Ebro: Due to the drought, the number of fires increased a lot,

although the damage descended with there not being particularly strong winds.

- Northeast: The fire incidence was influenced by the prolonged dry weather and the gales at the beginning and end of the year when the major fires occurred, i.e., outside the usual danger season. Tarragona and Barcelona were the provinces most affected. The fire ran through 7.659 ha from December 12 to 16 in Vandellós and Pratdip (Tarragona) driven by the wind.
- Douro: The drought gave rise to a similar fire incidence to the previous year's.
- Central Region: The number of fires continued to grow affecting areas which beforehand were unaffected, like the province of Cuenca where a fire occurred from August 7 to 13 running through 2.900 ha in Contreras.
- Levante: With the danger season extending much further than the normal, the number of fires increased alarmingly, although the damage remained at the previous year's level.
- Extremadura: The situation was similar to the previous year's, with danger during a time longer than the normal and high damage.
- Andalusia: As in the other regions, danger began in June, with the heatwave. The biggest fires occurred in Huelva where one covered 4.220 ha in Paterna del Campo, from June 13 to 17.
- Canary Isles: The number of fires tripled and the area affected doubled compared with 1980.

3.3 1982

There were 6.443 fires this year, with fire incidence dropping because of the danger season being shorter. The total area affected was 151.644 ha.

Fire incidence by regions occurred as follows:

- Galicia: Despite the high Spring fire incidence, the year's balance was more favourable due to summer being shorter.
- Cantabria: The dry spring season gave rise to numerous fires in Asturias with big losses.
- Ebro: Despite the drought, the number of fires dropped, although damage was similar to 1981's.
- Northeast: The most noteworthy were the Barcelona fires in the middle of July which coincided with a high heatwave. In one week, fire overran more than 10.000 ha of forests.
- Douro: The drought favoured fire incidence, although the measures taken enabled damage to be reduced.
- Central Region: The number of fires was reduced to half that recorded in 1981 despite the drought. Damage was also much less, in view of the lack of winds.
- Levante: The situation was similar to that of the other regions with a noticeable reduction in the number of fires and damage, despite the persistent drought and ground water deficit which dated from 1981.
- Extremadura: Damage was also less.
- Andalusia: The number of fires and losses descended. The La Almijara fire (Granada) in the month of August affecting 4.600

ha of which 3.870 were forest land is to be mentioned, however. The importance of this fire lies in the fact that it ran through parts of areas burned out in the big 1975 fire, destroying natural regeneration and creating a problem of desertification over an extensive area.

- Canary Isles: Losses were very small due to the weather aiding in the control of fires.

#### 4. Drought and fire effects

The immediate effect of fires is to destroy life in the terrain they overrun. The mediate effect is the acceleration of evolution processes in the vegetation and soil. A research project was commenced in Spain in 1979 on fire effects (VELEZ 1981 b) to which the analysis of the influence of drought thereon has been recently added. Some of the observations made in three areas strongly affected by fires are given hereafter.

##### 4.1 The big Ayora-Enguera fire (Valencia)

This broke out on July 17, 1979 at 8 a.m.. It was caused by a bolt of lightning and an extreme danger index was in force after two weeks without rain. Signs of incendiary fire which abnormally extended it were found.

It affected 22.796 ha of forest land covered with Pinus halepensis and 5.514 ha of brushland in the municipal districts of Ayora, Enguera, Teresa de Cofrentes, Jarafuel Bicorp, Quesa and Mogente. Timber losses were appraised at 621 million pesetas. It ended at 6 p.m. on July 21.

The area affected is located in a mixed stand of P.halepensis and Pinus pinaster covering about 60.000 ha. It is partly natural and partly reforestation. Some areas were planted in the 1920s and

others later on in the 1940s and thereafter. The area's rainfall is over 500 mm , with average summer temperatures between 22 and 24 ° C and average winter between 6 and 8°C. Its altitude varies between 700 and 900 metres.

One year after the fire, the regeneration of the trees was almost complete (90% of the area), both as regards P.halepensis and P.pinaster. The autumn following the fire had been fairly favourable, with frequent non-torrential rain, so that the seeds that had fallen from the pine cones opened by the fire were able to germinate with the arrival of Spring, rooted in well with the rain of that season and withstood the 1980 summer with a low mortality rate. In November, 1980, 20 cm tall pines were already being found together with others that had just germinated. The whole fire area had been affected by extensive burnt wood removal, since it was profitable on the market.

In October 1982, the situation of the pine trees which grew up after the fire continued to be good. In addition the brush had thickly regenerated, made up mainly of Quercus coccifera, Quercus ilex, Cistus albidus and Juniperus oxycedrus (RUIZ DEL CASTILLO 1982). That is to say that the vegetation had withstood the drought of the last few years, making full use of the scant rainfall there had been. The maps of water reserve in the ground have shown a deficit in this area for many months. On October 19 and 20, 1982, torrential rain fell over the area, at some points reaching over 500 mm in 48 hours (MIRÓ - GRANADA 1982). The effect of the rain was terrible downstream, causing enormous drainage in fields of crops and townships. Nevertheless, in the fire areas, the brush and regenerated pine stand held the soil efficiently, limiting washings by the torrents. However, the odd small fire had occurred in the area in the summer of 1982. The effect of the rain on the recently burned land was destructive, having bared the rock. Fortunately, these 1982 fires were very small and erosion damage was reduced.

#### 4.2 The la Almijara fire (Granada)

The first big fire in this area (VELEZ 1976) broke out on August 20, 1975 at 1 p.m., and was an incendiary fire. An extreme danger index was in force after 61 days since the last rainfall. It affected 11.762 ha of forest land with P.pinaster and 229 ha of brushland in the municipal districts of Jayena, Fornes, Arenas del Rey, Albunuelas, Lentegí and Otíver (Granada) and Nerja and Cómpeta (Málaga), all in the Sierra de la Almijara. Losses in timber and resins were assessed at 554 million pesetas. A strong wind blew during the first three days of the fire, reaching as much as 75 km/hour.

The area affected lies within a natural stand of P.pinaster unbrokenly covering about 40.000 ha of complicated topography on the watershed between the Atlantic and Mediterranean with heights of 800 to 1000 m.

The area's rainfall is less than 40 mm with average summer temperatures between 24 and 26°C and average winter between 10 and 12°C.

It is a very sparse wooded pine stand worked for its resin, with a very thick undergrowth of gorse (Ulex minor). In former times, apart from resin tapping, there was intense goat grazing. The disappearance of the goats and reduction in resin tapping due to the high costs of tapping and low resin prices led to the gradual abandoning of the forest and its invasion by brush. The importance of the vegetation in this area does not lie so much in its commercial use but in its ground protection effect. The area burned formed part of the basins of the Los Bermejales, Izbor and River Verde reservoirs.

One year after the fire, the pines were seen to be regenerating in some places, although in a small proportion; likewise the mainly prickly U.minor brush began to appear. Logging of the burnt wood was carried out over the whole area that first year.

Little work was done in the area in the following years, in view of the high costs of reforestation because of the rough terrain.

The continuous drought hindered the development of natural regeneration which, nevertheless, appeared over many places, particularly where fire insurance trees remained, not destroyed by the fire.

Unfortunately, in 1982 a fire broke out in the same area. It started at 12 noon on August 13 and was caused by brushland burning. The danger index was extreme after 39 days without rain and a wind of 36 km/hour. The fire affected 3.870 ha of P.halepensis and P.pinaster and 730 ha of brushland in the districts of Arenas del Rey, Fornes, Jayena and Alhama. The fire ended on August 17. A great part of this area had burned in the previous fire, so the natural regeneration was destroyed. The extremely intense drought over the area is increasing the risk of desertification, a process that will be stopped with great difficulty in view of the high costs of reforestation in this terrain.

In addition, the rains have shown their typical sense of the untimely. At the same time as in Valencia, there were torrential rains in Granada, although not so violent, during the autumn of 1982. The burnt areas, with steep slopes and no vegetation, underwent intense erosion. The water washings bared the mother rock, destroying accesses and lanes and cancelling out any possibility of the burnt pine stand regenerating naturally.

#### 4.3 The Las Hurdes and Sierra de Gata fires (Caceres)

1980 and 1981 were truly exceptional in the mountains located to the north of the province of Caceres. Numerous fires burst out in the pine stands covering them, causing a great deal of damage. These pine stands were created as a result of the extensive reforestation undertaken after 1940 and currently cover about

30.000 ha in Las Hurdes and 5.000 ha in the Sierra de Gata at altitudes around 1.000 m. The rainfall in the area exceeds 500 mm and the mean summer temperatures vary between 20 and 22°C with winter means between 4 and 6°C.

In former times, this region was one of the most economically and culturally depressed in Spain. In fact, the reforestation work has contributed in a decisive manner to the general raising of its population's standard of living, on giving permanent employment in planting, treating and operating jobs in the pine stand. In addition, the extensive mass of trees has changed the area's microclimate, making it wetter, regulating springs and streams and favouring the small crops in the valley. There are no local conflicts, therefore, which would have come out into the open through fires beforehand.

Fuel management work in the reforestations with the making of firebreaks, construction of roads, pruning and thinning works were begun in 1975.

For the foregoing reasons, the wave of fires in 1980 and 1981 came as a surprise since, in addition, many of them were incendiaries. Possibly the intense drought favoured the actions of people alien to the area whose wish was to cause conflicts artificially.

In 1980 there were five fires bigger than 1.000 ha:

- on July 12, a fire burned 1.950 ha of brushland in 12 hours after 28 days dry weather, with a 8 km/hour wind.
- on July 19, another fire burned 800 ha of cork stand and 200 ha of brushland in two days after 35 days without rain with a low wind but with temperatures reaching 39°C and relative humidity that dropped to 14%.
- on August 11, a fire burned 1.300 ha of brushland in 24 hours after 58 days dry weather, with a low wind and maximum temperature of 36°C.

- on September 16, a fire burned 1.225 ha of reforestation of P.pinaster, of which 500 ha were 40 years old and the rest 22. The fire lasted three days, after 20 days dry weather, with a 25 km/hour wind at the beginning, and so there was a crown fire.
- on September 25, the last big fire of the season burned 800 ha of P.pinaster reforestation 30 years old, after 5 days without rain. The fire lasted three days.

In 1981, the fires bigger than 1.000 ha were:

- on July 16, a fire burned 2.000 ha in three days, after 13 rainless days. 1.200 ha were P.pinaster varying in age from 5 to 20 years. The fire also affected some small chestnut stands amongst the pines. The rest of the area burned was brushland.
- on July 20, another fire, which lasted two days, burned 1.500 ha, of which 1.000 were 15 to 30 year old P.pinaster. The rest was brushland. The drought lasted 17 days and the wind was 15 km/hour.
- on July 21, another fire started, which lasted three days and burned 1.700 ha of P.pinaster 25 to 30 years old. There had been no rain for 18 days.

These fires were accompanied by many more of a lesser extension. Some of the 1981 fires overran areas burned in 1980, destroying the natural regeneration of pines and brushland which had begun to appear.

The 1981 Spring rains, although sparse, were highly concentrated and caused intense washings on the areas burned, particularly damaging the road system running round the wildlands.

In other areas observed in autumn 1981, the pine stand regeneration was extraordinary. The new pines withstood that autumn's drought with a low mortality rate and enable the pine stand to be reconstituted with simple clean up work. However, there is a big problem caused by the need to remove the burned

trees for which no commercial use has been obtained before the timber commences to deteriorate through the action of fungi and insects.

The regeneration of brushland included the following main species Erica australis, Genistella tridentata, Cistus populifolius, C.ladaniferus and C.salvifolius.

#### 5. Comments

The foregoing data enable the conclusion to be drawn that the areas most affected by drought are also those which have suffered the most devastating fires. Also, 1981, which appears to have been the driest in the century, recorded the maximum number of fires. Another important feature is the appearance of fires in certain regions of Spain traditionally exempt from this danger, e.g., the Pyrenees or the province of Cuenca.

That is to say, the drought has extended the danger season and the danger areas. It is curious to see that a parallel phenomenon has occurred with another important pine stand destruction agent in Spain, the caterpillar plague (Thaumetopoea pityocampa), likewise because of the drought. This plague has become extraordinarily active, with damage spreading to many places where the usual temperature and precipitation conditions prevented these insects developing.

However, the significance of drought in fire danger would seem to be to increase the probabilities of human action causing fires either through negligence or intentionally. Nevertheless, the extraordinary increase in the number of fires over the last few years is higher than could be inferred from the intensity of the drought. Blame cannot be attached simply to the drought for the increase in fire damage. It is therefore necessary to investigate the causality of the fires and the motivations causing some people to set them.

The influence of drought in fire effects is another issue of great importance. The factor of the rains' untimeliness is perhaps more significant than that of their intensity. The Mediterranean wildlands are marked by a thousand year old scarcity of rain. The plant species populating them require little water, but they need it at certain times. If the spring or autumn rains or both are lacking, the regeneration of plants after a fire will be at stake. If, on the other hand, the rains come, but with abnormally high intensities, erosion will occur also making regeneration difficult.

When fired areas are large, the accumulated effect of fire, drought and erosion increase the risk of desertification. This is a very serious problem in the Mediterranean area bringing about the organization of prevention and extinction work so that the number of highly extended fires (over 500 ha) may be reduced in order to minimize the effects of each fire.

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## EFFECTS OF WILDFIRES ON FOREST SOIL IN THE NORTHWEST OF SPAIN.

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### ABSTRACT

A study on wildfire effects on forest soil in forty two experimental plots showed that soon after fires, available P and exchangeable Ca, K and Mg contents increased considerably at the depth of 0-5 cm.

An increase of one pH unit was measured. Organic matter content decreased by about 40% and the C/N ratio lowered from 20.9 to 12.1; at 5-30 cms layer significant changes were not detected.

Two years after the wildfires, at the 0-5 cm layer, concentrations for K and Mg were lower than before fire, while Ca was invariable; pH was 0.1 higher than the initial value. Silt and clay dropped by 15% due to soil erosion. No changes were found at 5-30 cm layer.

Significant correlations were obtained between fireline intensity and absolute and relative reduction of O.M. contents after fire, absolute reduction of N content and relative modification of C/N ratio, as well as pH and conductivity of saturation extract at the 0-5 cm layer.

### 1. INTRODUCTION

Forest fires account for serious annual losses in N.W. Spain. Galicia possesses 25% of Spain's forests, and, for ten years, has suffered almost half of the fires which have occurred in this country. Each year, 50% of the total area burnt in Spain occur in Galicia; the province of Pontevedra is perhaps the most dramatic illustration of this situation; since 1968, forest fires have

destroyed more than 60% of its forests, with the loss of some 120.000 ha.

One of the most important repercussions to arise from these fires is the modification in texture and composition of the affected soils. This study intends to evaluate some of these changes, attempting to find a connection between intensity of fire and the evolution of edaphic properties.

## 2. AREA OF STUDY

Within the province of Pontevedra twelve fires, occurring in spring and summer, were chosen of varying extensions, between 5 and 429 ha. Stands of Pinus pinaster and Pinus radiata were chosen, the most representative of present forests, and in which no fire had occurred since reforestation; the age of the trees varied from 15 to 50 years, with average b. h. diameters between 10 and 30 cm, and height between 7 and 18.5 m.

In the above mentioned fire sites, a total of 42 plots were chosen each of 1.000 m<sup>2</sup> in area, which proved a convenient size for the purpose; their situation can be seen in fig. 1. The criteria used were as follows:

- a) Ample internal similarity. The problem of variation of populations under study was accentuated in burnt areas. Fire affects soil, trees and undergrowth in a very dissimilar form, and wide variations within a small area are very frequent.
- b) Availability of an unburnt control, which would allow comparison.
- c) To embrace a wide variety of values that would reflect the situation of forests after burning, (e. g. different intensities, orientations, accumulation), of combustible

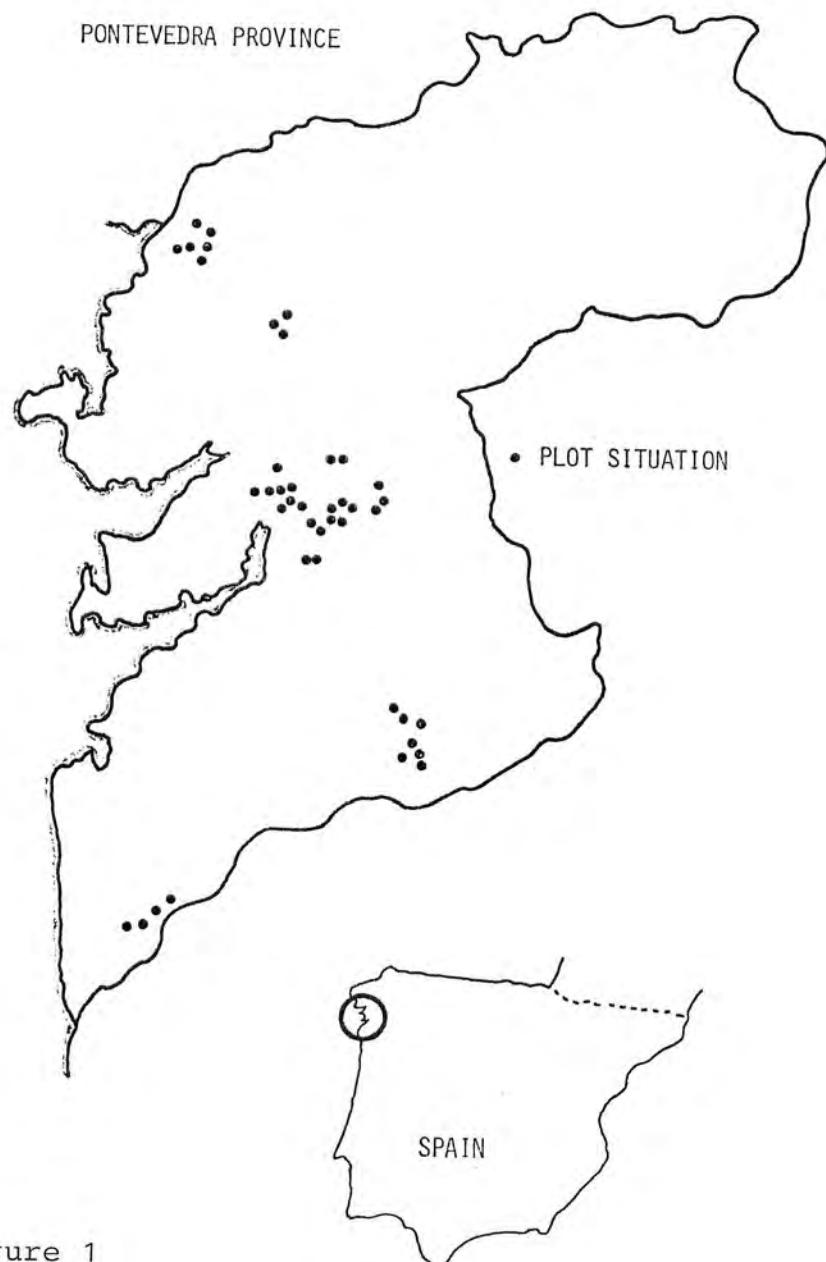


Figure 1

material, slopes etc.

Overall, the plots are situated in an area of a mild atlantic climate, with precipitation of 1.600 mm anually, average annual temperature of 15° C and a short period of summer drought (Gaussian) of approximamente one month.

The geological substrate is, in most cases, two mica granite, and in some plots micaschists, in almost all the cases slopes ranging from 15-30%. Undergrowth is composed of typical heathland-gorse species, with a predomination of *Ulex europaeus* and belonging principally to the *Ulicieeuropaei-Ericetum cinerea* association (BELLOT 1949).

### 3. MATERIAL AND METHODS

The fires occurred in variable meteorological conditions between 3 & 35 days after the most recent appreciable rainfall (0-5 mm); wind speeds during these fires varied from 5-19  $\text{tkh}^{-1}$ , and average relative humidity ranged from 34-78%. Almost all fires started around mid-afternoon with temperatures from 14-32° C. In these conditions, fires developed from intensities of 167  $\text{kCwm}^{-1}$  at light burning surface fires during the night, to others of high rate of spread, producing crown fires and reaching 19.000  $\text{kCwm}^{-1}$ .

In fourteen of the plots it was possible to make estimates of rate of spread and behaviour of the fires. In all of them, some days after the fires, soil samples were taken at two depths: 0-5 cm and 5-30 cm. Four average samples were taken from each plot, each one itself being an average of ten independant extractions. These samples were later analysed separately. The samples were always taken before the onset of autumn rainfall. This was a restricting criterion, given that it was essential to know the basic situation after a fire if it is required to compare results and be able to analyse the influence of intensity: many of the

inconsistencies between investigators are due to taking samples when rains have commenced, which can considerably alter the conditions of the soil. Our experience had shown that erosion and infiltration produces a rapid change in the state of the soil. In the same manner, average samples taken from ten further samples were extracted from each control plot. These samplings were repeated two years after the fire.

Later, the height of crown scorch was measured in all the trees situated in the plots, the height of trunk scorch, diameters at breast height (d.b.h.), also physiographical data. In each plot, burnt and control, a sampling was made to determine the amount of combustible material before and after the fire, by means of placing twenty random 1 m square quadrats and collecting all vegetation and its residues present.

This was later dried in an oven at 105° C until reaching a constant weight, and was then weighed.

The soil was analysed, making % OM determinations (WALKLEY and BLACK), % of total N (Semimicro KJELDAHL), pH, C/N, saturation extract conductivity, as well as exchangeables K, Mg and Ca cations (atomic absorption spectrophotometry) and available P (BRAY-2). The values assigned to each plot were arithmetic means of the four average samples of each plot.

The intensities of surface fires were calculated from the experimental formula of VAN WAGNER (1973). For those of the crown, calculations were made from the amount of fuel consumed and the rate of spread.

The corresponding data for the 42 plots, for each constituent of the soil, were subjected to a variance analysis, comparing the mean values for recently burned soil, after two years, as well as that of the control. Linear correlations were effected between average fire intensity and edaphic parameters.

#### 4. RESULTS AND DISCUSSION

Forest biomass accumulates nutrients throughout many years and are violently released by a wild fire. It is important to know the fate and evolution of these nutrients as it is necessary to quantify the effects of the fires, for them to be known in depth, and it is of great interest in order to plan the tasks of recovery of affected soil.

Particular emphasis has been laid in this work in studying an aspect which up to now has been dealt with very little. The majority of authors agree that forest fires are very variable, depending on many factors; intensity of fire is one of them. Some studies (VAN WAGNER 1965, ALBINI 1975, ROTHERMEL and DEEMING 1980, WELLS et al. 1975), insist on the necessity of characterising fires by parameters, which can reflect its effect on the soil. However, in almost all the studies on the ecological effect of fires this datum is omitted.

However, extracting this information is a fairly laborious task; variables such as intensity of reaction, residence time and flame length, which in laboratory fires and experimental fires in the field can be rigourously measured, cannot be easily and exactly determined in a real wild fire. In this study the fireline intensity was used; it is a basic variable, which in some cases can be calculated from the rate of spread and fuel consumption, or can be estimated from the height of crown scorch as an initial approximation.

##### 4.1 EVOLUTION OF COMPOSITION OF BURNT SOILS

###### 4.1.1 Exchangeable bases

Exchangeable cations retained by absorption complex represent the reserve of easily assimilable nutrients. Part of the existing nutrients after the fire originate in the combustion of the

organic matter, and from the combustion of the undergrowth and organic residues, especially litter and duff, making up the majority of organic material accumulated under pine forest canopy.

In table I corresponding average values for exchangeable K, Ca, Mg and available P are indicated. These values are the means of the 42 plots burnt, and refer to ppm with respect to fine dry earth in an oven of 105°C.

TABLE I: Average contents of elements in burnt and unburnt soil in indicated conditions (ppm).

ELEMENT	0 - 5 CM			5 - 30 CM	
	CONTROL	RECENTLY BURNT.	2 YEARS AFTER BURNT.	CONTROL	2 YEARS AFTER BURNING
Potassium	113	369***	72**	34	36
Calcium	62	500***	61	3	8*
Magnesium	102	346***	48***	6	9
Phosphorus	13,7	99,5***	41,6***	10,8	12,90

\* Significant to 5 %

\*\* " to 1 %

\*\*\* " to 0.1 %

All the nutrients studied considerably increase their concentration after the fire at a depth of 0-5 cm. Many investigators have found a similar effect. Among the most recent, ADAMS and BOYLE (1980) measured significant increases of Calcium, Magnesium, Potassium and Phosphorus for one month after the fire, decreasing after five months. CHRISTENSEN (1977), studying savanna pine soils, found that the fire provokes an increase of nutrients in herbaceous plants; WELLS et al. (1979) found a similar effect, including phosphorus, but there are cases in which this diminishes. ST. JOHN and RUNDEL (1976) found similar increases. CAMPBELL et al. (1977) found significant increases in burnt soils for Ca and Mg, but a decrease in K and no change for P.

After two years, concentrations for K and Mg are lower than before the fire, while Ca was invariable. What must be considered is that after combustion, K, Ca and Mg are like carbonates, calcium and magnesium being poorly soluble, and potassium very soluble.

The way in which these losses are effected coincides with the capacity for soil to retain these nutrients. It is estimated that for the three elements mentioned, the order of retention is:  
 $\text{Ca} \geq \text{Mg} > \text{K}$ .

Phosphorus shows different behaviour; its concentration increases greatly after the fire, and two years later maintains a high level, which is not too surprising as the movement of phosphorus is not great in acidic soils on account of its tendency to react with iron oxides and aluminium which are frequent in these soils.

The above is fortunate, as the phosphorus equilibrium is the most precarious of all nutrients, as its total reserves in mineral soil are very small (0.2 p. 100 or less) in these soils.

In the level 5-30 cm there are no significant differences except for calcium, which leads us to suspect that some of the

nutrients were lost through infiltration.

#### 4.12 Organic matter, Nitrogen and pH

In table II average values, corresponding to the contents of organic matter, are given with other variables.

TABLE II: Average contents of elements in burnt and unburnt soil in indicated conditions.

ELEMENT	0 - 5 cm			5 - 30 cm	
	CONTROL	RECENTLY BURNT	2 YEARS AFTER FIRE	CONTROL	2 YEARS AFTER FIRE
ORGANIC MATTER (%)	29.38	17.78***	17.09***	14.35	14.16
NITROGEN (%)	0.851	0.949	0.610***	0.496	0.516
C/N	21.25	11.6***	17.3***	17.6	16.8
pH	4.38	5.24	4.56**	4.4	4.53

\* Significant to 5%

\*\* " to 1%

\*\*\* " to 1%

As foreseen, the content of organic matter between 0-5 cm diminished quite a lot after the fire, as it has been pointed out by many investigators. After two years the OM content is

still inferior than that prior to the wild fire; however, the loss of Nitrogen must be of less degree than that of Carbon, as it is indicated by the great reduction of the C/N relation after the fire. VIRO (1974) points out that this quotient is more favourable for that of unburnt soil.

With respect to Nitrogen, CHRISTENSEN (1977) indicates that contents of  $\text{NO}_3^-$  and  $\text{NH}_4^+$  are not significantly different to those of unburnt soils. CAMPBELL et al. (1977) did not find  $\text{NO}_3^-$  in different quantities with respect to the control. VIRO (1976) however points out that the heating of the humus produces ammonia, losing total Nitrogen with the fire, while improving in mineral Nitrogen. MROZ et al. (1980) found, after artificial fires, that there are superficial losses of total and available Nitrogen, although these losses are transformed into gains in lower horizons, considering that the changes that this element undergoes depends on the type of organic matter. WELLS et al. (1979) suggest losses of N that are made up for fairly quickly. However, in our study, total nitrogen is still inferior to the initial stage after two years, possibly owing to the consumption by microbiological flora and vegetation activated by favourable conditions which permit fires, and the contribution of more bases and increase of pH. GIL (1983), studying the evolution of burnt soil in Galicia, found that the number of ammonifiers increases.

However, this decrease in total N must perhaps not be interpreted as an adverse factor, but that it has been made more accessible, signifying a greater absorption by plants as well as loss.

pH undergoes an initial increase, which, after two years, has dropped considerably, but remains higher than the initial value.

Between 5-30 cm the soil does not show any great differences.

#### 4.2 SILT AND CLAY

In table III average values for these components are given:

TABLE III: Average contents of clay and silt in burnt and unburnt soils in the indicated conditions.

COMPONENT	0 - 5 cm			5 - 30 cm	
	CONTROL	RECENTLY BURNT	2 YEARS AFTER FIRE	CONTROL	2 YEARS AFTER FIRE
CLAY	15.56	-	12.43***	13.06	12.99
SILT	14.94	-	12.08**	11.34	10.59

\* Significant to 5%

\*\* " to 1%

\*\*\* " to 1%

Two years after the fire there is a significant decrease in the contents of silt and clay in the first 5 cm of the soil. These components do not move to lower horizons, as results for 5-30 cm show, but are lost by erosion and represent a considerable loss of material. VEGA et al. (1983) have quantified the erosion produced on a hillside after a intense wildfire, confirming that after forest fires in Galicia there are important losses in the soil that may well jeopardize it.

#### 4.3 RELATIONSHIP BETWEEN FIRE INTENSITY AND EDAPHIC PARAMETERS

In table IV are given the linear correlation coefficients which have been obtained from intensity values and each one of the

variables analysed beforehand for the 0-5 cm layer in each plot.

TABLE IV: Linear correlations between average intensities of all plots and all soil variables in the 0-5 cm layer.

VARIABLE	CORRELATION	VARIABLE	CORRELATION
$M_{01} - M_{02} = \Delta M_0$	0.368*	$K_2 - K_1 = \Delta K$	0.163
$\Delta M_0/M_{01}$	0.574***	$\Delta K/K_1$	-0.071
$N_1 - N_2 = \Delta N$	0.574***	$Ca_2 - Ca_1 = \Delta Ca$	0.062
$\Delta N/N_1$	0.2967	$\Delta Ca/Ca_1$	-0.101
$C_1/N_1 - C_2/N_2 = C/N$	0.0149	$Mg_2 - Mg_1 = \Delta Mg$	-0.142
$\Delta C/N$	0.441**	$\Delta Mg/Mg_1$	-0.181
$C_1/N_1$			
$pH_2 - pH_1 = \Delta pH$	0.501***	$P_2 - P_1 = \Delta P$	-0.255
$\Delta pH/pH_1$	0.529***	$\Delta P/P_1$	-0.081
$C_2 - C_1 = \Delta C$	0.367*	$\Sigma C_2 - \Sigma C_1 = \Delta \Sigma C$	0.101
$\Delta C/C_1$	0.331*	$\Delta \Sigma C/\Sigma C_1$	-0.266

Notes: \* Significant to 5 % Subindex 1 = unburnt  
 \*\* " to 1 % " 2 = immediately  
 \*\*\* " to 0.1% after fire.

$\Sigma C$  = Sum of K, Mg, Ca, and P concentrations.

Significant correlations were obtained between fire intensity and absolute reductions of organic matter after the fire, and this relation is improved when the O.M. reduction is expressed in terms relative to initial value.

The more intense the fire, the reduction of O.M. represents a greater proportion relative to initial content.

This does not occur in N. It does not seem that the loss, with respect to the initial percentage, becomes any greater, supposing that the intensity increases. So this correlation is not significant. However, there is a greater absolute loss of N when the intensity of the fire increases.

The absolute variation of the C/N relation is not strictly allied to lineal intensity. However, in relative terms, this relation seems to improve with high intensity fires. The more intense the fire, the relative decrease of C/N is greater with respect to the C/N quotient of unburnt soil.

The pH shows a relation with fire intensity, a characteristic which had been mentioned more or less intuitively by most authors, though without having made an simultaneous measured of both variables. Again, the relation is more evident in the quotient referring to initial pH, showing that the effect mentioned is stronger as fire intensity is greater. Conductivity reflects the same phenomena, although less significant.

It does not fail to seem paradoxical that the absolute and relative concentrations of K, Ca, Mg and P and the sum total of elements show no change in respect to fire intensity. This is probably due to the fact that this parameter is insufficient in showing the whole effect of the fire. It is obvious that a fire can be of a very high lineal intensity, simply by its rate of spread without producing consumption of fuel in any great proportions, which supposes that it does not produce any great amount of ash. It is probable that a measurement of fuel consumed could possibly improve the preceeding relationships.

## 5. CONCLUSIONS

We can indicate that fires in N.W. Spain are provoking many sudden changes in the conditions of fertility in the first 5 cm of soil, shown by spectacular increases in average contents of exchangeable cations: K (3 times more), Ca (8 times), Mg (3,6 times) and available P (7 times). OM undergoes an important reduction (39 %) and pH increases by 0.86. The C/N relationship diminishes and the amount of total N of residual OM is not affected. These effects, however, do not seem to occur in the 5-30 cm layer.

After two years, the deposited nutrients have vanished in the 0-5 cm layer, showing lower concentrations for K and Mg, equal for Ca, and P has remained higher than at the beginning. Only Ca has been retained, very slightly, in the 5-30 cm layer.

The loss of clay and silt by erosion should be stressed, and that the soil is being depleted of these important materials.

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## RECOVERY OF PINUS HALEPENSIS MILL. WOODLANDS AFTER WILDFIRE

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### 1. INTRODUCTION

Due to its frequent recurrence fire is an important factor influencing the dynamics of the plant communities in the French mediterranean area. Former studies (BRAUN-BLANQUET 1936, KUHNHOLTZ-LORDAT 1938, 1958, KORNAS 1958, BARRY 1960) considered fire as creating more and more degraded successive stages. But they did not analyse exactly the vegetation succession in the course of time after fire. Recently TRABAUD (1977, 1980, 1982) and TRABAUD and LEPART (1980) demonstrated that burnt phytocenoses both floristically and structurally recovered very quickly reverting to a state similar to the previous ones existing before fire. By such results they reached the same establishments found by researchers from California (SAMPSON 1944, PATRIC and HANES 1964, HANES and JONES 1967, HANES 1971, VOGL and SCHORR 1972), from South Africa (KRUGER 1977), and from Australia (SPECHT et. al. 1958, PURDIE 1977a, 1977b, PURDIE and SLATYER 1976).

To have a precise knowledge of changes occurring in the French mediterranean vegetation following fire, a study has begun fifteen years ago to follow the modifications brought by wildfire. Several (8) communities were investigated and observed during about twelve years; the present contribution deals with the Pinus halepensis Mill. woodlands which are very flammable and combustible communities and consequently frequently fired.

### 2. METHODS AND KINDS OF OBSERVATIONS

The "direct" (or diachronic) method (PAVILLARD 1935) based on permanent plots was chosen to observe the vegetation recovery on burnt areas. This method allows to observe and follow relatively

small both floristic and structural changes. The study mainly concerns the first years (10-12 yr) following fire, these are of primary importance for the establishment of vegetation.

The 7 studied plots concerning the Aleppo pine woodlands are located in formerly burnt areas in the northwest region of Montpellier. Thanks to the courtesy of the "Service d'Incendie et de Secours du Département de l'Hérault" the burnt areas could be precisely located and their age known. After a reconnaissance of the fired areas, the study plots were selected according to the apparent homogeneity of the stands.

Each observation plot consisted of a permanent 20 m intersect line (LEVY and MADDEN 1933, LONG 1957, 1958, DAGET and POISSONET 1971). Reference posts are cemented into the ground. Observations were done every 10 cm. Presence and number of hits along a needle were recorded for each species. In addition to these observations a floristic survey of the species present in a 100 m<sup>2</sup> plot (i.e. in a 2,5 m wide strip at either side of the line) was carried out.

During the first five years which followed fire, the observations were performed a few months after the wildfire, then every year in spring. Afterwards the vegetation was observed only every two years as the stands appeared to physiognomically stabilize.

### 3. RESULTS

#### 3.1 Development of floristic composition

The floristic richness corresponding to the number of taxa encountered in plots at each time of observation was first considered.

During the years following fire, the development of floristic richness follows a general model similar in several studied

communities (TRABAUD 1980, TRABAUD and LEPORT 1980). Immediately after fire, the ground is entirely bare; then plants appear progressively. Floristic richness is low during the first twelve months. It grows gradually to reach a maximum between the 10<sup>th</sup> and 40<sup>th</sup> month. Then, the floristic richness decreases. Finally a relative stabilization does appear from the 60<sup>th</sup> month onwards (fig. 1).

In the same area, a parallel study on burnt pine woodlands also found that diversity presented the same trends as floristic richness and confirmed these results (MICHELS 1982).

The generally higher number of species during the first three years can be attributed to the opening of the vegetation cover created by fire, to the disappearance of litter and to the richness in nutrients of the upper soil layer.

The curves of the development of floristic richness are similar to those which are observed when an unbalanced biological system reverts to a metastable state after a perturbation. TRABAUD and LEPORT (1980) have proposed an index of fugacity to explain the changes in floristic richness and how the community flora stabilizes.

A species is called fugacious when it does not remain on a plot all along the period of observations. The fugacity of any species is measured by the number of observations in which it is missing. A fugacity index for the floristic ensemble of a plot should correspond to the mean value of the fugacities of the species present on the plot at a given time. Fugacity index can be considered as a measure of the floristic stability of a plot : if the index is high the community has not reached a stable state, if it equals zero the community is floristically stable.

Immediately after fire the index of fugacity is low (fig. 2). The species which are the first to appear on the plots do remain thereafter. Then fugacity increases and reaches its maximal value

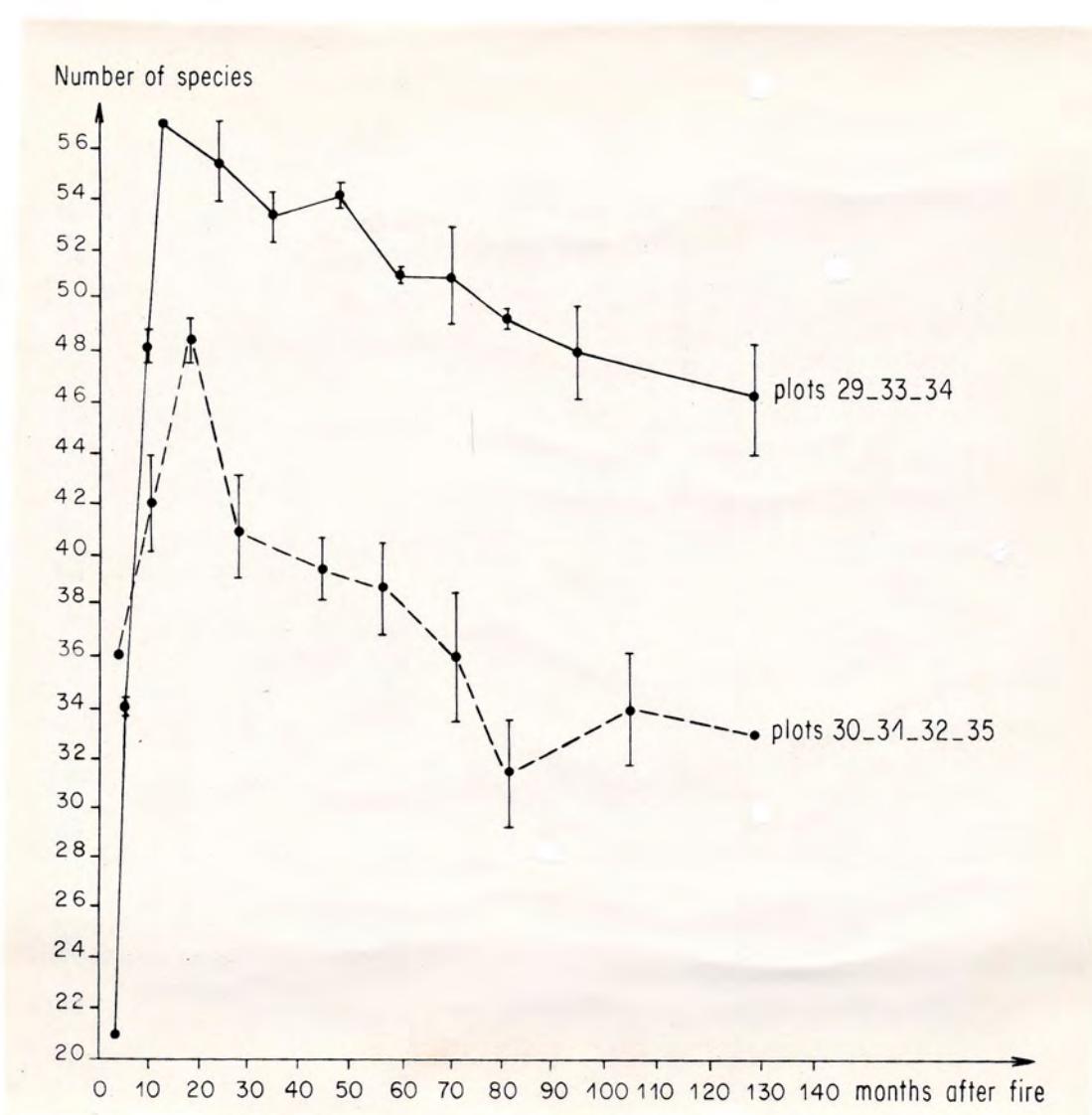


Fig.1: Post-fire development of the floristic richness  
in Pinus halepensis woodlands

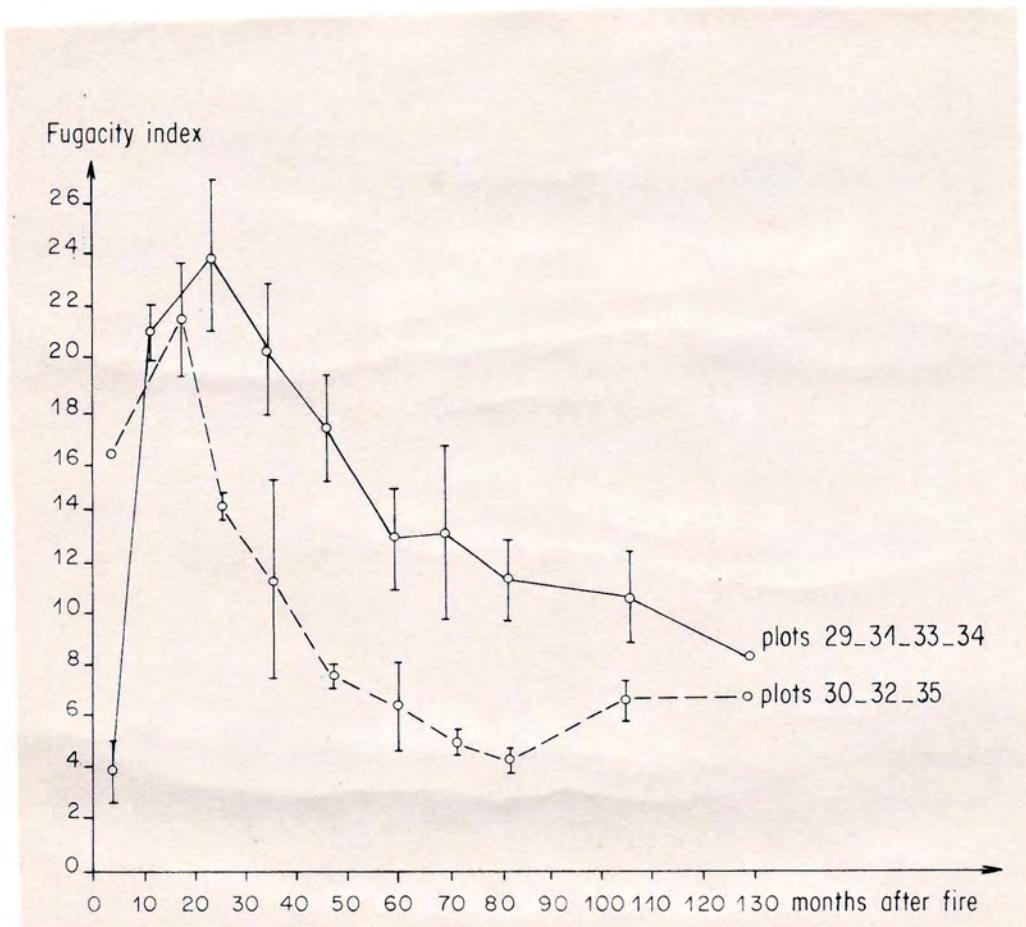


Fig.2: Post-fire development of the fugacity index in *Pinus halepensis* woodlands

during the second and third year after wildfire when floristic richness is at its maximum. Thus the fugacity follows the model of the floristic richness. Therefore the richness of the intermediate stages clearly proceeds from species (most of them coming from outside the community) which temporarily add to the community richness and will disappear as the stands get older. Most often these species are annuals. Then the fugacity index decreases progressively to stabilize towards the 8<sup>th</sup> year after fire.

### 3.2 Changes in the quantitative development

Not only fire influences the floristic composition of communities but it also modifies their structure and phytomass. Structure stands for the spatial distribution both horizontally and vertically of plants.

#### a) Horizontal growth

When only the presence of a species is recorded at each observation point along the line this gives a specific frequency (GORDON 1958, DAGET and POISSONET 1971, 1974). If this frequency is referred to the total number of points observed on the line the result is the percentage of ground covered by the species, which may represent the cover of this species.

As the recovery of vegetation is very quick following fire, the total cover reaches rapidly a large amount of the ground surface, therefore it seems better to follow the cover changes according to the principal life forms of plants (RAUNKIAER 1905, GODRON et al. 1968). Hence, plants were put together according to their potential life forms, that is the adult size they would reach without any fire or perturbation. Four main groups were set up:

- woody plants higher than 30 cm: woody phanerophytes
- woody plants always smaller than 30 cm: woody chamaephytes

- grasses
- other herbaceous plants: forbs.

Rapidly after fire vegetation sprouts and covers the ground surface. As a matter of fact, generally fifteen days after a wildfire plant begin to sprout, then progressively tend to become denser. The cover of woody phanerophytes regularly increases as communities get older (fig. 3a). At the end of the period of observations (12 years after fire) the growth tends to slow down and stabilize. The communities reach an equilibrium stage similar to that of the mature state. The cover of woody chamaephytes passes through a maximum which persists from the third to the sixth year following fire, then decreases (fig. 3b).

The developments of the grass and the forb covers (fig. 3c and 3d) are similar to that of woody chamaephytes. Cover reaches a maximum which can spread over several years but never passing beyond the fifth. Then the cover of these two types of life forms decreases less and less rapidly as communities grow older.

As woody plants develop and invade a more and more important area, the cover of all the herbaceous plants tend to decrease. There is a sort of competition for growth between the different life forms, woody plants prevailing over the herbs. This tendency appears very soon after fire. However, towards the end of the period of observations (about 12 years) a relative steady state seems to appear. The ratio of the different forms remains rather constant. This stage is very similar, if not identical, to that of older communities which have not been burnt.

#### b) Vertical growth

The number of plant hits along the generating line of the observation needle gives an estimation of the above ground phytomass (DAGE and POISSONET 1971, 1974). The growth of vegetation was observed according to different strata:

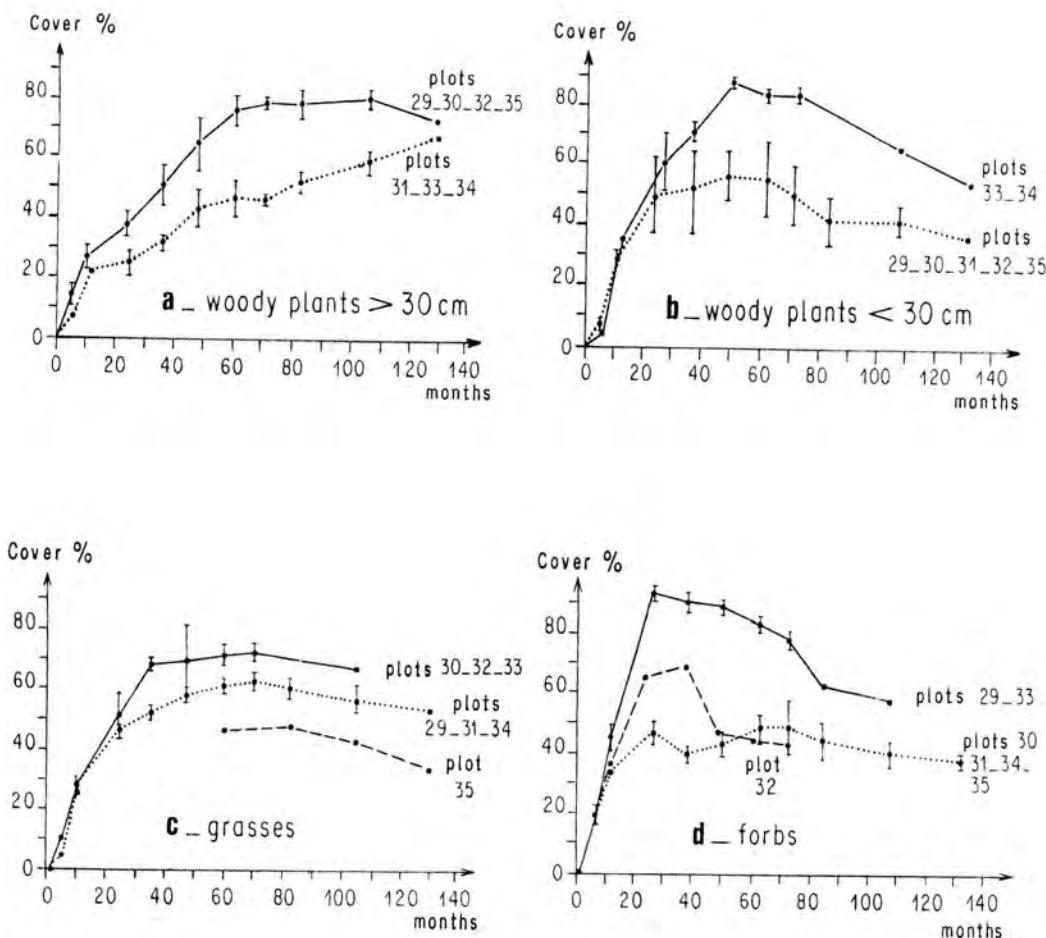


Fig.3: Post-fire development of the cover in Pinus halepensis woodlands according to life forms

layer 1: 0 - 25 cm  
layer 2: 25 - 50 cm  
layer 3: 50 - 100 cm  
layer 4: 100 - 200 cm  
layer 5: 200 - 400 cm

As communities grow old plant material tends to become more important in higher strata, whilst it decreases in the lower strata. Immediately after fire layer 1 appears and dominates during the first five years (fig. 4a). Progressively the importance of this layer will decrease. Layer 2 increases, then stabilizes. Layers will appear the more lately as they are located at a higher point: layer 3 appears only the second year following fire (fig. 4c). The decreasing importance of layer 1 after the fifth year is due to the fact that vegetation grows up and the maximum of plant material tends to be at the periphery of plants (tip of twigs and branches).

If pine woodlands do not grow higher than layer 3 during the period of observations this is due to the strategy used by the dominant plant (pine) to survive fire, for Quercus ilex woodlands reached layer 5 during the 12 years of observations (TRABAUD 1980). The oak sprouts and grows up very quickly (in 70 months its height can reach 2 m), whereas Aleppo pine can reproduce only by seeds and has a slower growth during the first years following fire (it reaches only 1 m in 10 years). But with time the higher layers will prevail.

Thus, after fire, there is a recovery towards a steady structural state similar to that existing before fire. In 25 years the pine woodlands will be restored.

#### 4. DISCUSSION AND CONCLUSION

The post-fire development of the floristic composition of the P.halepensis woodlands is very different from that of

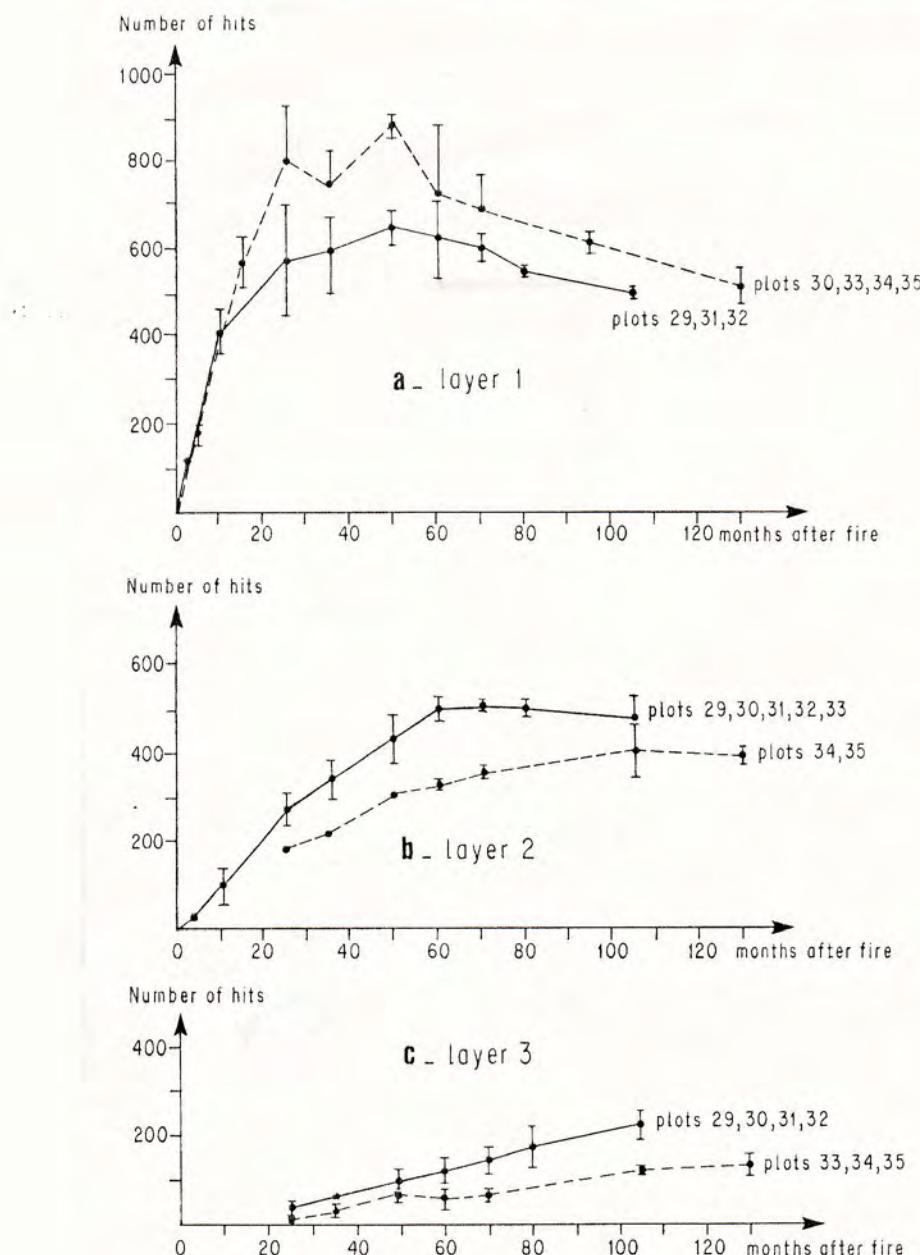


Fig.4: Post-fire development of plant material in Pinus halepensis woodlands according to layers

N.B.: For all the figures the confidence limits correspond to the 5 percent level of probability

revegetation of bare soil or after abandonment of old fields (BOURNERIAS 1959, BAZZAZ 1968, 1975, MELLINGER and McNAUGHTON 1975, GUILLEM 1978). The opening of the vegetation allows alien species to come in but these are rapidly eliminated with the return of community species existing before fire. During the period of study there was no succession in the sense of substitution of a community by another one. Concerning the floristic composition fire seems to be a rather superficial phenomenon. Vegetation obviously follows the model proposed by EGLER (1954) as "initial floristic composition", that is all the taxa of the mature stages appear in the plots immediately after fire, even if afterwards the relative abundance of individuals changes a little. There is no "relay floristics" or different communities succeeding on a same plot through time.

There is a progressive increase of the phytomass, and a change of the ratio of the plant material from the lower layers immediately after fire to the higher layers as vegetation grows old. Likewise, the relative importance of life forms (woody and herbaceous) progressively changes through time. Which is identical to the theoretical model proposed by ODUM (1971) for simulating the mass changes occurring through succession following fire allowing to explain the development of plant forms.

Infrequent wildfires do not profoundly modify the flora and structure of Aleppo pine woodlands in the French mediterranean region because these phytocoenoses have been probably influenced by fire for a long time and species present adaptive traits to survive fire.

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## KONTROLLIERTES BRENNEN IM FEUER-MANAGEMENT SÜDBRASILIANISCHER KIEFERNAUFFORSTUNGEN

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### 1. Einleitung

Zur Deckung des Nutz- und Brennholzbedarfes und zur Sicherung des Landschaftspotentials werden weltweit in zunehmendem Maße Aufforstungen mit raschwüchsigen Baumarten angelegt. In den Regionen der Subtropen und der Tropen wird dabei schwerpunktweise auf die Gattungen Pinus spp. und Eucalyptus spp. zurückgegriffen, deren weite ökologische Amplitude eine Anpassung an extreme Standortbedingungen erlaubt und in kurzem Umtriebszeiten von 15 bis 30 Jahren die Erzielung guter Holzerträge ermöglicht (FAO 1967).

In Brasilien, das zu einem der führenden Aufforstungsländer zählt, stellen die Pinus spp. etwa ein Drittel der für die Periode 1967-1980 projektierten Aufforstungsflächen (IBDF in MAFFIA 1982). Der Schwerpunkt des Kiefernbaues liegt dabei in dem im Süden des Landes gelegenen Bundesstaat Paraná. Von den insgesamt etwa 100 bekannten Arten der Gattung Pinus spp., deren natürliches Verbreitungsgebiet sich im Wesentlichen auf die nördliche Hemisphäre beschränkt, werden dort vorzugsweise Pinus elliottii Engelm., Pinus taeda L. und Pinus caribaea Morelet angebaut (s. a. GOLFARI 1971).

Diese Arten zeichnen sich durch ein außerordentlich schnelles Wachstum aus. Die damit einhergehende hohe Produktion an Nadelstreu führt mit Beginn des Bestandesschlusses zur Bildung einer mächtigen Streuauflage, die den Aufwuchs von Bodenvegetation und eines Unterstandes weitestgehend verhindert; durch diese Artenarmut sind die Aufforstungen vergleichbar mit Agro-Ökosystemen, die durch geringe ökologische Stabilität gekennzeichnet sind (CONELL and ORIAS 1964, VAN MIEGROET 1979).

Im Totastraum der Bestände, in denen eine natürliche Astreinigung innerhalb der angestrebten Umtriebszeiten zwischen 15 und 30 Jahren nur sehr zögernd erfolgt, bleiben die herabfallenden Nadeln hängen und bilden eine zusätzliche, vertikale Schichtung der Streu. Zusammen mit den periodisch anfallenden Durchforstungsabfällen hat diese Anordnung des forstlichen Brennmaterials eine hohe Schadfeuerdisposition zur Folge. Wald- und Freiflächenbrände, die Südbrasilien am häufigsten durch das Felderbrennen oder die Brandrodung verursacht werden (SOARES und CORDEIRO 1974), können in den niederschlagsarmen Monaten des südlichen Winters katastrophale Ausmaße annehmen. Im Jahr 1963 verbrannten alleine in Paraná innerhalb weniger Wochen über 1,5 mio ha Sekundärwald, 0,5 mio ha Araukarien-Naturwald (Araucaria angustifolia (Bert.) O.Ktze.) und über 33.000 ha Neuaufforstungen (TORIBIO 1982). Im Jahr 1981 nahmen die Waldbrände wiederum große Ausmaße an und führten zu einer Schadfläche von mehreren mio ha, darunter ca. 40.000 ha Aufforstungen, von denen besonders die Kiefernplantagen im Süden Brasiliens betroffen waren (SBS 1982).

Die hohe Waldbranddisposition dieser Aufforstungen mit fremdländischen Kiefernarten wirft die Frage ihrer zukünftigen Bewirtschaftungsform auf. Hierbei kann ein Blick in die Ökologie natürlicher Kiefernwaldgesellschaften Nordamerikas hilfreich sein. In Regionen, in denen Blitzschlagfeuer regelmäßig auftreten, haben die vielfachen Wechselbeziehungen zwischen Feuer und Vegetation die Ausformung von Feuer-Ökosystemen begünstigt (s.a. KOZLOWSKI and AHLGREN 1974, GOLDAMMER 1978, WRIGHT and BAILEY 1982). Neben der selektiven Wirkungsrichtung haben regelmäßig auftretende Feuer die wiederholte Reduzierung forstlichen Brennmaterials zur Folge. In Waldbeständen entwickeln sie sich daher auch meist nur als Bodenfeuer geringer Intensität, denen die im unteren Stammteil dickborkigen Kiefern angepaßt sind, gehen nicht in die empfindlichen Kronen über und bewirken somit langfristig die Sicherung der Bestände vor der Entwicklung eines Schadfeuers.

In der nordamerikanischen Fortwirtschaft ist man daher in Abkehr

	Zielobjekt	Potentielles Zielobjekt	Wirkungsmechanismus	Angestrebter Effekt	Substitution	Unerwünschte Nebenwirkung
Reduzierung der Schadfeuergefahr	Nadelstreu, Durchforstungsabfälle		Herausbrennen der aerial/ flash fuels	Bei Waldbrand: Bodenfeuer entwickelt sich nicht zum Vollfeuer	Herausziehen, Zerhacken, Vergraben	Feuer gerät außer Kontrolle
Verbesserung der Begehbarkeit	Durchforst.- abfälle, Schlagraum der Endnutzung		Reduzierung sperrigen Materials	Geringere Kosten, Befahrbarkeit mit Pflanzmaschine	Herausziehen, Zerhacken, zusammen-schlieben	
Herbeiführung von Naturverjüngung	Schlagraum, Nadelstreu, Samenbaum		Schaffung Keimbett, Verbesserung Samenertrag	Kostensparnis durch Nutzung des Verjüngungspotentials	Mechanische Bodenbearbeitung	Förderung konkurrierender Vegetation
Beeinflussung der Bodenvegetation			Förderung oder Unterdrückung Begleitflora	Brandhemmender Unterstand, Ausschaltung der Konkurrenz	pflanzung, un- terbau, mech./ chem. Läuterung	
Schaderreger	Nagetiere	<i>Armill. mellea</i> Heterodas. ann. Cironart. fusif. Scolytidae	Beinträchtigung Habitat, Zwischenwirt od. Schädling direkt	Vermeidung Pflanzenausfall, Zuwachsverlust	Pestizide	Erhöhte Disposition durch Schwächung des Baumes; Förderung des Zwischenwirtes, Anregung Sporenproduktion
Nutzlinge		?	Habitatverbesserung: Nektar + Pollen der Begleitflora für Prädatoren	Biologische Schädlingskontrolle	Pestizide	
Wuchsleistung	Streu-auflage		Beschleunigung Nährstoffkreislauf; Verringerung Interception der Streu	Verbesserung der Wuchsleistung	Düngung, Kalkung	Nährstoffverluste

Tab. 1: Potentielle Zielsetzungen des Einsatzes von kontrolliertem Feuer in südbrasilianischen Kiefernaufforstungen

von der strikten Feuerbekämpfung dazu übergegangen, das kontrollierte Durchbrennen von Koniferenwäldern, insbesondere von Kiefernwaldgesellschaften, als Maßnahme der Schadfeuerverhütung in das Feuer-Management zu integrieren (s. DeBRUIN 1974). Für die forstliche Praxis stehen entsprechende Empfehlungen und Anleitungen bereits zur Verfügung (MOBLEY et al. 1973, US FOREST SERVICE 1976, MARTIN and DELL 1978, FISCHER 1978).

In die Bewirtschaftung von Kiefernaufforstungen außerhalb des natürlichen Verbreitungsgebietes hat das kontrollierte Brennen noch keinen entsprechenden Eingang gefunden. Untersuchungen über die Auswirkungen eines kontrollierten Feuers in P.elliottii sind aus Australien bekannt (VAN LOON and LOVE 1973). Für den Einsatz von kontrolliertem Feuer in den Kiefernaufforstungen Südamerikas lagen neben einem Pilotversuch in Pinus radiata D. Don in Chile (JULIO 1975) und in Pinus oocarpa Schiede und P. caribaea in Minas Gerais/Brasilien (SOARES 1979) bislang nur hypothetische Formulierungen vor (GOLDAMMER 1976, 1982, SOARES 1977) (s. a. Tab. 1).

In der vorliegenden Arbeit wurde versucht, anhand des Beispiels von Aufforstungen mit P.elliottii und P.taeda verschiedene grundsätzliche Fragestellungen der Erhebung forstlichen Brennmaterials und des Verhaltens und der Auswirkungen des kontrollierten Feuers zu klären. Die Ergebnisse, die in ausführlicher Form bei GOLDAMMER (1983) dargestellt sind, werden hier in Auszügen skizziert.

## 2. Material und Methoden

Für die Durchführung der Untersuchungen im südbrasilianischen Bundesstaat Paraná, der zwischen  $22^{\circ} 29'30''$  und  $26^{\circ} 42'59''$  südlicher Breite und  $48^{\circ} 02'24''$  und  $54^{\circ} 37'38''$  westlicher Länge und im Wesentlichen in den nach KÖPPEN mit Cfa und Cfb zu charakterisierenden Kimazonen liegt (MAACK 1968), wurden insgesamt 19 Versuchsbestände mit P.elliottii und P.taeda

ausgesucht. Sie liegen im Versuchswald der Bundesuniversität von Paraná, Fazenda Canguiri, bei Curitiba, und dem Forstbetrieb Klabin do Paraná, Fazenda Monte Alegre, Telêmaco Borba.

## 2.1 Erhebung der Streuaflagen, der Durchforstungsabfälle und des Nadelfalles

In den nicht-durchforsteten Beständen oder in den häufig vorzufindenden bis zu 16 Jahren alten und nur einmal durchforsteten Plantagen wird der größte Teil der Brennmaterialauflage durch die Nadelstreu gestellt. Das größere Material ist von den Nadeln überdeckt, so daß der Eindruck einer sehr homogenen Bodenaufgabe entsteht. Unter derartigen Voraussetzungen wurde die Menge des forstlichen Brennmaterials auf dem Bestandesboden über zufällig verteilte Kleinflächen-Stichproben ermittelt. In einem Holzrahmen mit einer Innenfläche von 1 m<sup>2</sup> wurde das gesamt Brennmaterial außer Nadeln und Zapfen gesammelt. Die Nadelauflage wurde mit Hilfe eines Holzrahmens (Seitenlänge 30 x 30 cm) und eines geschliffenen Spatels herausgestochen. Die Hochrechnung der Brennmaterialauflage in t·ha<sup>-1</sup> erfolgte nach Trockengewicht.

Nach einem Durchforstungseingriff bildet sich eine sperrige Brennmaterialauflage aus Ästen und Kronen bis zur Derbholzstärke. Die Erfassung dieses räumlich unregelmäßig angeordneten Brennmaterials ist schwierig. Die in den USA speziell für P.taeda oder P.elliottii entwickelten Regressionsmodelle, in die beispielsweise Grundfläche, BHD, Kronengewicht und Eigenschaften des Unterstandes Eingang gefunden haben, sind entweder nur auf nicht durchforstete Bestände anwendbar (BRENDER et al. 1976), beschränken sich auf die Kronenmasse (WADE 1969) oder berücksichtigen eine Begleitflora, die in Brasilien nicht angetroffen wird (EDWARDS and McNAB 1976, McNAB et al. 1978). In Beständen mit einem vorangegangenen Durchforstungseingriff wurde daher eine Inventur des Brennmaterials mit Hilfe einer "planar intersect technique" (BROWN 1974) durchgeführt.

Da eine natürliche Astreinigung von P.taeda und P.elliottii erst sehr zögernd etwa ab dem Alter von 15 bis 20 Jahren erfolgt, bleibt ein Teil der herabfallenden Nadelstreu im Totastraum zwischen Bestandesboden und Kronen hängen. Insbesondere vor der ersten Durchforstung füllt dieses am leichtesten entzündliche Brennmaterial den Stammraum horizontal und vertikal auf ("draped" fuels). Bei der ersten Durchforstung wird es dann nicht nur entzerrt, sondern die fallenden Bäume reißen auch einen Teil der Totäste mit oder zertrümmern sie. Eine Erfassung dieser Nadelmasse wurde daher nur in einem 9-jährigen, nicht durchforsteten Bestand vorgenommen. An 10 Bäumen wurden dabei sämtliche an den Ästen hängenden Nadeln eingesammelt und das Trockengewicht bestimmt.

Zur Untersuchung des Nadelfalles wurden zehn verschiedene Bestände ausgesucht, die bei Beginn der Versuchsanlage zwischen 5 und 22 Jahre alt waren. Die Nadeln wurden in Streufallen mit einer Sammelfläche von 1 m<sup>2</sup> aufgefangen. Pro Bestand wurden jeweils zehn dieser Fallen entlang einer Stichprobenlinie und unabhängig vom Standort der Stämme und der Kronenprojektion angelegt. In keinem Bestand war ein Unterstand vorhanden, der den Streufall hätte verfälschen können. Während der 13-monatigen Beobachtungsperiode zwischen Mai 1981 und Mai 1982 wurden die Streufallen monatlich geleert, das Trockengewicht bestimmt und der monatliche Nadelfall pro Hektar hochgerechnet.

Zur Trockengewichtsbestimmung wurden die Streuproben bei 85°C bis zur Gewichtskonstanz gebracht: Dieses Verfahren ist bei der Erhebung des übrigen forstlichen Brennmaterials nicht notwendig, da die Errechnung über die "planar intersect technique" auf dem Trockengewicht basiert. Der Feuchtigkeitsgehalt der Streu ist während des Verbrennungsvorganges eine kritische Variable (s.a. VAN WAGNER 1972). Die Errechnung erfolgte über Darrtrocknung bzw. ein thermogravimetrisches Meßgerät\*.

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\* COMPU-TRAC MA-3, Motorola Proc. Contr., Inc., Tempe/Arizona

## 2.2 Erfassung der Feuerintensität

Das Verhalten von Gegenwind- und Lauffeuern wurde auf Grundlage des von BYRAM (1959) vorgeschlagenen Ausdrucks der "Feuerintensität" beschrieben, alternativ auch mit der dazu eng in Beziehung stehenden Flammenlänge (s.a. ROTHERMEL and DEEMING 1980). Als Heizwerte der Streu wurden die Berechnungen von HOUGH (1969) zugrunde gelegt.

## 2.3. Erfassung der Auswirkungen auf den Standort

Unter besonderer Berücksichtigung der Feuchtigkeitsverhältnisse wurde die Temperaturentwicklung unterhalb, in und oberhalb der Streuauflage gemessen (NiCr-Ni-Thermoelemente). Daneben sollte die Untersuchung der Bodenfauna Hinweise auf die Tiefenwirkung des kontrollierten Feuers geben und ihre mögliche Reaktion auf veränderte Umweltbedingungen aufzeigen. Dazu wurden in zwei Brandparzellen und ihren entsprechenden Kontrollflächen zylindrische Bodenproben (Volumen: 225 cm<sup>3</sup>, Tiefe: 4 cm) entnommen und mit Hilfe eines Apparates nach BERLESE/TULLGREN (BALOGH 1958) nach Bodentiergruppen ausgezählt.

Die Beobachtung der in diesen artenarmen Biozönosen sporadisch vorkommenden Bodenvegetation sollte einen Hinweis auf die Beeinflussung der Keimungsbedingungen bzw. die Reaktion der Pflanzen auf das kontrollierte Durchbrennen hin ermöglichen. In zwei nahe beieinanderliegenden Beständen mit 15-jähriger P.elliottii, in denen vereinzelte Bodenpflanzen zu finden waren, wurden die Pflanzen bestimmt und die Standorte dauerhaft markiert; vor dem Brennen (April 1981) und ein Jahr danach (März 1982) wurde eine Aufnahme nach der synsystematischen Methode von BRAUN-BLANQUET (1964) durchgeführt.

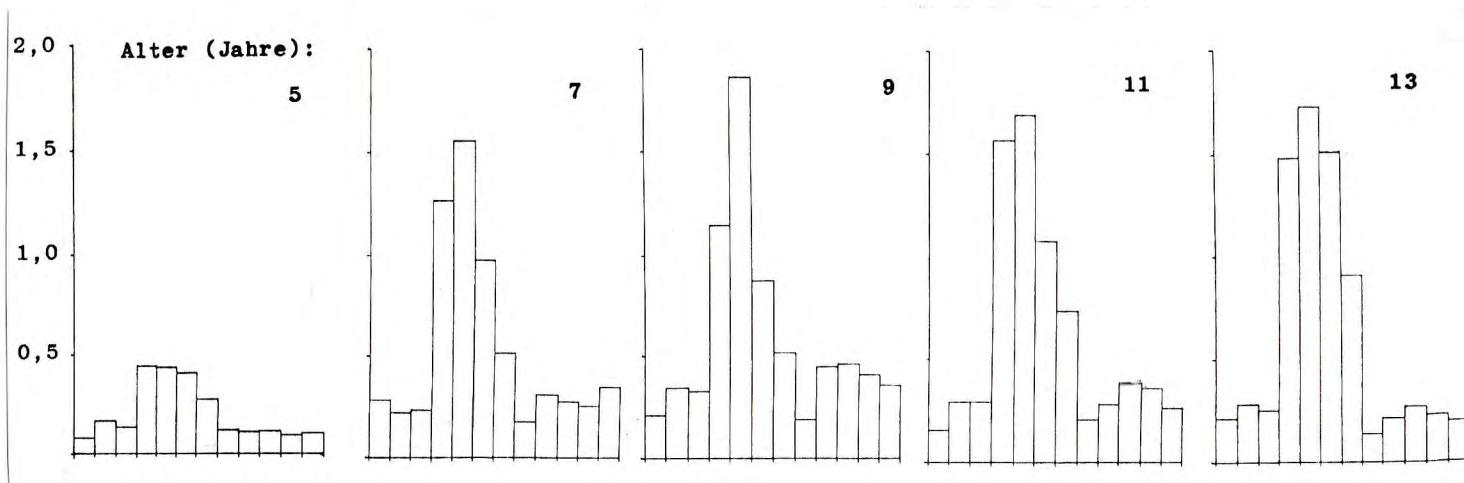


Abb.1a: Monatliche Verteilung des Nadelfalles ( $t \cdot ha^{-1}$ ) auf den Bestandesboden in 5- bis 13-jährigen Aufforstungen mit Pinus taeda. Fazenda Monte Alegre, Paraná, 1981-82.

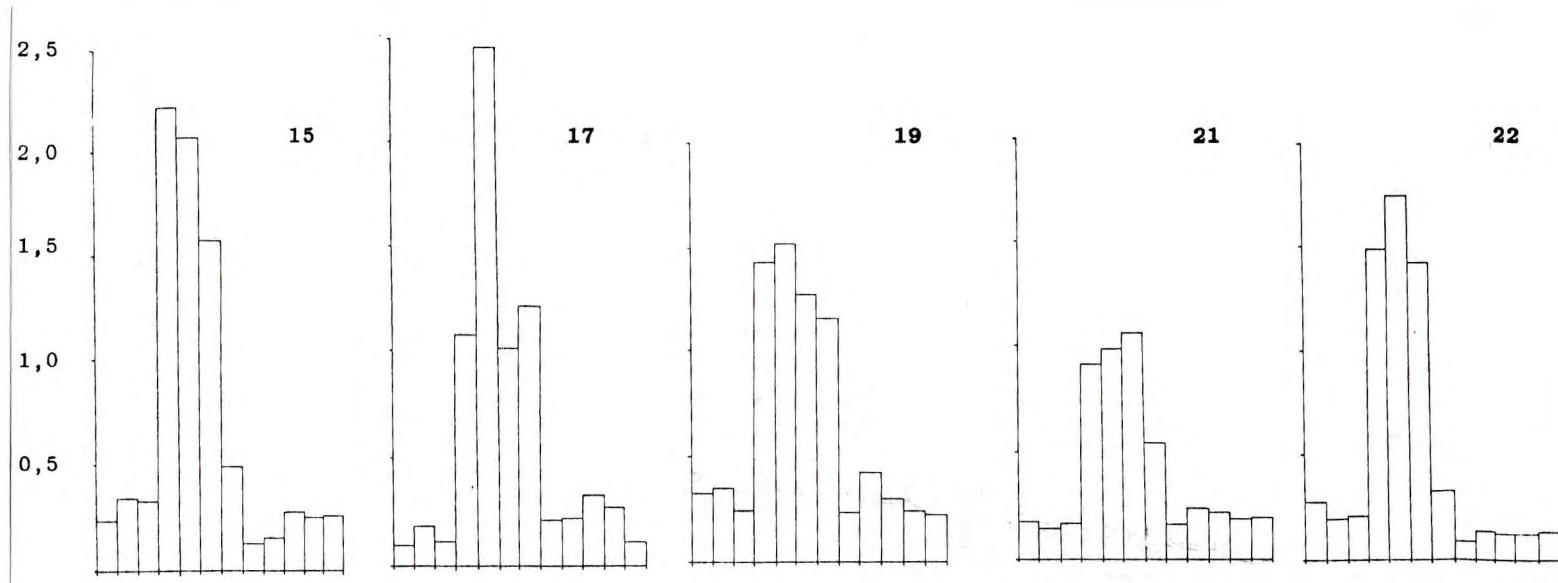


Abb. 1b: Monatliche Verteilung des Nadelfalles ( $t \cdot ha^{-1}$ ) auf den Bestandesboden  
in 15- bis 22-jährigen Aufforstungen mit Pinus taeda. Fazenda Monte  
Alegre, Paraná, 1981-82.

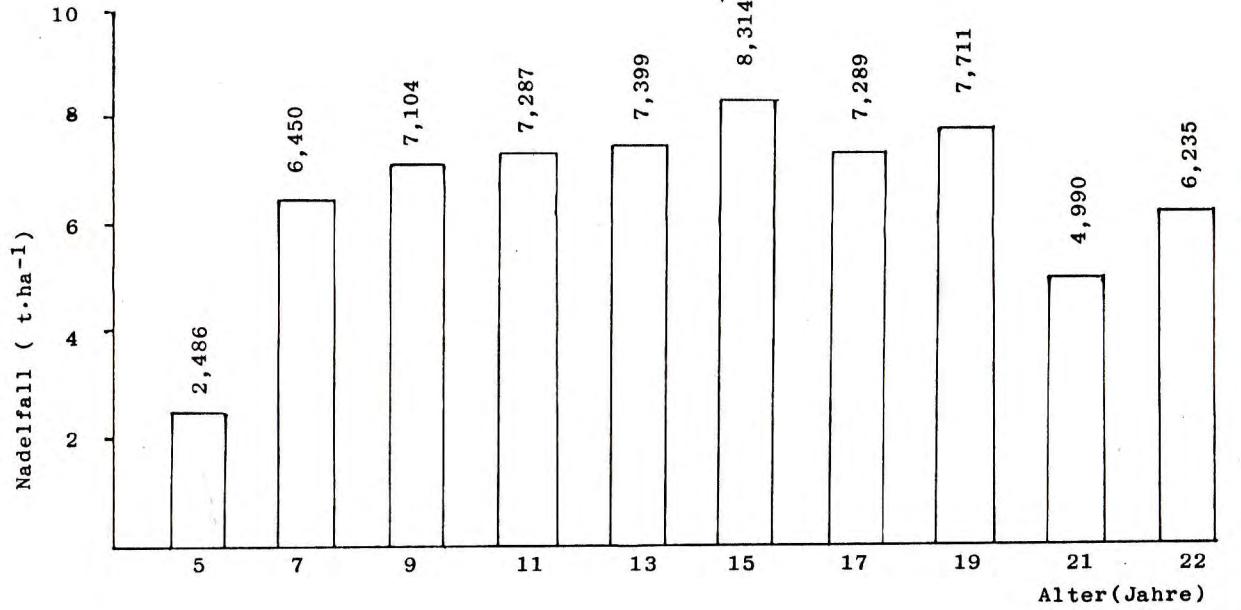


Abb. 2: Gesamter jährlicher Streufall ( $t \cdot ha^{-1}$ ) in 5- bis 22-jährigen Beständen mit Pinus taeda in Monte Alegre, Paraná, 1981-82.

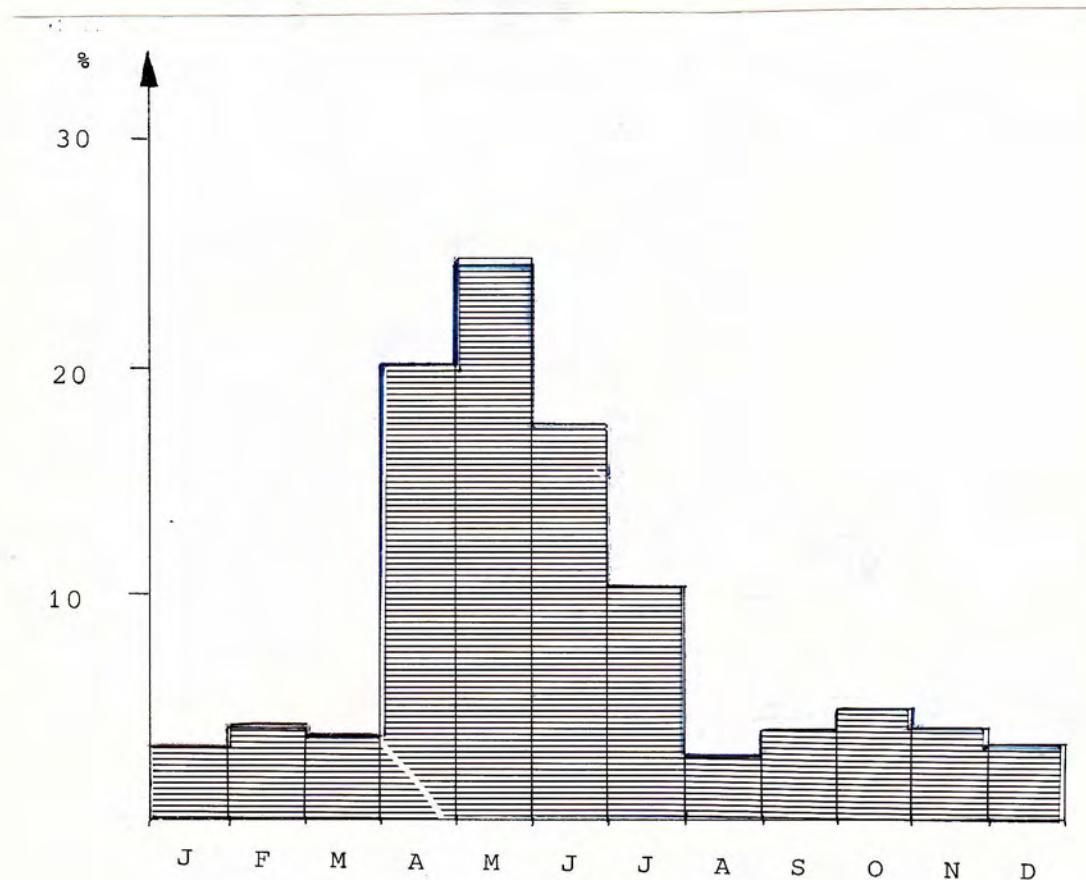


Abb.3: Durchschnittliche prozentuale Verteilung des Nadelfalles von Pinus taeda auf den Bestandesboden im Jahresgang. Fazenda Monte Alegre, Paraná, 1981-82.

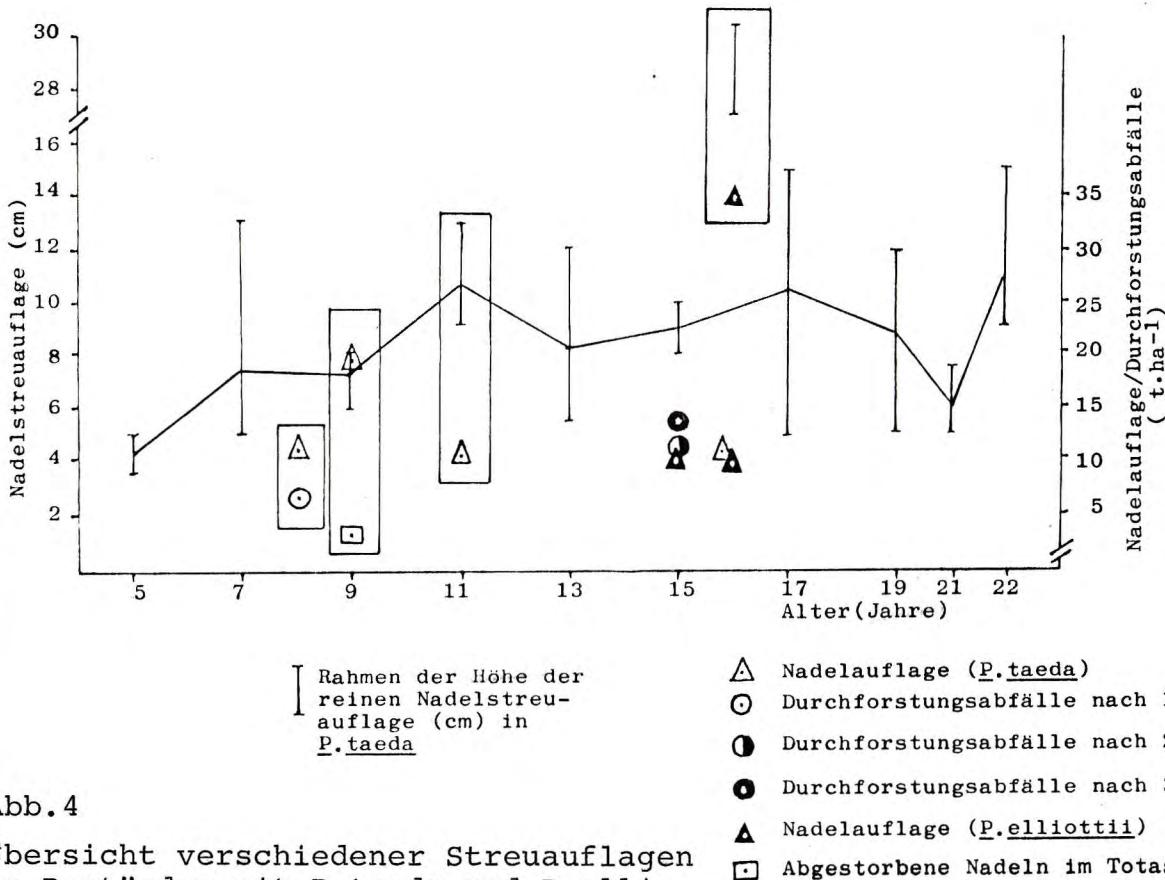


Abb. 4

Übersicht verschiedener Streuaflagen in Beständen mit P. taeda und P. elliottii in Paraná.

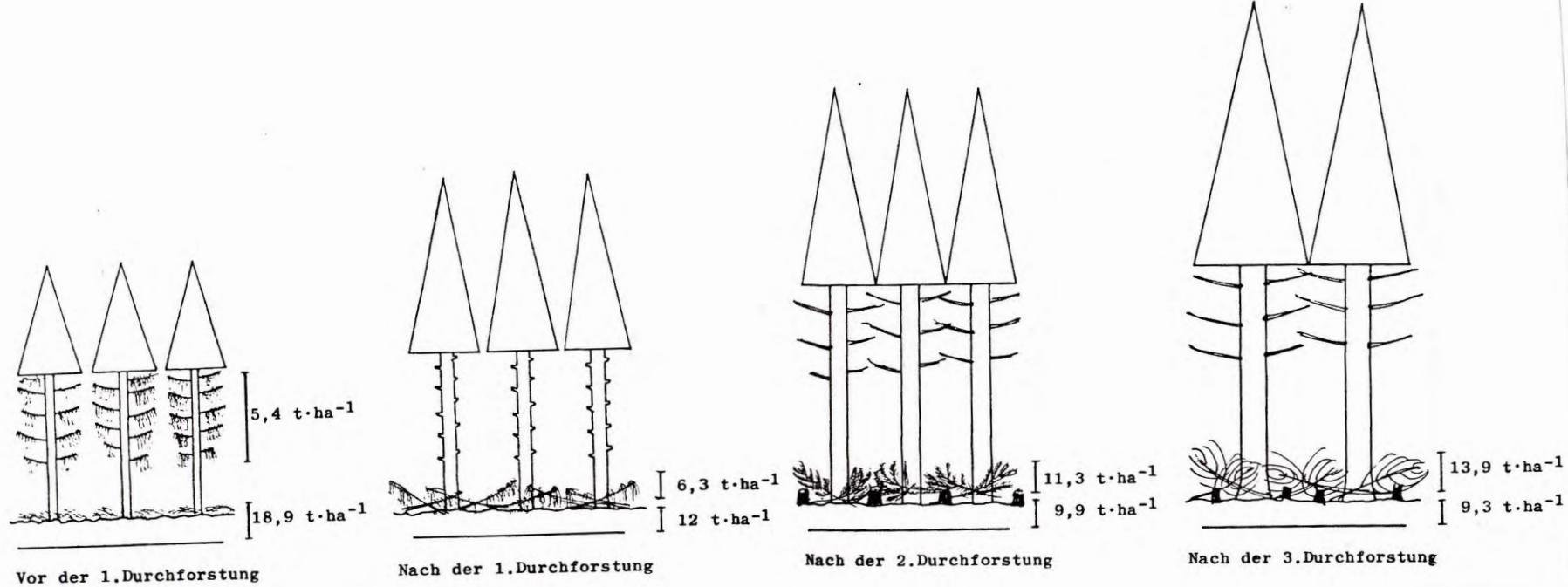


Abb.5: Beispiele von ermittelten Auflagegewichten der Nadelstreu und der Durchforstungsabfälle in verschiedenen Phasen der Bestandesentwicklung (P.taeda und P.elliottii). Fazenda Monte Alegre, Paraná.

### 3. Ergebnisse

#### 3.1 Der Komplex des Brennmaterials

Die Hochrechnung des Trockengewichtes der in den Streufallen aufgefangenen Nadeln auf den monatlichen Nadelfall in  $t \cdot ha^{-1}$  ist für die einzelnen Altersgruppen von P.taeda in Abb. 1a und 1b und der jährliche Streufall in Abb. 2 dargestellt. Abb. 3 zeigt, daß der anteilige monatliche Nadelfall als Mittelwert aller Bestände seinen Schwerpunkt in den Monaten April bis Juni mit zusammen 71,8% aufweist. Die Höhen der Streuauflagen und ihr Gewicht schwanken erheblich, ohne in einem Bezug zum Alter oder Durchforstungsstatus zu stehen: Bei Höhen zwischen 5 und 29 cm wurden Auflagegewichte zwischen 8,9 und 35,2  $t \cdot ha^{-1}$  gemessen (Abb.4). Die Auflage der Durchforstungsabfälle (bis zur Derbholzstärke) variiert ebenfalls beträchtlich. In Abb.5 sind vier verschiedene Bestandesphasen von P.taeda und P.elliottii exemplarisch dargestellt. Die im Totastraum hängengebliebenen Nadeln beliefen sich bei einem 9-jährigen Bestand mit P.elliottii vor der 1. Durchforstung auf ein Gewicht von  $5,4 t \cdot ha^{-1}$ .

#### 3.2 Feuerintensität

In den Streuauflagen, in denen sich bereits deutliche Schichten zunehmender Zersetzung (AooOL, AooF, AoH) ausgebildet haben, ist ein ausgeprägter Gradient des Feuchtigkeitsgehaltes mit zunehmender Tiefe vorhanden. In einem 15-jährigen Bestand mit P.elliottii betrug der aktuelle Feuchtigkeitsgehalt der AooOL-Schicht ( $4,5 t \cdot ha^{-1}$ ) 34,9%, der AooF-Schicht ( $4,3 t \cdot ha^{-1}$ ) 146,5%. Mit einer Feuerintensität von  $18,09 kJ \cdot m^{-1} \cdot s^{-1}$  wurden dabei insgesamt  $4,8 t \cdot ha^{-1}$  Auflagematerial verbrannt (Gegenwindfeuer). In einem weiteren Bestand mit P.elliottii konnte eine Dreischichtung des Feuchtigkeitsprofiles beobachtet werden (AooOL: 29,5%, AooF: 161,7%, AoH: 301,9%). Mit einer Feuerintensität von  $39,23 kJ \cdot m^{-1} \cdot s^{-1}$  wurden  $5,5 t \cdot ha^{-1}$  Streuauflage verbrannt (Gegenwindfeuer).

Der hohe Feuchtigkeitsgehalt der AooF-Schicht (219,2%) und die schwache AoooL-Auflage (Feuchtigkeitsgehalt 38,5%) erlaubten das Herausbrennen der hängengebliebenen Nadeln im Totastraum bei leichtem Gegenwind. Während auf dem Boden  $1,17 \text{ t} \cdot \text{ha}^{-1}$  AoooL-Streu verbrannt wurden, betrug die Reduzierung der abgestorbenen Nadelmasse aus dem Totastraum 70% ( $3,79 \text{ t} \cdot \text{ha}^{-1}$ ), wobei die Kronen zwischen 10 und 30% versengt wurden.

Das Herausbrennen der Nadeln aus sperrigen Durchforstungsabfällen in einem 15-jährigen Bestand mit P.taeda bei leichtem Mitwind und einer Intensität von  $455 - 1.290 \text{ kW} \cdot \text{m}^{-1}$  wurde aufgrund des starken Feuchtegradienten in der Streuauflage ermöglicht (AoooL: 35,6%, AooF: 230,0%).

### 3.3 Die Auswirkungen des Feuers auf den Standort

Die isolierende Wirkung der tiefer gelegenen, feuchten Streuschichten zeigen die Temperaturkurven in Abb.6, die bei einem Gegenwindfeuer geringer Intensität und einem Mitfeuer hoher Intensität in der Streuschicht und 0,5 m oberhalb gemessen wurden.

Bodenproben zur Untersuchung der Bodenfauna wurden in einem 15-jährigen Bestand mit P.elliottii im gebrannten Teil und der Kontrollfläche 9 Monate nach dem Brennen im Hochsommer und einem gleichaltrigen und -strukturierten Bestand 6 Wochen nach dem Brennen im Frühjahr entnommen (Abb.7 und 8). Die Unterschiede zwischen Brand- und Kontrollflächen sind statistisch nicht gesichert.

Die pflanzensoziologische Aufnahme in den untersuchten Beständen zeigte ein Jahr nach dem Brennen keinerlei Neuansiedlungen, so daß sich die Auswertung der Vegetationsaufnahme auf eine reine Zustandsanalyse der zuvor vorhandenen Bodenpflanzen beschränken mußte. Sie ist in Tab.2 nach Artmächtigkeit und Häufungsweise gekennzeichnet und Gruppen zugeordnet, die ihr

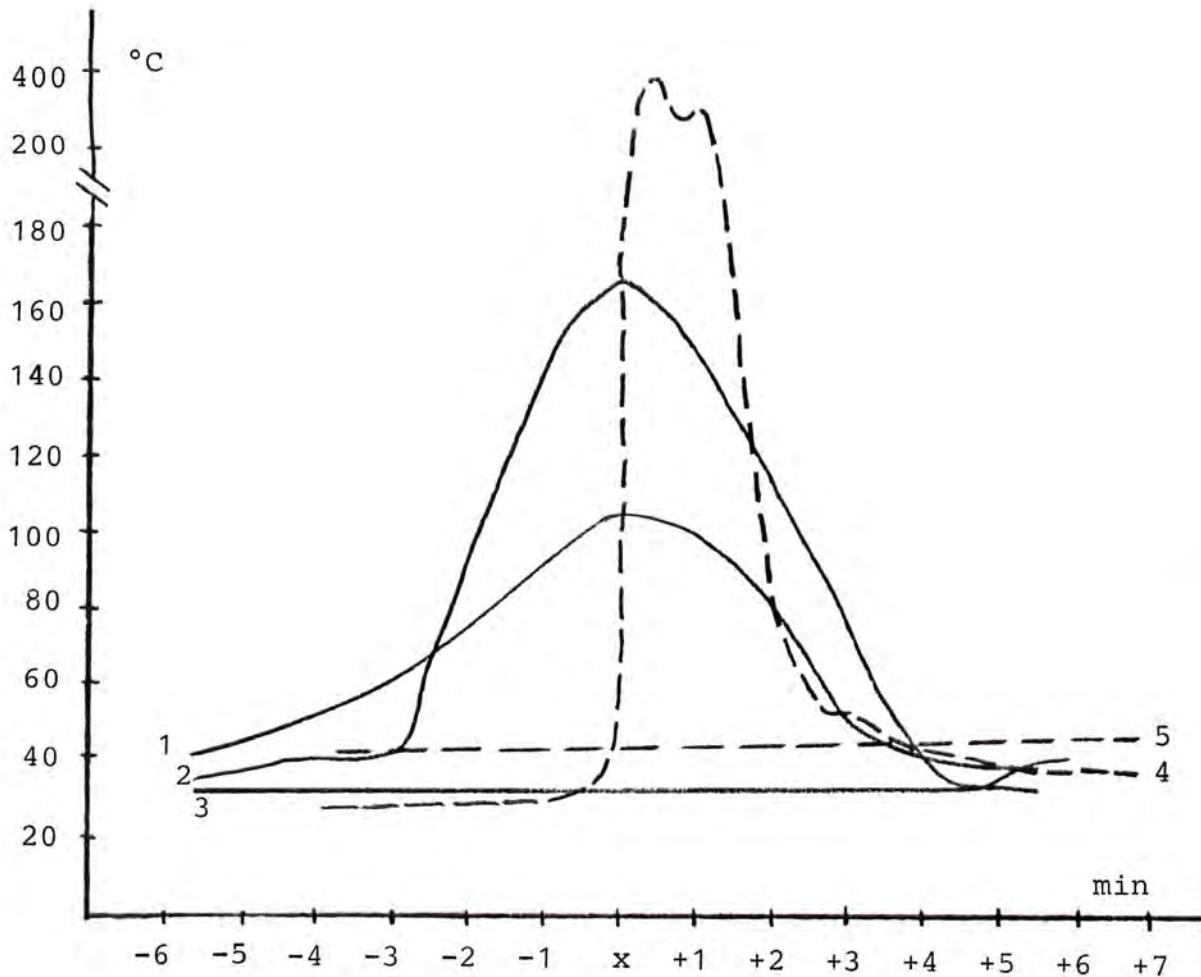


Abb. 6: Ausgeglichene Temperaturprofile beim Kontrollierten Brennen

Gegenwindfeuer (—) in einem 16-jährigen Bestand mit P.elliottii. Stärke der Streuschicht 20 cm. Feuchtegradient:  $A_{000L}=35\%$ ,  $A_{0H}=146\%$ . Feuerintensität:  $18,09 \text{ kJ} \cdot \text{m}^{-1} \text{s}^{-1}$ .

Mitwindfeuer (---) in einem 15-jährigen Bestand mit P.taeda. Stärke der Streuschicht 25 cm, Feuchtigkeitsgehalt 230%. Feuerintensität beim Herausbrennen der Nadeln aus den Durchforstungsabfällen:  $455,91-1290,73 \text{ kW} \cdot \text{m}^{-1}$  bei Flammenhöhen zwischen 1,3 und 2,1 m.

$x$  = Passierzeit des Feuers an der Meßstelle

Meßpunkte Gegenwindfeuer: (1) 50 cm über der Streuoberfläche  
 (2) Auf der Streuauflage  
 (3) Oberfläche des Mineralbodens

Meßpunkte Mitwindfeuer: (4) 50 cm über den Durchforstungsabfällen  
 (5) In der Streuschicht, 5 cm über dem Mineralboden

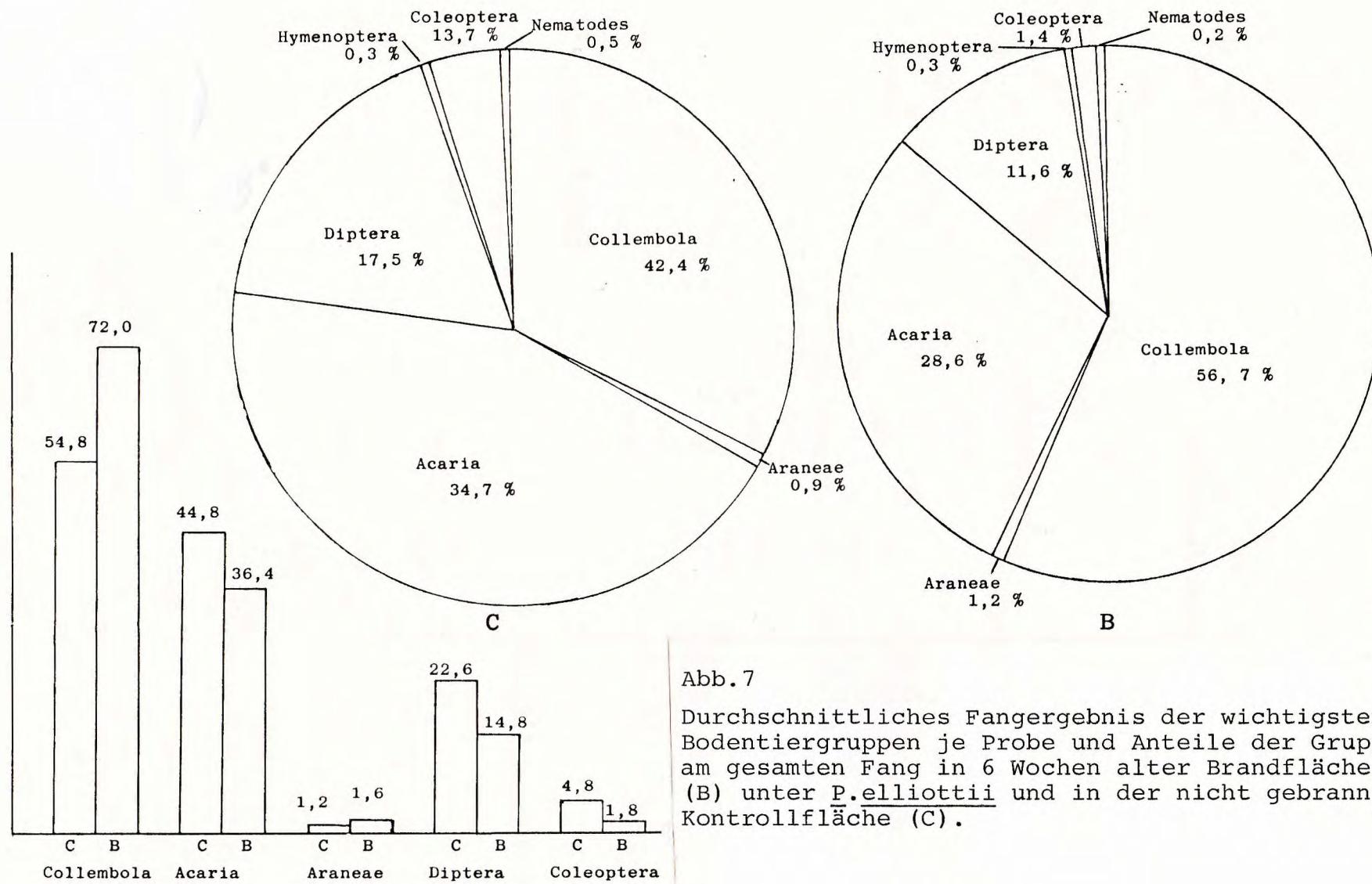


Abb. 7

Durchschnittliches Fangergebnis der wichtigsten Bodentiergruppen je Probe und Anteile der Gruppen am gesamten Fang in 6 Wochen alter Brandfläche (B) unter P.elliottii und in der nicht gebrannten Kontrollfläche (C).

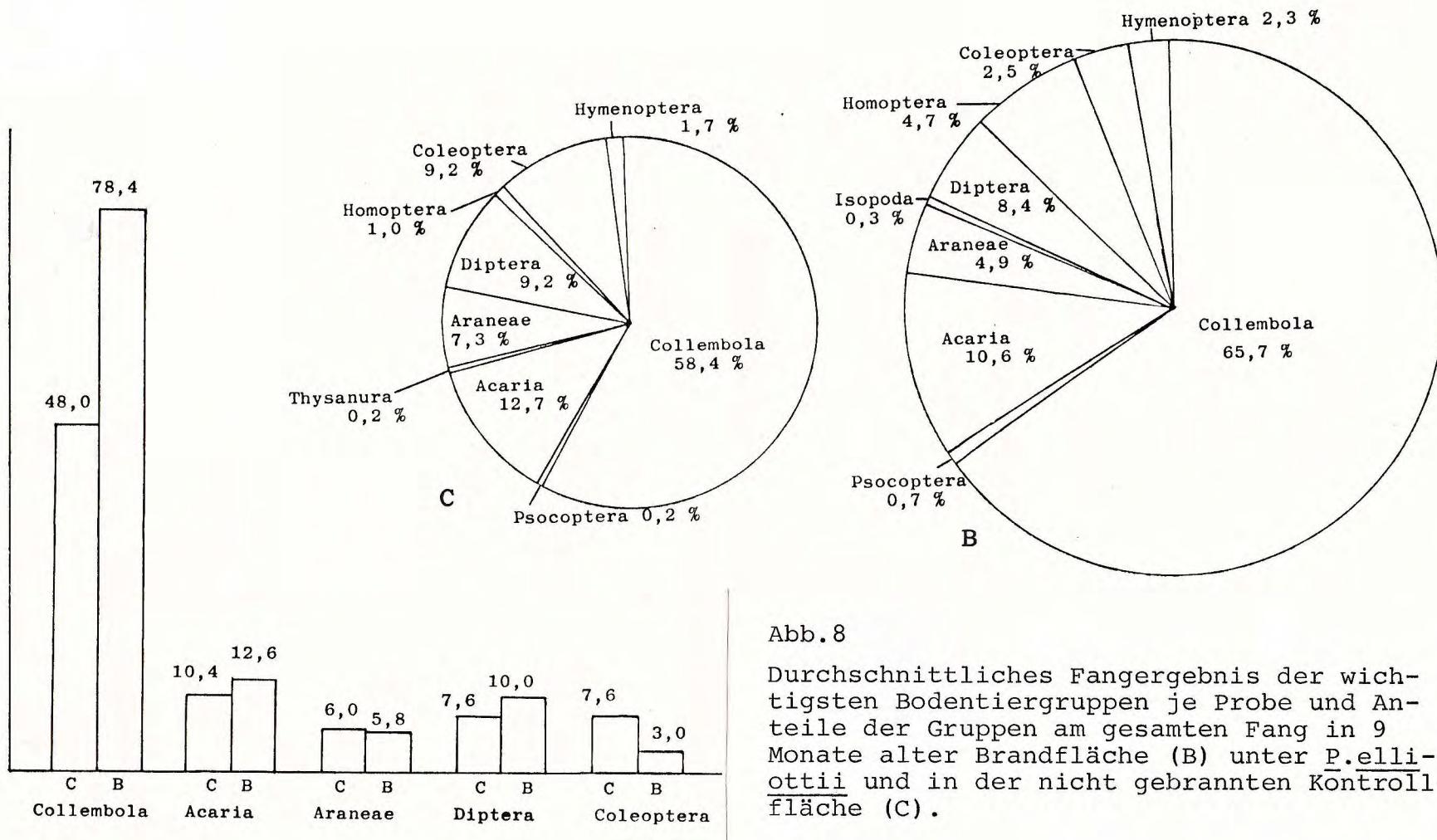


Abb. 8

Durchschnittliches Fangergebnis der wichtigsten Bodentiergruppen je Probe und Anteile der Gruppen am gesamten Fang in 9 Monate alter Brandfläche (B) unter P. elliottii und in der nicht gebrannten Kontrollfläche (C).

<u>Pflanzen mit Wiederausschlag</u>	<u>Pflanzen durch Feuer abgetötet</u>
<u>Ocotea puberula</u> (Lauraceae)	+.1
<u>Fagara kleinii</u> (Rutaceae)	+.1
<u>Vornonia</u> sp. (Compositae)	+.1
<u>Vacum</u> sp. (Sapindaceae)	+.1
<u>Compomanesia</u> sp. (Myrtaceae)	+.2
<u>Jacaranda puberula</u> (Bignoniaceae)	+.1
<u>Solanum sancta-catharinæ</u> (Solonaceae)	+.1
<u>Polystichum</u> sp. (Pteridophyta)	+.2
<u>Blechnum</u> sp. (Pteridophyta)	+.1
<u>Ilex paraguaiensis</u>	+.1
Rosaceae	+.1
Compositae	+.1
Myrcinaceae	+.1
Celastraceae	+.1
Rubiaceae	+.1
Celastraceae	+.1
Myrtaceae	+.1
Flacourtiaceae	+.1
	<u>Plexia</u> sp. (Orchidaceae)      .+.1
	<u>Rapanea ferruginea</u> (Myrsinaceae)      +.2
	<u>Maytenus</u> sp. (Celastraceae)      +.1
	<u>Nectandra</u> sp. (Lauraceae)      +.1
	<u>Eugenia</u> sp. (Myrtaceae)      +.1
	<u>Rubus</u> sp. (Rosaceae)      +.1
	Gramineae      +.2
	Melastomataceae      +.1
<u>Pflanzen z.T. abgetötet, z.T. mit Wiederausschlag</u>	
	<u>Podocarpus lambertii</u> (Podocarpaceae)      +.1
	<u>Leandra</u> sp. (Melastomataceae)      +.2
	<u>Allophylus edulis</u> (Sapindaceae)      +.1
	<u>Solanum</u> sp. (Solanaceae)      +.1
	<u>Piptocarpha</u> sp. (Compositae)      +.1
	Artmächtigkeit: + = spärlich od. sehr spärlich vorhanden, Deckungswert gering
	Häufungsweise: 1=einzel, 2=gruppenweise wachsend

Tab.2: Pflanzensoziologische Aufnahme nach Artmächtigkeit und Häufungsweise in den gebrannten Beständen 1 und 2. Brenndatum: April 1982. Kontrolle des Regenerationsvermögens: März 1982. Fazenda Canguiri, Paraná.

Regenerationsvermögen nach einem Jahr nach dem Brennen charakterisiert; Merkmale hierbei sind Wiederausschlag und vollständige Abtötung durch die Feuereinwirkung.

#### 4. Diskussion

Die jährliche Menge des Nadelfalles ist im Vergleich zu ähnlichen Untersuchungen in Pinus spp. wesentlich höher (HEYWARD and BARNETTE 1936, METZ 1952, WILL 1959, VAN LOON and LOVE 1973, POGGIANI 1981). Den synoptischen Auswertungen weltweiter Streuproduktion von BRAY and GORHAM (1964) und MEENTEMEYER et al. (1982) folgend dürfte dieses Ergebnis auf die Klimabedingungen und die geographische Breite zurückzuführen sein.

Das sehr uneinheitliche Bild der Höhe und des Gewichtes der Nadelstreuauflagen und der Durchforstungsabfälle bis zur Derbholzstärke wird durch die Standortsbedingungen und den Durchforstungsrhythmus bestimmt. Das einzige dynamische Modell der Brennmaterialauflage in Beständen mit P.taeda, das von JOHANSEN et al. (1976) von den sehr komplexen natürlichen P.elliottii-Vergesellschaftungen abgeleitet wurde, ist selbst im natürlichen Verbreitungsgebiet nur beschränkt anwendbar (US FOREST SERVICE 1978) und lässt sich aufgrund der unterschiedlich gehandhabten Durchforstungszyklen auf die südbrasilianischen Verhältnisse nicht übertragen.

Eine von SOARES (1979) durchgeführte Bestimmung der Brennmaterialauflage in 4,5- bis 7,5-jährigen Beständen mit P.oocarpa und P.caribaea var. hondurensis in Minas Gerais/Brasilien ( $20^{\circ}$  S) zeigt eine Entwicklung des Auflagegewichts von durchschnittlich 5,7 auf  $10,6 \text{ t} \cdot \text{ha}^{-1}$  innerhalb dieses Altersrahmens. Der Autor berichtet dabei auch von einer extremen Streuung und einem Höchstwert des Auflagegewichtes von  $17,3 \text{ t} \cdot \text{ha}^{-1}$ , wobei der Bestand allerdings nicht näher beschrieben ist.

Zusammenfassend kann festgestellt werden, daß die Menge der forstlichen Abfälle in den Kiefernaufforstungen von Paraná und in dem von SOARES (1979) gezeigten Beispiel von Minas Gerais erheblich höher ist als in den Ursprungsgebieten dieser Arten. Mit zunehmender Aufforstungsfläche und steigendem Anteil älterer Altersklassen ergibt sich hier in den nächsten Jahren ein wichtiger Ansatz für weitere Untersuchungen, die nicht nur als Grundlage für Entscheidungen im Feuer-Management, sondern auch für die potentielle Nutzung der Durchforstungsabfälle für die Energiegewinnung darstellen (s.a. CARVALHO 1982, BALLONI et al. 1982).

Der ausgeprägte Feuchtigkeitsgradient in den stärkeren Streuschichten lässt die Voraussagbarkeit und Steuerung des Feuerverhaltens zu. Damit lässt sich auch das locker gelagerte Brennmaterial ohne eine Gefährdung für den stehenden Bestand herausbrennen. Gleichzeitig wird die weitgehend zersetzte AooF/AoH-Schicht als Schutz des Mineralbodens erhalten.

Die Feuerintensität bewegte sich im Fall des 15-jährigen Bestandes mit P.elliottii mit  $18 \text{ kJ} \cdot \text{m}^{-1} \cdot \text{s}^{-1}$  an der Untergrenze des von McARTHUR (1962) für das kontrollierte Brennen in Waldbeständen gesetzten Rahmens. Die Tatsache, daß hierbei ca. 48% der "flash fuels" verbrannt werden konnten, zeigt die Notwendigkeit der Überprüfung dieses Modells auf, nach dem unterhalb einer Intensität von  $17,3 \text{ kJ} \cdot \text{m}^{-1} \cdot \text{s}^{-1}$  ein kontrolliertes Feuer als zu schwach und mit der Tendenz, leicht von alleine zu verlöschen, charakterisiert wird.

Die in Abb.7 dargestellten Temperaturentwicklungen auf der Mineralbodenoberfläche bzw. in der feuchten Streuschicht zeigen das Isolationsvermögen der intakt gebliebenen Streuauflage. Diese verbliebene Schutzschicht führt offensichtlich dazu, daß die Bodenfauna durch direkte oder indirekte Einflüsse des Feuers sowohl qualitativ als auch quantitativ nicht berührt wird, wie es nach Waldbränden bzw. heißem Schlagabbaum- oder Rohhumusbrennen beobachtet wurde (s.a. JAHN und SCHIMITSCHEK 1950, 1951,

KARPPINEN 1957, HUHTA et al. 1967, 1969, FELLIN and KENNEDY 1972, VLUG and BORDEN 1973). Hinsichtlich der in der Streu lebenden Milben und Springschwänze kann die vorliegende Beobachtung durch Untersuchungen gestützt werden, die zeigen, daß das Austrocknen der Streu und der jahreszeitliche Einfluß eine vertikale Abwärtsbewegung dieser Gruppen in die tiefer gelegenen - und hier durch Temperaturerhöhungen erwiesenermaßen wenig beeinflußten - Streuschichten und den Mineralboden mit sich bringen (USHER 1970, 1971, METZ 1971).

Die erwünschte Verbesserung der Keimungsbedingungen für Bodenpflanzen wird durch die belassene Streuschicht und den jährlichen Nadelfall allerdings nicht erreicht. Das beobachtete Ausschlagvermögen eines Teiles der Bodenpflanzen nach dem Durchbrennen kann durch den Schutz der Überdauerungsorgane im Mineralboden bzw. bodennaher Proventivknospen in der unteren Streuschicht erklärt werden.

Für den Einsatz des kontrollierten Feuers in den Kiefernaufforstungen Südbrasiliens läßt sich zusammenfassend feststellen, daß die Feuchtigkeitsverhältnisse in der Nadelstreuenschicht das Herausbrennen des locker gelagerten und daher leicht entzündlichen forstlichen Brennmaterials im Bestand erlauben. Die Feuerintensität hängt dabei von der Anordnung und Kompaktheit des Brennmaterials und der gewählten Brenntechnik ab. Bei der Heranziehung von Bodenflora und -fauna als Weiser für die Auswirkungen des Feuereingriffes zeigt sich, daß sich mit dieser Form des kontrollierten Brennens unerwünschte ökologische Nebenwirkungen weitestgehend reduzieren lassen.

##### 5. Schlußbetrachtung

Nach VOGL (1977, in NIERING 1981) können Ökosysteme in drei Feuer-bezogene Kategorien eingeordnet werden: Als feuerunabhängig, als durch Feuer begründet (Feuer-Folger) oder als feuerabhängig bzw. -angepaßt. Eine Einordnung der

Aufforstungen mit exotischen Kiefernarten in Südamerika in eine dieser Kategorien steht vor dem Dilemma, die Charakteristika einer feuerangepaßten und feuerabhängigen Baumart in Einklang mit einer Umwelt zu bringen, deren bioklimatische Eigenschaften eine Ausformung eines Feuerökosystems per se nicht zulassen.

Folgt man den synoptischen Betrachtungen von LOUCKS (1970) über die Stabilität von Pflanzengesellschaften, so führt der bewußte Ausschluß von periodischen Störungs- und Recyclingeingriffen zur Zerstörung der Formation. Das natürliche und das kontrollierte Feuer stellen einen solchen Störfaktor dar. Sein Ausschluß - oder das Nicht-Einbringen - aus den Kiefernaufforstungen Südbrasiliens hat eine Anhäufung von forstlichem Brennmaterial zur Folge, dessen freigesetzte thermische Energie bei Auftreten eines Waldbrandes in einer Trockenperiode zur Zerstörung des Ökosystems führen kann.

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## EFFECT OF FIRE ON THE PLANT ENVIRONMENT IN PINE FORESTS

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Read by Erhard Schaefer, Germany

Forest fires destroy plant biomass and bring about negative alterations in the forest environment, thus causing serious economic problems. During World War II and the time period directly after left enormous devastations of pure pine stands due to wild fires. Impairment of stands caused by fires contributed then to the occurrence of outbreaks of harmful insects, particularly in the western part of the country.

At present, nevertheless, the forest fires indicate an increasing trend, although they do not devastate large areas as in the period mentioned.

The number of fires grows. This is the phenomenon directly connected with economic activities in the forests as well as the increasing recreational penetration of forest. Under present conditions, there are only few fires which are caused by lightnings each years. The number of forest fires in 1975 amounted to 1920 (1818 ha), in 1976 to 3827 (6931 ha), in 1982 to 3798 (5752 ha); the number of fires caused by lightnings are: 11 in 1975, 8 in 1976, and 5 in 1982. This paper is limited to a complex discussion of the impact of fire upon forest environment. That is why only preliminary results of studies concerning the influence of temperature on woody plants are presented here.

High risk of fires in Polish forests results first of all from a considerable predominance of coniferous stands and from remarkable acreage under young plantations and young stands.

Pine stands of young age-classes, with particularly big amounts of inflammable material, are the at most exposed to the

Tab.1: Quantitative and percentual compilation of forest fires which occurred in 1970  
on various forest sites

Month		III	IV	V	VI	VII	VIII	IX	X	Total
Site										
Dry coniferous forest				14/9,6	24/12,8	22/14,1	20/16,5	9/14,0	1/20	90/12,1
Fresh coniferous forest			22/37,3	70/47,9	113/69,5	98/62,9	76/62,8	41/64,1	3/60	423/57,1
Moist coniferous forest			2/3,4	1/0,7	2/1,1	4/2,6	2/1,7	1/1,6		12/1,6
Fresh mixed coniferous forest	1/33,3	12/20,3	34/23,3	35/18,7	19/12,2	18/14,9	8/12,5	1/20		128/17,3
Moist mixed coniferous forest			5/8,5	4/2,7	1/0,5	6/3,8	1/0,8	2/3,1		19/2,6
Mixed deciduous forest	1/33,3	12/20,3	18/12,3	6/3,2		3/1,9	2/1,7	2/3,1		44/5,9
Fresh deciduous forest			2/3,4	1/0,7	1/0,5			1/0,8		5/0,7
Moist deciduous forest	1/33,4	2/3,4			2/1,1					5/0,7
Marshy deciduous forest										
Alderwood				2/1,4	1/0,5	2/1,3	1/0,8			6/0,8
Montane moist coniferous forest										
Montane coniferous forest				1/0,7	2/1,1	1/0,6				4/0,5
Montane mixed coniferous forest				1/0,7		1/0,6				2/0,3
Montane mixed deciduous forest		2/3,4								2/0,3
Montane deciduous forest								1/1,6		1/0,1
Total		3/100	59/100	146/100	187/100	156/100	121/100	64/100	5/100	741/100

occurrence and spread of fires. Stands in I and II-nd age class (0-20 and 21 to 40 years), occupy at present 50% of the forested area, i. e. ca. 4 mil ha. Table 1 presents the occurrence of fires in various types of forest sites in Poland. It shows the average distribution of fires according to site types in relation to the season of a year.

Contemporary science defines a forest as an ecological pattern, in which the elements of flora and fauna are linked along with the abiotic elements with interrelationships into a spatially outlined entity.

Factors of the abiotic nature, as light, water or temperature play an enormous role in the forest life. Each of the factors mentioned, while being in deficit or in excess, exerts a negative impact on the forest. Forest fire, as one of factors of abiotic nature, in light of studies carried out by the Forest Research Institute and other scientific units cooperating, seems to exert exclusively a negative impact on the forest. Such an opinion can be substantiated by following phenomena:

- charring of plant material in the course of burning,
- negative impact of high temperatures on plants and animals,
- negative influence of high temperature and burning process upon physical, chemical, and biological properties of forest soils.

The effect of high temperature associated with forest fires causes, depending on their duration and height, death of assimilation apparatus and cambium on tops of shoots, twigs, stems of trees, and root parts situated close to the soil surface. Particularly frequent is the destruction of foliage.

When one assumes that the temperature of 50°C is lethal to the cambium, then in the case of the total fire in a stand, i. e. the fire in the course of which the foliage of the plants is charred, the stand has to be removed. Damage and possibility of regeneration of the cambium in a tree stem, particularly in its

lower part, where air temperature and heat attains their highest values, is an important problem. Thermal killing of phloem and cambium in the lower part of a stem had been usually found.

Joint research carried out in 1974 by the Section of Forest Fire Protection, Forest Research Institute, and the Institute of Plant Biology, Agricultural University, enabled the preliminary determination of temperature of branches and litter burning just on the ground surface attained 540°C. The lowest values of this temperature amounted to 450-500 °C. Changes of temperature recorded at 3-second intervals, fluctuated around 1-2 °C. The temperature at the ground level increased from 495 to 561°C. The soil temperature at the depth of 3 cm in the course of these experiments ranged from 200°C (at the beginning) to 239°C after several minutes, and under a longer burning reached even 330°C.

Present studies on the impact of fire on trees, carried out by the Section of Forest Fire Protection, enabled the presentation of distribution of air temperature values, those of the layer of soil cover (litter, rooting wood) burning, and soil temperature recorded in the course of so-called controlled fire.

Table 2 presents temperature values measured at definite time intervals. Maximal temperature values measured at one minute intervals amounted to:

+ 200 cm -	83°C	- 21 minutes of fire
+ 130 cm -	190°C	- 21      "      "
+ 50 cm -	637°C	- 21      "      "
+ 5 cm -	825°C	- 23      "      "
0 cm -	515°C	- 38      "      "
- 5 cm -	132°C	- 115     "      "
- 10 cm -	100°C	- 115     "      "
- 20 cm -	70°C	- 150     "      "

Tab.2: Distribution of temperatures occurring during the fire of soil cover (°C)

Temperature measurements	Time of temperature measurement (min)								
	0	10	20	30	40	50	60	120	180
<b>A. Air temperature:</b>									
at the height of 5 cm	22	24	605	488	196	132	92	50	40
50 cm	20	67	378	60	43	40	38	38	38
130 cm	22	54	146	58	40	36	36	36	30
200 cm	22	37	60	30	36	30	30	30	26
<b>B. Soil temperature:</b>									
beneath the litter layer	24	24	68	380	437	344	372	78	50
at the depth of 5 cm	18	18	30	50	66	86	100	132	126
10 cm	16	16	16	20	40	58	70	100	96
20 cm	14	14	14	14	16	28	40	66	66

The nature of temperature impact on individual strata of vegetation and soil is to be seen from data contained in table 2 and the maximum values presented. One can see an obvious differentiation of air temperature in relation to the height above the ground level and thus an occurrence of real danger in the close-to-ground stratum of a tree stem. High air temperatures are caused by the direct action at the front of the fire in the forest, are short-in-time and dependent upon the general pattern of meteorological factors (i. e. the wind velocity). The temperature at the soil surface, directly beneath the layer of burning litter, is utmost dangerous for the survival of trees. It affects the root-collar and roots themselves and through its prolonged impact causes the killing of cambium, because even the thickest layer of bark is not resistant against temperature that risk. Presented values of soil temperature at individual depths also indicate their destructive action upon living organisms.

Measurements taken on several trees permit to draw few general conclusions about the insulative properties of the bark of pine trees. Individual trees behave quite differently. The bark thickness alone is not sufficient to determine accurately the penetration of high temperatures.

This statement was confirmed in numerous stands affected by fire. The bark on root collar, despite its rather considerable thickness, does not provide an efficient insulation against high temperatures as one would expect. Moisture probably decreases the insulating properties of bark at the root collar. The bark in higher locations is ever more dry than in the root collar and empty spaces are better insulation than those filled with water. Besides, air temperature values at these levels are by far lower (except for the short moments, when the fire front passes).

Recent studies on the mechanism the destruction of the foliage and cambium in pine trees by high temperature, as well as field observations, indicate that fire entirely destroys thickets and stands in the first age-class. Stands in the second age-class

also have a low chance of survival. Stands in older age-classes on poor sites, where root systems are less developed in the close-to-surface horizon, reveal better prospects for the survival after the ground fire. Similar stands on better sites are subject to destruction. This is a consequence not only of the distribution and the structure of the root system, but also of the accumulation of greater amounts of inflammable material in these stands. This material burns longer extending thus the duration of exposure of the root collar and the roots.

Recently, TV equipment was used in studies carried out by the Section on tree resistance against high temperatures. This equipment permits the measurement of temperature occurring inside the tree in relation to the distance from the external layer subjected to the impact of high temperature. Studies were only initiated, so final conclusions about the usefulness of this equipment cannot be drawn yet. It may be cited as an example, that in the case of a stem felled near the ground surface, within 2 hours after a not intensive fire (smouldering substrate) the mean value of temperature fluctuated from 54°C beneath bark to 22°C in the pith zone. However, the temperature within the bark zone exceeded 54°C and therefore, the cambium was destroyed.

From the thermograms produced in the course of experiments, it results that the value of temperature inside the wood depends on fire intensity. It should be added, that the mortality of stands occurs one year to three years after a fire and is of great economic significance. Quite frequently intensive mortality occurs in a stand of first class health. This leads, consequently, to the removal of the stand. At the same time through the destruction of the herbaceous layer and the litter fires adversely affect the chemical, physical, and biological properties of forest soils.

This is why, according to the statement in the introduction, the fire should be considered as a phenomenon with definably negative impact on forest environment.

## PESTS AND DISEASES ON PINE PLANTED AFTER WILDFIRES IN NORWAY

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### ABSTRACT

In comparison with several other countries, only small areas are hit each year by wildfires in Norway. On low productivity sites, however, some of the burned areas have shown difficulty in regenerating because of widespread attacks from fungi and insects. In low lying southern regions these may restrict the regeneration for a couple of years only. Under less fortunate climatic conditions other species of both fungi and insects may restrict the regeneration of Pinus sylvestris for longer than two decades.

I shall present results from one area with short-time damage, mainly caused by the fungus Rhizina undulata and the insects Hylobius abietis, Brachyderes incanus, and Strophosoma capitatum. All of these are dependent on dying tree roots for their propagation. Their attacks were thereby restricted to the first 2 to 3 years after the fire. The plants could therefore probably attain sufficient protection after one treatment with selected fungicides and insecticides under Norwegian conditions.

The long-lasting forms of damage were mainly connected to the fungus Gremmeniella abietina, while also Phacidium infestans and the insects Microdiprion pallipes and Rhyacionia duplana have attacked the plants. Even if it should be possible to protect the plants with frequent treatments with chemicals, this seems economically impossible on a practical scale. Artificial regeneration with P.sylvestris could therefore not be recommended in such areas, but Pinus contorta shows promising results so far.

## INTRODUCTION

Only small areas are hit by wildfires each year in Norway as compared to several other countries. During the period 1946 to 1974 the average was 470 ha of a total forest area of 7.5 mill. ha. In the dry summers of 1947, 1959, and 1976, however an average of 2000 ha forest land burned. After a widespread use of prescribed burning in parts of the country during the years around 1960, up to 1500 ha annually, this practice is carried out on a very small scale only within silviculture nowadays.

For natural reasons, most of the wildfires take place on low productivity soils, mainly sedimental sands with a vegetation of Calluna vulgaris, Cladonia spp. and P.sylvestris or shallow layers of moraine soil with C.vulgaris, Vaccinium vitis-idaea, V.myrtillus, and mixed stands of P.sylvestris and Picea abies. Areas with richer soils seem to present less severe problems in reforestation after burns. On areas of thick humus layers dominated by V.myrtillus and P.abies, a wildfire may usually improve the conditions for both natural and artificial regeneration.

I will therefore concentrate in this paper on problems faced in artificial reforestation of low productivity soils with P.sylvestris and furthermore on results from two different experimental areas with short- and long-time damages respectively.

### Short-time damage

The area hit by short-time damage covers 950 ha and is situated at a height of 240 m above sea level and at 61 degree north in the south-eastern part of Norway. It covers both sedimental, wind-transported sand and outwashed moraine soil. The fire took place in June 1976. Three year old (2/1) bare-rooted plants were planted in the spring of 1977. Dead plants were replaced in the spring both of 1978 and 1979. Results shown in Figures 1 and 2

are based on 8200 plants on sand and moraine soil, and in Figure 3 on 1280 plants from this and similar areas.

More than 50 per cent of the plants died during the first and another 42 per cent in the next year (Fig. 1). Some of these plants were killed by H.abietis. About 1/5 of the dead plants showed coherent bark gnawing around the lower part of the stem. A large part of the killed plants was dead after 3 to 4 weeks. Most of these dead plants were planted on areas adjacent to fresh stumps after the harvest of trees killed by the fire. These areas also carried large numbers of fruit bodies of the fungus R.undulata. Including also areas without stumps and fruit bodies there were found averages of 0.6 fruit bodies per sq.m in 1977 and 0.2 in 1978. Later no fruit bodies were found until some trees were felled at the edge of the burned area in 1979. This resulted in new Rhizina fruit bodies and dying of plants on the burned area close to the stumps in 1980. The fungus was isolated from roots of dead plants. Several earlier reports from other countries demonstrate the ability of this fungus to attack tree roots and kill the trees. It is therefore reasonable to suggest that this fungus is the main cause of the heavy losses of plants during the first two summers after the fire. The annual height increment has been increasing since planting(Fig. 1).

An experiment with the fungicide Benlate, started in the spring of 1978, also gives evidence to support this assumption. Three-year old (2/1) plants were dipped in a suspension with 0.3 per cent of the active compound Benomyl before planting or planted without this treatment in an area with fruit bodies of R.undulata. Nine per cent of the treated and 35 per cent of the untreated plants died during the first growth season. Later this fungus did not seem to be able to kill plants based on the stumps from 1976 not even after planting in the autumn of 1978. Benlate-treated one year old containerized plants planted on another area with large amounts of fruit bodies burned the previous year, had less than 10 per cent dead plants after two growth seasons. The effect of Benlate will be tested further in new experiments.

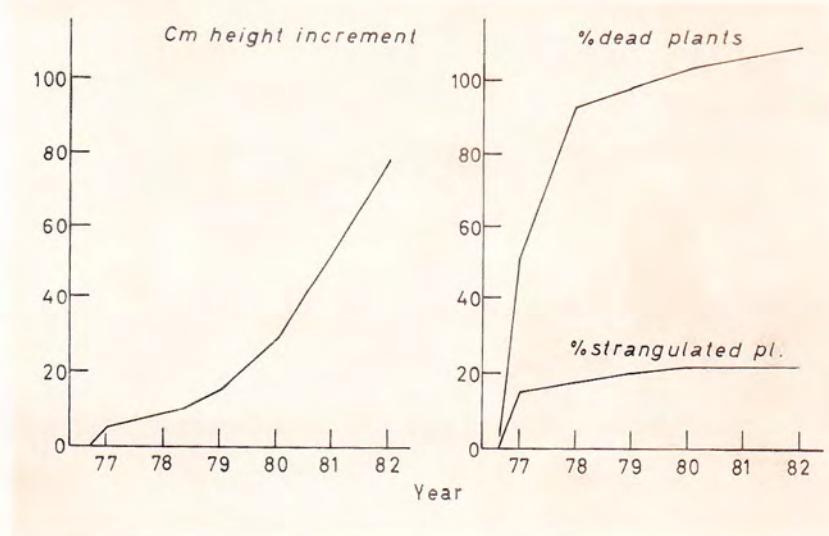


Fig.1

During the first growth seasons 93 per cent of the initial plant number died, approximately 1/5 of these were strangulated by Hylobius abietis (right diagram). The height increment was 80 cm during six growth seasons (left diagram).

The normal treatment with a DDT-suspension in the nursery before sale of plants gives insufficient protection against H.abietis and needle-eating insects which may be found in dense populations on burned areas. As shown before about 20 per cent of the plants were severely damaged by H.abietis (Fig. 1). In addition 82 per cent of plants on sand and 61 per cent of plants on moraine soil showed visible attacks by bark-eating insects until the autumn of 1979 (Fig. 2). Later very few H.abietis were caught in the area.

New experiments demonstrated that an additional treatment with DDT or Lindane before planting decreased the attacks, but that synthetic pyretroids such as Permethrin, Fenvalerat, and Ac 222.705 gave the best protection against H.abietis (Fig. 3).

The needle-eating insects were probably dominated by S. capitatum and B.incanus in the described area. These attacked 92 per cent of plants on sand and 61 per cent of plants on moraine soil during the first summer. New attacks hit 80 and 57 per cent respectively the next summer and 7 and 1 per cent in the third summer after the fire (Fig. 2). Despite the fact that most of the needles on each plant could be eaten, these attacks killed only a very small share of the plants. Because most of the consumed needles are developed after planting, a treatment before planting could not be expected to prohibit these attacks.

The reason for the rather short duration of 2 and 3 years for the damage caused by these organisms, is that the fungus as well as the insects are dependent on dying tree roots for their propagation on burned areas. When tree roots have been dead for some time, they are not fit for this purpose any longer. The fungus will then return to its inactive state, while the remaining insects withdraw from the area.

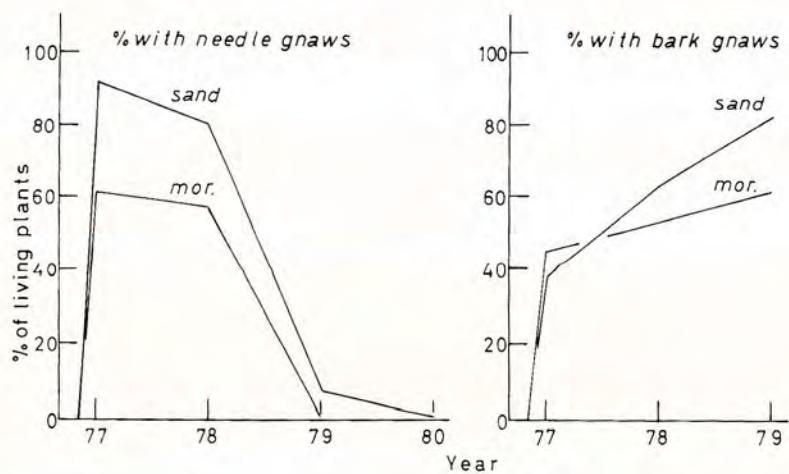


Fig. 2

Bark-eating insects attacked 82 per cent of living plants on sand and 61 per cent of plants on moraine soils during the three first growth seasons (right diagram). Needle-eating insects attacked 92 per cent of plants on sand and 61 per cent of plants on moraine soil during the first growth season and 80 and 57 per cent respectively in the next. In the third season only 1 and 7 per cent of the plants were attacked (left diagram).

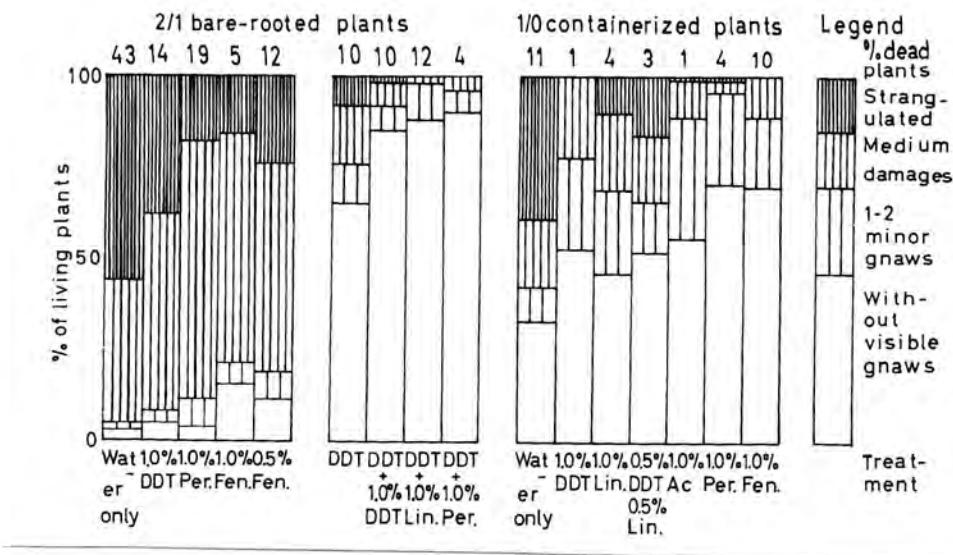


Fig.3

Compared to plants treated with water only, the chlorinated hydrocarbons DDT and Lindane (Lin.) decreased the attacks from bark-eating insects (right and left diagrams). Also treatment with DDT in addition to the normal DDT-spraying in the nursery decreased the attacks (central diagram). Synthetic pyretroids represented by Permethrin (Per.), Fenvalerat (Fen.), and Ac 222.705 (Ac) induced an even better protection. Concentrations are given as per cent active compound.

### Long-lasting damage

The area hit by long-lasting damage covers 150 ha and lies only 40 km north from the previously described area at a height of nearly 300 m above sea level. It covers sedimental sand with a vegetation of C.vulgaris and single trees of P.sylvestris, and in lower parts of Betula odorata, with heights of up to about 3 m. The fire took place in 1959, but earlier attempts of planting and seeding of P.sylvestris have been unsuccessful.

The first experimental plots were planted in 1976, close to the edge of the burned area, with three year old (2/1) bare-rooted P.sylvestris. A 5 cm layer of spruce bark was mixed into the soil before planting in one of the plots. Dead plants were replaced in 1978 and 1979. This was followed by planting of similar P.sylvestris plants in 1978 both on the burned area, and on a neighbouring part of an unburned area where the trees had just been harvested. At the same time one plot on the burned area was planted with one year old containerized P.contorta plants. Dead plants were replaced in 1979 in these new plots. Each plot comprises 440 plants, and 330 of these have been fertilized up to three times. Numbers given in text or on figures, however, are averages of both fertilized and unfertilized plants from each plot. Fertilization on soil without bark increased growth with a small percentage only because of the low cation exchange capacity.

For P.sylvestris, the percentage of dead plants increased with the age of plants and seems to reach 100 after a period of 8 to 10 years at the burned and after 6 years at the unburned area (Fig. 4). Slightly above 10 per cent of the plants on the unburned area were strangulated by H.abietis and near 60 per cent of living plants were attacked. Such attacks were not found at the adjacent part of the burned area, separated by a narrow forest road and a mantle of about 10 m. These attacks do not fully explain the differences in survival between the two areas.

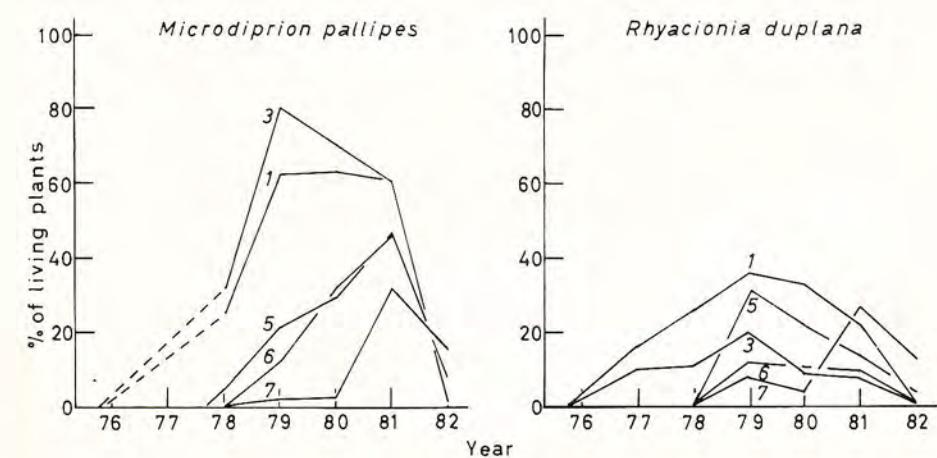


Fig. 5

The insects *Microdiprion pallipes* and *Rhyacionia duplana* attacked the largest share of plants in 1979 with up to 80 per cent of living plants for the first and 36 per cent for the last mentioned. These attacks were gradually reduced to between 15 and 1 per cent in 1982.

P.contorta has 7.5 per cent mortality so far, as against 50 per cent for P.sylvestris on the burned area, and 86 per cent on the unburned area after planting in 1978. The soil improvement with bark increased both the growth and the mortality. The annual height increment has been fairly constant throughout the period (Fig. 4). The growth is restricted both by lack of nitrogen and by attacking insects and fungi.

Climatic conditions in cooperation with fungal attacks are supposed to be the main reason for the accelerating mortality in P.sylvestris. As average for all P.sylvestris plots without bark, 48 per cent of living plants had at least one dead shoot within the spring of 1981. This number increased to 65 per cent until the autumn of 1982. In the bark-improved soil, with taller plants, as much as 77 and 89 per cent of the plants had dead shoots in 1981 and 1982 respectively. The pathogenic fungus G.abietina was identified from most of the dead shoots investigated in 1981. Also P.infestans was identified both years, but covered only a small percentage of the attacks - below 10 per cent - each year. When the weather conditions in the spring are favourable for this fungus, however, it may cause a large mortality in plants at this stage. P.contorta have shown promising resistance against these fungi with only 3 per cent of living plants with dead shoots so far.

Two insect species have attacked a large share of the P.sylvestris plants in parts of the experimental period. They attacked mainly the last year's needles or the tip of the new shoots, and were identified as M.pallipes and R.duplana respectively. Up to 80 per cent of living plants were attacked by M.pallipes and 36 per cent by R.duplana in 1979 (Fig. 5). M.pallipes seemed to prefer the tallest plants which grew in the bark-improved soil. The smaller plants from 1978 were consequently attacked most severely in 1981. The attack frequency was gradually reduced, and in 1982 below 8 per cent of P.sylvestris plants were found to have visible insect attacks. Probably because of a lower initial growth rate than for

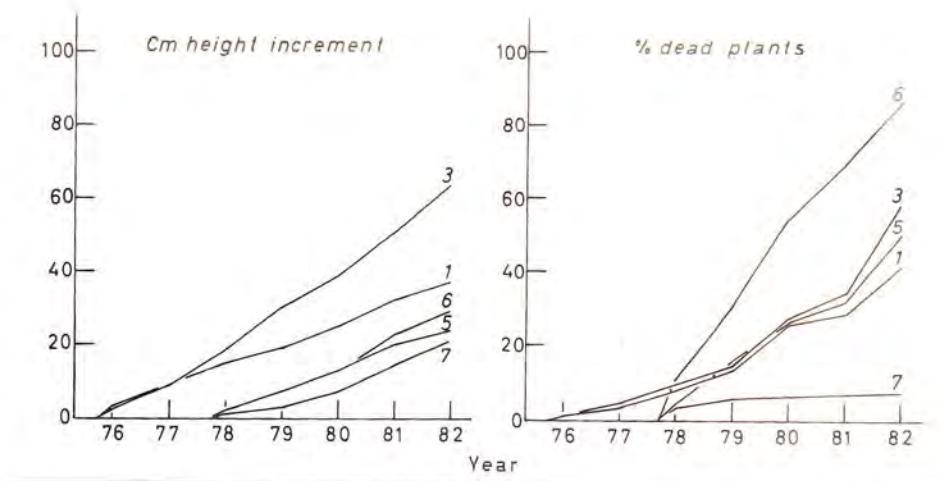


Fig. 4

The mortality increased with the age of plants and reached 42 per cent of the initial plant number on untreated soils (1) and 58 per cent after soil improvement (3) during seven growth seasons. After planting in 1978 the percentage of dead plants after five seasons was 86 per cent on unburned soil (6), 50 per cent on burned soil (5), while Pinus contorta had 7,5 per cent dead plants only on burned soil (7) (right diagram). The height increment was 36 cm during seven growth seasons on untreated soil (1), as against 63 cm after soil improvement (3). Planting in 1978 gave increments of 29 cm on unburned soil (6) and 24 cm on burned soil (5), while P. contorta grew 20 cm during these five growth seasons on burned soil (7).

P.sylvestris, P.contorta was attacked to a considerable smaller degree during the first 3 to 4 years. This species, however, showed the highest rate of attacked plants in 1982 with approximately 15 per cent for each of the insect species.

In the early spring of 1981 6 per cent of the plants from 1976, 30 per cent of P.sylvestris plants and 92 per cent of P.contorta plants from 1978 did not show insect attacks in the last year's needles nor carry dead shoots. No visible insect attacks were found on plants from natural regeneration with heights of approximately 1 to 3 m during the whole period.

Because of the nature of the insect attacks these are not supposed to make any important contribution to the mortality of P.sylvestris in this case. Even if newly started experiments with fungicides against G.abietina and P.infestans should indicate possibilities to reduce the high frequency of mortality for P.sylvestris, such treatments will be too expensive on these low productivity sites. It is reasonable to believe that the treatments have to be repeated annually - possibly twice each year.

### Conclusions

Short-time damage by R.undulata and H.abietis could probably be reduced to an acceptable level by treating the plants with Benlate and synthetic pyretroids before planting. On low productivity sites exposed to hard attacks by G.abietina and P.infestans all artificial regeneration should be carried out with P.contorta instead of P.sylvestris.

### Acknowledgements

I wish to express my sincere thanks for helpful cooperation to my colleagues at the Division of Forest Protection and for revision of the language to Mr. S. Walters.

## AUSWIRKUNGEN DES KONTROLLIERTEN BRENNENS AUF VEGETATION UND STANDORT AUF VERSCHIEDENEN BRACHE-VERSUCHSFLÄCHEN

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Seit 1975 werden im Auftrag des Ministeriums für Ernährung, Landwirtschaft, Umwelt und Forsten auf 16 verschiedenen Versuchsflächen in Baden-Württemberg Landschaftspflegeversuche durchgeführt (SCHREIBER 1977). Die Versuchsflächen tragen Grasland-Vegetation der Verbände *Arrhenatherion*, *Cynosurion*, *Trisetion*, *Calthion*, *Filipendulion*, *Molinion*, *Mesobromion*, *Violion caninae*, *Trifolion medii*, *Magnocaricion* und *Convolvulo-Agropyrion* (SCHIEFER 1981). Neben dem kontrollierten Brennen sind auch Varianten mit Mulchen, Mähen, Beweidung und ungestörter Sukzession eingerichtet. Das Brennen erfolgt im Winter (ca. 1.November - 15.März) mit dem Ziel einer teilweisen Beseitigung der Streudecke (SCHREIBER 1978, 1981, SCHIEFER 1982). Bei der Durchführung des kontrollierten Brennens wurden in einem Brennprotokoll folgende Kenngrößen erfaßt: Bewölkung, Windgeschwindigkeit, Temperatur, relative Luftfeuchte, Streufeuchte, Feuchtigkeit des Oberbodens, phänologischer Zustand der Vegetation, Feuerart, Feuergeschwindigkeit und Ergebnis des Feuereinsatzes (% der verbrannten Streu). Die Pflanzenbestandsaufnahmen erfolgten auf Dauerflächen, wobei wir die Bedeckung nach einer feinstufigen Skala geschätzt haben.

Die Veränderungen im Pflanzenbestand hängen im wesentlichen von der Feuerart und der Ausgangsvegetation ab. Sie lassen sich mit Hilfe der Wuchs- und Lebensformen der einzelnen Pflanzenarten kausal erklären (SCHIEFER 1981). Durch heiße Feuer werden vor allem Moose, Horst- und Rosettenpflanzen stark geschädigt, während sich Arten mit Rhizomen ausbreiten (Tab. 1; vgl. auch ZIMMERMANN 1979). Kalte Feuer verursachen meist keine direkten Schäden an der Vegetation, es kann jedoch auch hier zu kräftigen Bestandsveränderungen kommen, weil Brennen die Vitalität und Blühintensität einiger Pflanzenarten fördert. Während

Tab. 1: Verhalten einzelner Pflanzenarten bei kontrolliertem Brennen.

Mittlere Änderungen der Deckungsprozente innerhalb von 2-4 Jahren in einer unterschiedlich großen Anzahl von Dauerflächen ( ).

Reaction of several plant species upon prescribed burning.

Average changes in cover percentage during 2-4 years in a different number of permanent plots ( ).

	<u>ABNAHME</u> (decrease)		<u>ZUNAHME</u> (increase)
<u>Horstpflanzen</u> (caespitose plants)			
Festuca r. ssp. commutata	17,1 - 7,2 (5)	Poa pratensis	0,8 - 2,5 (5)
Trifolium pratense	2,0 - 0,7 (5)	Agrostis tenuis	7,5 - 16,6 (4)
Anthoxanthum odoratum	1,8 - 0,5 (4)	Veronica chamaedrys	1,5 - 2,6 (4)
Dactylis glomerata	6,6 - 1,8 (4)	Brachypodium pinnatum	4 - 30 (3)
Festuca pratensis	0,8 - . (3)	Polygonum bistorta	50 - 73,3 (3)
Briza media	1,4 - 0,2 (3)	Galium album	2 - 4,4 (3)
Cynosurus cristatus	1,4 - 0,1 (3)	Achillea millefolium	2,1 - 4,7 (3)
<u>Rosettenpflanzen</u> (rosette plants)			
Taraxacum officinale	1,8 - 1,0 (5)	Iris pseudacorus	0,5 - 4 (2)
Plantago lanceolata	2,1 - 0,5 (4)	Filipendula ulmaria	15 - 32,5 (2)
Hieracium pilosella	2,1 - 0,2 (3)	Agropyron repens	. - 3 (1)
Leontodon hispidus	0,6 - . (2)	Cirsium arvense	1 - 3 (1)
Hypochoeris radicata	0,3 - . (2)	Trifolium medium	40 - 70 (1)
		Galium verum	3 - 10 (1)

Brachypodium pinnatum auf brachliegenden Flächen meist steril bleibt, blüht es im ersten Jahr nach dem Brand sehr üppig und zeigt auch vegetativ einen höheren und dichteren Wuchs. Auch Molinia caerulea, Calamagrostis epigeios, Trollius europaeus, Thalictrum aquilegifolium, Rubus idaeus, Gentiana ciliata, G. germanica, Trifolium medium, Lathyrus tuberosus sowie Listera ovata ließen eine deutlich erhöhte Vitalität und Blühintensität erkennen. Die genannten Effekte sind weniger durch die beim Brennen frei werdenden Nährstoffe zu erklären, als vielmehr durch die Beseitigung der wuchshemmenden Streudecke und die dadurch bewirkte Temperaturerhöhung des Bodens sowie die erhöhte Lichtintensität in Bodennähe (vgl. HULBERT 1969, WEAVER und ROWLAND 1952). Die Förderung ihrer generativen und vegetativen Entwicklung verschafft diesen Pflanzen Konkurrenzvorteile, so daß sie sich ausbreiten können.

Brennen wirkt sich in vielfältiger Weise auch auf den Standort aus. So lag die Bodentemperatur in einem gebrannten Mesobrometum von März bis September in 5 cm Tiefe um 2-5°C höher als in der ungestörten Sukzession (Abb. 1; Brennbedingungen siehe Tab. 2). Das hatte eine Verfrühung der phänologischen Entwicklung einiger Pflanzenarten um 2-3 Wochen zur Folge. Salvia pratensis blühte auf der Brennparzelle in allen Versuchsjahren (1975-1982) 2-3 Wochen früher als auf der brachliegenden Fläche. Diese Unterschiede sind im wesentlichen durch die Streuschicht bedingt. Auf der Sukzessionsparzelle in Rangendingen bildet sich eine dichte Streudecke aus, die wie eine Isolierschicht wirkt und die Erwärmung des Bodens verzögert. Durch kontrolliertes Brennen wird die Streu beseitigt, wodurch diese Hemmung entfällt. In Arrhenatherion-, Filipendulion- und Calthion-Gesellschaften haben einzelne Bodentemperaturmessungen dagegen keine Unterschiede ergeben. In diesen Pflanzengesellschaften konnten wir auch bisher keine phänologischen Unterschiede beobachten. Die Streu wird hier wegen der frischen bis feuchten Standortsverhältnisse relativ schnell zersetzt, so daß sich keine geschlossenen, dichten Streudecken ausbilden.

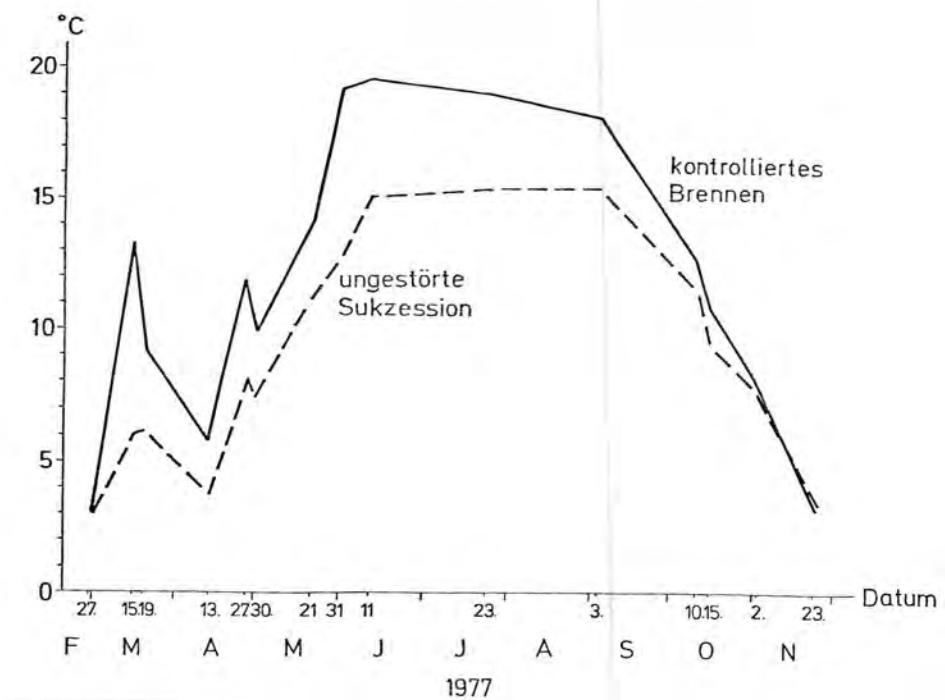


Abb. 1: Bodentemperaturen ( $^{\circ}\text{C}$ ) in 5 cm Tiefe auf der Versuchsfläche Rangendingen. Alle Messungen erfolgten nachmittags.

Standort: wechseltrockener Pelosol aus Gipskeuper, Mesobrometum arrhenatheretosum.

Soil temperatures ( $^{\circ}\text{C}$ ) in a depth of 5 cm on the plots "undisturbed succession" and "prescribed burning" on the experimental field of Rangendingen. All measurements took place in the afternoon.

Versuchsfläche experimental field	Brenntermin date of burning	Luft-temperatur air temperature (°C)	relative Luftfeuchte relative air humidity (%)	Wind wind (m/s)	Streu feuchte Ober-/Unterlage litter humidity upper-/under layer (% Wassergehalt) (% water content)	Streumenge litter quantity (dt/ha)	Feuerart fire type	unverbrennbare Streu unburnt litter (%)	Vegetation
									vegetation
Oberstetten	6. 3.79	8	70	3	20	25	GF	0	halbruderale Dauco-Arrhenatetum brometosum
	14. 2.80	5	72	2	21	27	GF	20	
	24.11.80	11	79	3	28	30	GF	20	
St. Johann	10. 3.76	2	gering	6-7	< 30	25	GF	0	Gentiano-Koelerietum, Subass. von Triisetum flavesrens
	7. 3.77	10	gering	3	< 30	20	GF	0	
	10. 3.78	8	mittel	2	< 30	20	GF	0	
	19. 3.79	10	62	2	18	30	GF	0	
	24. 3.80	8	mittel	3	20	25	GF	0	
	24.11.80	14	48	4	27/39	17	MF	30	
	12. 2.82	9	50	2	12/39	13	MF	15	
Rangendingen	3. 3.76	5	mittel	2	< 30	35	MF,BF	0	Mesobrometum arrhenatheretosum, brachliegend
	7. 3.77	12	85	1	30-50	20	BF	0	
	3. 3.78	28	57	0-5	13	30	BF	< 20	
	2. 3.79	24	44	3	15	25	GF	0	
	29. 2.80	6	81	0	14	20	BF	0	
	20.11.80	14	65	1	25/52	19	MF	10	
	25.11.81	3	60	3,5	31	10	MF	20	
	15. 2.78	-1	80	1	15/50	35	BF	40-50	
Rangendingen, außerh.d. Versuches									
Ebersbach	23. 3.81	14	65	5	25/46	70	MF	10	Filipenduletum

Tab.2: Kenngrößen und Rahmenbedingungen des kontrollierten Brennens auf verschiedenen Versuchsflächen. Unterstrichene Zahlen sind gemessene Werte, alle übrigen Angaben sind geschätzt. GF=Gegenwindfeuer, MF=Mitwindfeuer, BF=Bodenfeuer.

Parameters and conditions of prescribed burning on different experimental fields. Underlined figures are measured, all other data are estimated. GF=backfire, MF=headfire, BF=low fire

Beim Bodenwassergehalt waren auf zwei Versuchsflächen mit Mesobromion-Gesellschaften deutliche Unterschiede zwischen den Brenn- und Sukzessionsparzellen festzustellen. In Rangendingen lag er während der Vegetationsperiode 1981 in der Brennparzelle um 2-7% niedriger als auf den brachliegenden Flächen. Diese Unterschiede reichten bis in 20 cm Tiefe (Abb. 2). In St. Johann ließen sich diese Unterschiede nur von März bis Juni nachweisen, während sich die Verhältnisse ab Juli umkehrten (Abb. 3). Die Untersuchungen der Bodenwassergehalte in den Jahren 1976 und 1977 erbrachten tendenziell dieselben Ergebnisse. Der niedrigere Wert in der Brennparzelle dürfte im wesentlichen eine Folge der durch die Beseitigung der Streu erhöhten Evaporation sein. Nach unseren Untersuchungen gehen nur auf relativ trockenen Standorten mit Magerrasen die Bodenwassergehalte in den Brennparzellen zurück. Auf feuchten, niederschlagsreichen Standorten wiesen sie in den einzelnen Parzellen dagegen stets gleiche Werte auf.

Auf einigen Versuchsflächen haben wir bis zu drei Jahre lang die Stickstoffmineralisation nach der von ZÖTTL (1958), ELLENBERG (1964) und RUNGE (1970) entwickelten Methode untersucht, weil der Stickstoff der in erster Linie ertragsbestimmende chemische Wuchsfaktor ist; außerdem wird sie sehr stark durch die Standortsfaktoren beeinflußt. In St. Johann und Rangendingen lag die Stickstoffmineralisation der Brennparzelle in allen drei Jahren niedriger als in der ungestörten Sukzession (Abb. 4). Dies dürfte zum einen durch den auf gebrannten Flächen niedrigeren Bodenwassergehalt verursacht werden, zum anderen entweicht Stickstoff beim Brennen teilweise gasförmig, was einen Verlust bedeutet. Nachdem in den ersten Versuchsjahren teilweise heiß gebrannt wurde (Brennbedingungen siehe Tab. 2), und der N-Verlust bei heißen Feuern größer ist als bei kalten (AHLGREN & AHLGREN 1960, DAUBENMIRE 1968, GOLDAMMER 1978, MUHLE 1974, SCHREIBER 1978), dürfte diesem Gesichtspunkt durchaus Bedeutung zukommen. Auch der niedrigere Bodenwassergehalt ist auf diesen zur Trockenheit neigenden Standorten wahrscheinlich von erheblicher Bedeutung. Das zeigt sich auch darin, daß auf den gebrannten Parzellen der Nitrifikationsgrad, d.h. der prozentuale Anteil des

### RANGENDINGEN

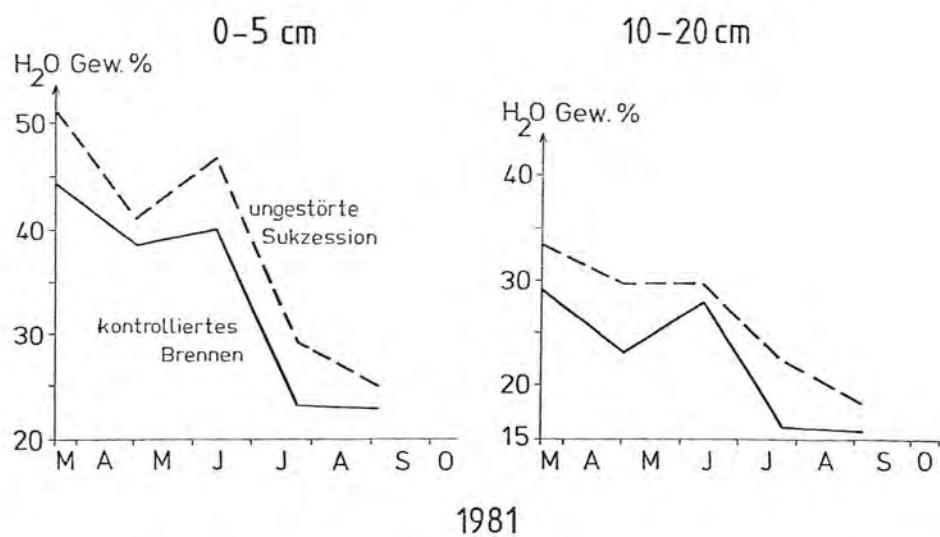


Abb. 2: Wassergehalt des Bodens an fünf Probenahmeterminen 1981 auf der Versuchsfläche Rangendingen. Standort: s. Abb. 1.

Soil moisture content on the plots "undisturbed succession" and "prescribed burning". Samples were taken on 5 days in 1981 on the experimental field of Rangendingen.

ST. JOHANN

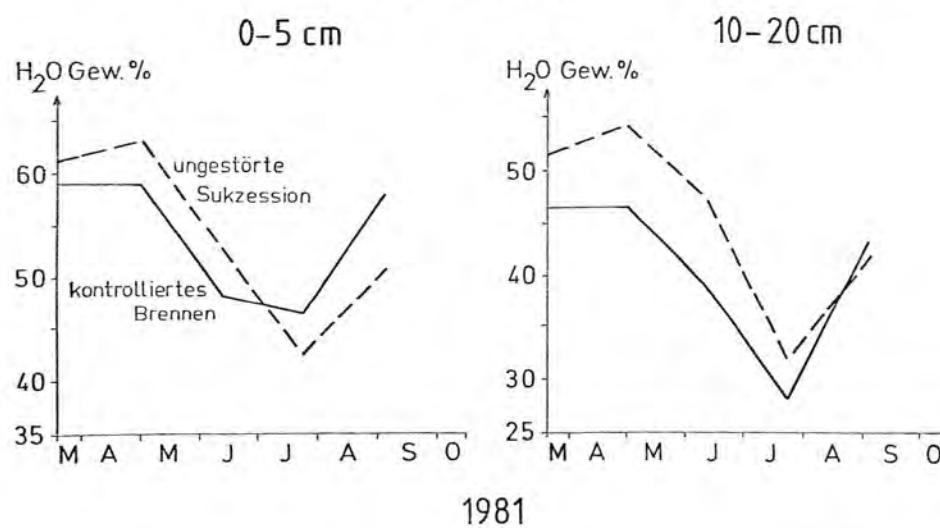


Abb. 3: Wassergehalt des Bodens an fünf Probenahmeterminen 1981 auf der Versuchsfläche St. Johann.  
Standort: mäßig trockene Braunerde-Rendzina  
aus Weißjura δ; Gentiano-Koelerietum, Subass.  
von Trisetum flavescens.

Soil moisture content on the plots "undisturbed succession" and "prescribed burning".  
Samples were taken on 5 days in 1981 on the experimental field of St. Johann

## Stickstoffmineralisation

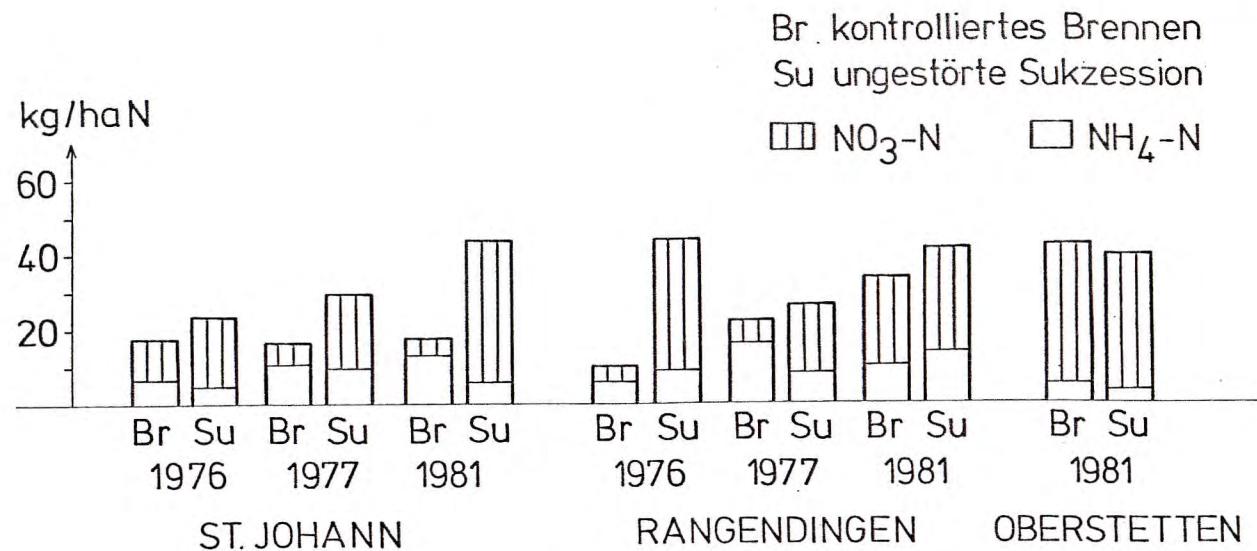


Abb. 4: Summe der Ammonium- und Nitratstickstoff-Akkumulation während der Vegetationszeit 1967, 1977 und 1981 in den Oberböden (0-20 cm) der Versuchsflächen St.Johann, Rangendingen und Oberstetten. Standort: St.Johann und Rangendingen s.Abb. 1 und 3. Oberstetten: mäßig trockene, kalkhaltige Terra fusca aus oberem Muschelkalk; halbruderale Dauco-Arrhenatheretum brometosum.

Sum of ammonia - and nitrate nitrogen accumulation on the plots "undisturbed succession" and "prescribed burning" during the vegetation period of 1976, 1977 and 1981 in the upper soils (0-20 cm) of the experimental fields of St.Johann, Rangendingen and Oberstetten.

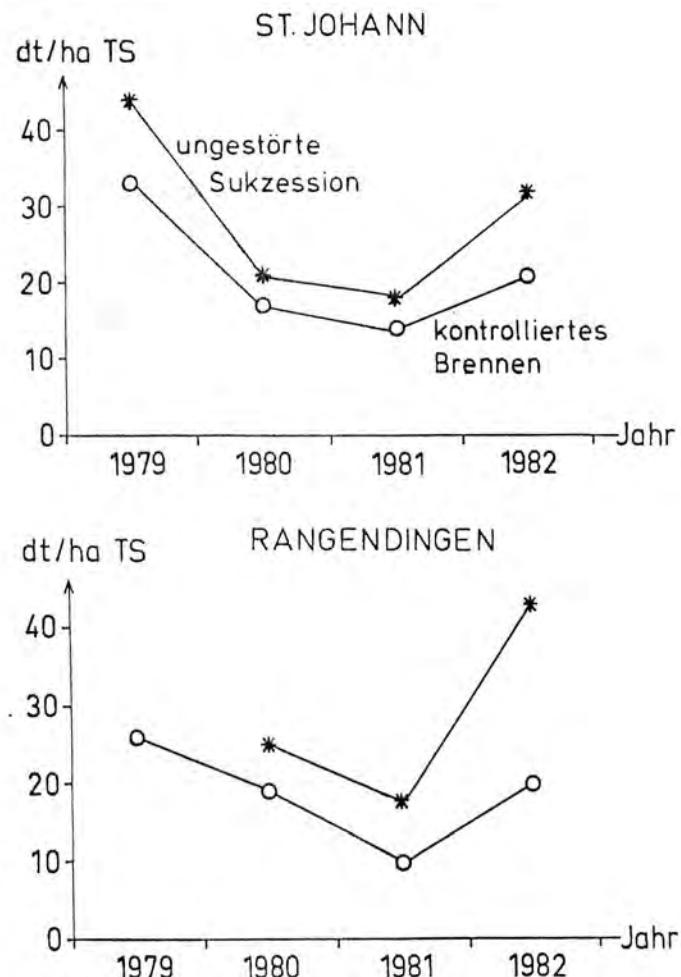


Abb.5: Erträge (dt/ha TS) auf den Versuchsflächen St.Johann und Rangendingen. Die Ertragsermittlungen erfolgten jeweils Mitte August.

yields (dt/ha dry matter) on the plots "undisturbed succession" and "prescribed burning" on the experimental fields of St.Johann and Rangendingen. Yield was constantly investigated in mid-August.

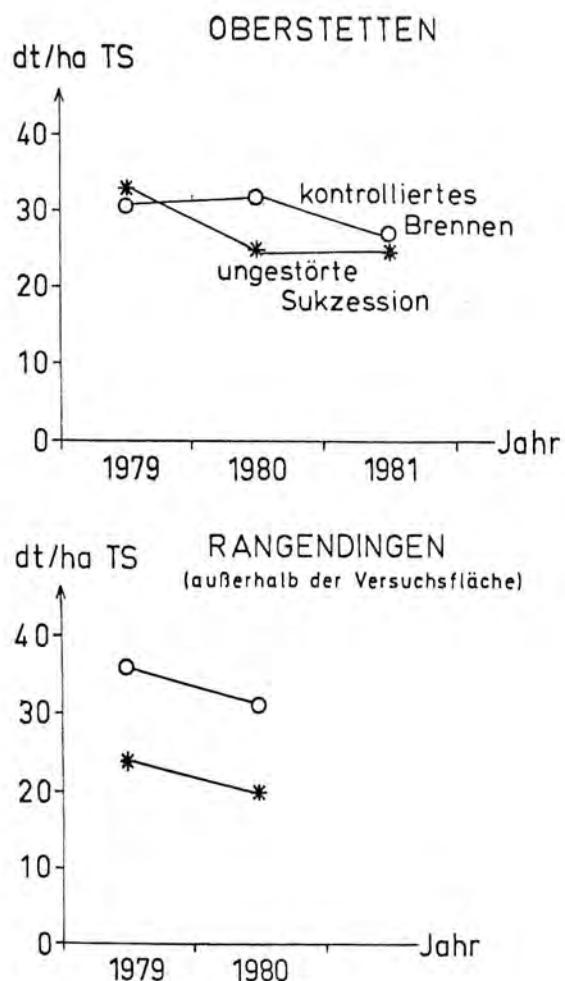


Abb.6: Erträge (dt/ha TS) auf den Versuchsflächen Oberstetten und Rangendingen (außerhalb der Versuchsfläche). Die Ertragsermittlungen erfolgten jeweils Mitte August.

Yields (dt/ha dry matter) on the plots "undisturbed succession" on the experimental fields of Oberstetten and Rangendingen (outside of the experimental field). Yield was constantly investigated in mid-August.

NO an der insgesamt mineralisierten Stickstoffmenge abnimmt. Die Nitrifikation sinkt nämlich bei unteroptimalen Wassergehalten stark ab, während die Ammonifikation in geringerem Maße vom Wassergehalt abhängig ist (RUNGE 1965). In Oberstetten dagegen lag die Stickstoffmineralisation der Brennparzelle geringfügig höher als in der Sukzessionsparzelle und der Nitrifikationsgrad wies gleiche Werte auf (Abb. 4). Der Vergleich der Bodenwassergehalte der Brenn- und Sukzessionsparzelle ergab hier keine signifikanten Unterschiede, und die Feuerintensität war in den letzten Jahren meist gering. Es zeigt sich, daß heiße Feuer - zumindest auf relativ trockenen Böden - die Stickstoffmineralisation und insbesondere die Nitrifikation verringern, während kalte Feuer die N-Mineralisation eher erhöhen.

Auf einigen Versuchsflächen haben wir seit 1979 die Erträge der Brenn- und Sukzessionsparzellen ermittelt. In St. Johann und Rangendingen kam es als Folge des Brennens zu einem Ertragsrückgang, während in Oberstetten und auf einer neben dem Versuch in Rangendingen gelegenen Fläche der Ertrag zunahm (Abb. 5 und 6). In St. Johann, Rangendingen und Oberstetten verhalten sich Erträge und Stickstoffmineralisation auf den beiden Parzellen gleichgerichtet. Dabei ist der Ertragsrückgang in St. Johann und Rangendingen sicherlich nicht allein durch die verringerte Stickstoffmineralisation bedingt, sondern auch durch eine Veränderung anderer Standortsfaktoren (z. B. des Bodenwassergehaltes). Darüber hinaus kommt auch der direkten Schädigung von Pflanzen durch heiße Feuer eine erhebliche Bedeutung beim Ertragsrückgang zu. Besonders erwähnenswert ist, daß die ertragsmindernde Wirkung eines heißen Feuers jahrelang nachwirken kann - vor allem durch eine nachhaltige Schädigung der Vegetation -, selbst dann, wenn in den Folgejahren kalt gebrannt wird. Bei kaltem Brennen kommt es dagegen eher zu einer Ertragszunahme (Abb. 6). In Rangendingen wurde am 15.2.1978 außerhalb der Versuchsfläche ein seit Jahren brachliegender Halbtrockenrasen kontrolliert gebrannt; es handelte sich um ein kaltes Feuer (Brennbedingungen siehe Tab. 2). Die gebrannte

Galium album und R.idaeus stark gefördert, so daß der Pflanzenbestand am 28.6.1982 in der Brennparzelle 100 cm hoch war, während er in der Sukzessionsparzelle erst 70 cm Höhe erreichte. Auch in Magnocaricion- und Phragmition-Gesellschaften werden die dominierenden Rhizom-pflanzen wie Carex gracilis, Carex acutiformis und P. communis durch heiße Feuer nicht geschädigt, so daß auch hier nach dem Brennen mit Ertragssteigerungen zu rechnen ist.

Abschließend wollen wir noch auf ein Problem hinweisen, das die Auswertung von Brennversuchen gelegentlich etwas erschwert. Auf jährlich gebrannten Parzellen ist es teilweise schwierig, die Veränderungen im Pflanzenbestand und in den Standortsbedingungen kausal zu erklären, weil die Brennbedingungen jährlich wechseln und besondere Feuerereignisse jahrelang nachwirken können. Beispielsweise vermag ein heißes Feuer den Pflanzenbestand so stark zu schädigen, daß es zu jahrelangen Ertragsdepressionen kommt und die entgegengesetzte, d. h. ertragssteigernde Wirkung kalter Feuer in den Folgejahren völlig überkompensiert wird. In diesem Fall ist es kaum möglich, die Vegetations- und Standortsveränderungen anteilmäßig den unterschiedlichen Feuerarten zuzuordnen. Deshalb schlagen wir vor, auf jährlich gebrannten Parzellen stets nur eine Feuerart und eine Feuerintensität anzuwenden. Die Wirkung unterschiedlicher Feuerarten und -intensitäten sollte auf verschiedenen Parzellen erforscht werden. Die Nachwirkung der einzelnen Brennbedingungen auf Vegetation und Standort kann am besten auf Parzellen mit mehrjährigem Brennintervall (Brennen jedes 2. oder jedes 3. Jahr) untersucht werden. Im Bereich des landwirtschaftlichen Versuchswesens sind diese Forderungen bei Düngungsversuchen seit langem erfüllt; hier werden oft über 10 Düngungsvarianten angelegt.

Die Analyse der Mineralstickstoffproben erfolgte in den Labors des Lehrstuhls für Landschaftsökologie der Universität Münster; für diese Unterstützung danke ich Herrn Prof. Dr. K.-F. Schreiber sehr herzlich.

Fläche zeigte im Sommer 1978 einen auffällig höheren und üppigeren Wuchs und war intensiver grün als der nicht gebrannte Teil. Die Ertragsermittlungen erbrachten im Jahre 1979 und auch 1980, d. h. in der 3. Vegetationsperiode nach dem Brennen, einen um etwa 50% höheren Ertrag als auf der danebenliegenden Brachfläche. Dieser jahrelang nachwirkende Ertragsanstieg als Folge eines einzigen kalten Feuers kann nur zum Teil damit erklärt werden, daß der Pflanzenbestand nicht mehr der wuchshemmenden Wirkung der Streu unterworfen war und daß beim Brennen größere Mengen pflanzenverfügbarer Nährstoffe freigesetzt wurden (vgl. GOLDAMMER 1978, SCHREIBER 1978, 1981), vielmehr ist die nachhaltige Wirkung auf die Phytomassenproduktion Folge einer Bestandsveränderung. So haben sich in diesem mäßig artenreichen, von Saumarten durchsetzten Halbtrockenrasen nach dem ersten Brennen Leguminosen (T. medium und L. tuberosus) kräftig ausgebreitet - auch andere Autoren berichten über einen Anstieg des Leguminosenanteils nach dem Brennen (DAUBENMIRE 1968, GOLDAMMER 1978). Die Leguminosen haben vermutlich den Mineralstickstoffgehalt des Bodens erhöht, so daß sich seit 1980 anspruchsvolle und ertragsreiche Arten wie Dactylis glomerata und Arrhenatherum elatius ausbreiten konnten. Es zeigt sich, daß es auch bei kaltem Brennen zu starken Bestandsveränderungen kommen kann, weil einige Pflanzenarten dabei stets gefördert werden. In Einzelfällen konnten wir sogar bei heißem Brennen kräftige Ertragssteigerungen feststellen. Die Pflanzenbestände dieser Versuchsflächen waren von Rhizompflanzen beherrscht, die gegen heiße Feuer gänzlich unempfindlich sind. Im Jahre 1981 haben wir in Ebersbach (Alpenvorland) einen neuen Versuch in einer brachliegenden Streuwiese angelegt. Die Brennparzelle wurde im März 1981 erstmals gebrannt; dabei war die Feuerintensität relativ hoch (Brennbedingungen siehe Tab. 2). Die Ertragsermittlungen im August 1982 ergaben für die Parzelle ungestörte Sukzession einen Ertrag von 55 dt/ha TS und für die Parzelle Brennen jedes 2. Jahr (gebrannt nur 1981) 67 dt/ha TS. Brennen hat in diesem Filipenduletum die dominierenden Rhizompflanzen Filipendula ulmaria, Lysimachia vulgaris, Inula salicina, Mentha aquatica, Phragmites communis, C. epigeios,

### Zusammenfassung

Heiße Feuer schädigen vor allem Moose, Horstpflanzen und Rosettenpflanzen, während sich Arten mit unterirdischen Ausläufern und Rhizomen ausbreiten. Durch kaltes Brennen wird die Vegetation zwar nicht direkt geschädigt, es kann jedoch auch hier zu Bestandsveränderungen kommen, weil die Vitalität und Blühintensität einiger Pflanzenarten gefördert wird.

Kontrolliertes Brennen bewirkt in Mesobromion-Gesellschaften - im Vergleich zu brachliegenden Flächen - von März bis September eine Erhöhung der Bodentemperatur in 5 cm Tiefe um 2-5 °C, was eine Verfrühung der phänologischen Entwicklung einiger Pflanzenarten um 2-3 Wochen zur Folge hat. In Arrhenatherion- und Filipendulion-Gesellschaften waren diese Wirkungen nicht zu beobachten. Auf gebrannten Flächen mit Mesobromion-Gesellschaften lag der Bodenwassergehalt während der Vegetationsperiode um 2-7% niedriger als auf Brachflächen. Auf feuchten, niederschlagsreichen Standorten waren dagegen keine Unterschiede nachzuweisen.

Heiße Feuer bewirken meist einen Ertragsrückgang, wobei dieser Effekt jahrelang anhalten kann. Umgekehrt erhöhen kalte Feuer die Phytomassenproduktion um bis zu 50%. Diese Ertragsunterschiede werden u.a. durch eine Erhöhung bzw. Verminderung der Stickstoff-Mineralisation verursacht. In Filipendulion- und Magnocaricion-Gesellschaften hat auch heißes Brennen eine ertragssteigernde Wirkung, weil die dominierenden Rhizompflanzen gegen Feuer völlig unempfindlich sind.

## SUMMARY

### Effects of prescribed burning on vegetation and soils on different landscape management sites

On behalf of the Ministry of Agriculture and Environment since 1975 different measures of landscape management are tested on 16 experimental fields in Baden-Württemberg. The experimental fields are covered with grassland vegetation in the broadest sense. Apart from prescribed burning there also exist experimental plots with mulching, mowing, grazing and undisturbed succession. Burning takes place in winter (1.11.-15.3.) with the aim of a partial removal of dead organic matter.

Hot fires are damaging first of all mosses, caespitose plants (e.g. Bromus erectus) and rosette plants (e.g. Hieracium pilosella), while species with rhizomes (e.g. Agrostis tenuis) are expanding their coverage. Cool fires do not damage the vegetation directly, however, changes in the plant stand are possible in this case too, because fire increases vigor and vitality of some species (e.g. Brachypodium pinnatum).

In Mesobromion communities prescribed burning effects - compared to undisturbed succession- an increase in soil temperature from March till September in a depth of 5 cm by 2-5°C; this causes a precocity of the phenological development of some species (e.g. Salvia pratensis) by 2-3 weeks. In Arrhenatherion- and Filipendulion communities these effects could not be observed.

On burnt areas with Mesobromion communities soil moisture was 2-7% lower during the vegetation period than on abandoned land. On moist sites, however, no differences could be proved. Hot fires result in a reduction of yield; this effect can hold for years. On the other hand cool fires increase the biomass production by up to 50%. These differences in yield are caused among other things by an increase respectively reduction of the nitrogen mineralization.

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## AUSWIRKUNGEN DES ABFLÄMMENS VON WEINBERGBÖSCHUNGEN IM KAISERSTUHL AUF DIE FAUNA - FRAGESTELLUNGEN UND ERSTE ERGEBNISSE

Klaus Lunau und Leo Rupp, Bundesrepublik Deutschland

Seit Mitte 1982 wird im Auftrag des Ministeriums für Ernährung, Landwirtschaft, Umwelt und Forsten Baden-Württemberg eine Untersuchung über die Auswirkungen des ortsüblichen Abbrennens der Weinbergböschungen auf die Fauna durchgeführt. Zum besseren Verständnis der Problematik sollen der Kaiserstuhl als das Untersuchungsgebiet sowie die historische Entwicklung des Abbrennens als Pflegemaßnahme kurz dargestellt werden, um vor diesem Hintergrund die Fragestellungen und die ersten Ergebnisse der Untersuchung zu schildern.

### DER KAISERSTUHL - DAS UNTERSUCHUNGSGEBIET

Der Kaiserstuhl erhebt sich wie eine Insel 300 Meter hoch über die Oberrheinebene, dieses aus dem Jungtertiär Gebirge vulkanischen Ursprungs ist nur 92 qkm groß. Seine für Mitteleuropa einzigartige Geomorphologie beruht auf einer Lößüberdeckung aus den vier Kaltzeiten des Pleistozäns. Durch seine klimatische Begünstigung - der Kaiserstuhl zählt zu den wärmsten und trockensten Gebieten Deutschlands - ist hier eine Lebensgemeinschaft mit einer für Deutschland einmaligen Tier- und Pflanzenwelt entstanden, die viele mediterrane und pontische Elemente aufweist (WILMANNS 1977a, WIMMENAUER 1977).

### ABBRENNEN ALS PFLEGEMASSNAHME - HISTORISCHE ENTWICKLUNG

Als Folge einer Änderung der Wirtschaftsstruktur im Kaiserstuhlgebiet von einer Mischwirtschaft, geprägt von Wein, Obst-, Getreideanbau und Viehhaltung zu einem intensiven Rebanbau entfiel die bisherige Nutzung und Pflege der Weinbergböschungen

(FISCHER 1982). Einst stellte das Mähgut der Rebböschungen einen bedeutenden Anteil des Viehfutters und bildete vor allem im zentralen Kaiserstuhl eine wichtige Grundlage zur Viehhaltung. Mit dem Rückgang der Tierhaltung nach dem 2. Weltkrieg wurde die traditionelle Bewirtschaftung der Böschungen in Form der Mahd als unzumutbare Mehrbelastung seitens großer Teile der Winzerschaft angesehen. Als alternative Pflegemaßnahme setzte sich das Abbrennen der Böschungsvegetation durch. Es kann damit nach Meinung der Winzer folgendes erreicht werden:

- Unterbindung des Aufkommens schattenspendender Gehölze
- Vermeidung der Entstehung einer dicken Streuauflage, die bei starker Durchnässung durch ihr hohes Gewicht zu Abrutschungen der Vegetationsnarbe führen kann.
- Schaffung und Erhalt einer ordentlichen Böschung nach Ordnungsvorstellungen mit gärtnerischem Vorbild.

Die Intensivierung des Weinanbaus hat zu einer Ausdehnung der Rebanbaufläche geführt, zudem wurde in verschiedenen Rebflurbereinigungen das ursprünglich kleinflächig terrassierte Rebgelände für den Einsatz von Maschinen neu gestaltet, dabei entstanden auch hohe und großflächige Böschungen. Die nun starke maschinelle Bearbeitung und der hohe Biozideinsatz auf den Anbauflächen ließen die Rebböschungen zu wichtigen Refugien der Tierwelt des gesamten Rebgeländes werden. Aus der Sicht des Naturschutzes ist daher die richtige Gestaltung und Pflege der Rebböschungen eine entscheidende Voraussetzung, um diese Standorte als Lebensräume für die typische Fauna der offenen Standorte des Kaiserstuhls in einer intensiv genutzten Reblandschaft erhalten zu können. Es bestehen erhebliche Bedenken und Hinweise, daß durch jährliches Abflämmen der Weinbergböschungen gerade die schützenswerten Arten des Kaiserstuhls vernichtet werden und eine allgemeine Feldfauna übrig bleibt, wie sie auf Kulturflächen mit vergleichbaren Störfaktoren vorgefunden wird. Vor allem in den sechziger Jahren wurden die Böschungen häufig geflämmt, seit 1975 besteht jedoch ein gesetzliches Flämmverbot. Von der Winzerschaft wird eine

Änderung der bestehenden gesetzlichen Regelung angestrebt; unterdessen wird ein Teil der Böschungen weiterhin illegal geflämmt.

#### ZIELSETZUNG

Die Versuchsplanung war so angelegt, daß unterschieden wurde zwischen

- den unmittelbaren Folgen des Abbrennens durch direkte Hitzeeinwirkung (Primärwirkung);
- sowie den Auswirkungen der Biotopveränderungen infolge des Abflämmens auf die überlebenden Tiere (Sekundärwirkung).

Dabei sollten hier nur Ergebnisse zur Primärwirkung dargestellt werden, da der geringe Untersuchungszeitraum weitergehende Aussagen noch nicht erlaubt. Das Feuer stellt für die betrachtete Tiergemeinschaft keinen natürlichen Standortfaktor dar, somit wurden in der Evolution keine Anpassungen an diesen Faktor erworben. Für die potentielle Gefährdung der Tiere ist daher der Entwicklungs- und Aktivitätszustand sowie der Aufenthaltsort zum Zeitpunkt des Feuers entscheidend.

#### CHARAKTERISIERUNG DES FEUERS

Von den verschieden exponierten Untersuchungsflächen sollen hier nur die Ergebnisse einer südexponierten Böschung vorgestellt werden, die 75 m lang und 6 bis 8 m hoch ist. Dort ist die für diese Exposition charakteristische Pflanzengesellschaft, ein *Diplotaxis-Agropyretum* ausgebildet (FISCHER 1982, WILMANNS 1977b). Das Flämmen wird von den Winzern an sonnigen Tagen der Wintermonate Dezember bis März durchgeführt, wenn die durch Frosteinwirkung abgestorbene Vegetation für eine gute Feuerentwicklung hinreichend abgetrocknet ist (siehe Abb. 1).



Abb.1: Abbrennen der Vegetation an einer südexponierten Böschung  
am 18.2.1983.

Der Feuchtigkeitsgehalt der Streu, die Windstärke und -richtung, die Höhe der Böschung sowie die Gefährdung der am Böschungskopf stehenden Reben werden bei der Art des Feuers berücksichtigt, das vom Fuß oder Kopf der Böschung als Mit- oder Gegenwindfeuer entzündet wird. Daraus geht hervor, daß diese Form des Abflämmens ein "kontrolliertes Brennen" darstellt (GOLDAMMER 1978). Mit Hilfe einer Thermoelementmessung, die einen Meßbereich von -100 bis +1000°C umfaßte, wurde der Temperaturverlauf kontinuierlich mit einem Kompensationsschreiber aufgezeichnet. Dabei wurden an einer Meßstelle jeweils drei Meßfühler in verschiedenen Höhen über der Bodenoberfläche angebracht (-1 oder 0 oder 1, 5, 12 cm). Es zeigte sich in vielen Messungen folgender charakteristischer Temperaturverlauf (siehe Abb. 2):

- Nachdem das Feuer die Meßstelle erreicht hat, steigt die Temperatur in wenigen Sekunden bis zum Maximum an.
- Das Temperaturmaximum liegt in 5 und 12 cm Höhe über der Bodenoberfläche bei 700°C.
- Auf der Bodenoberfläche liegt das Temperaturmaximum, je nach Feuchtigkeitsgehalt der Streu zwischen 150 und 450°C.
- Meist bleibt der untere, feuchtere Teil der Streuauflage unverbrannt, so daß im Mineralboden nur geringe Temperaturerhöhungen von wenigen °C gemessen wurden.
- Die Phase der Temperaturabnahme dauert länger als die Phase des Temperaturanstiegs. Besonders ausgeprägt ist dies auf der Bodenoberfläche.
- Eine Temperatur von 100°C wirkt auf der Bodenoberfläche ca. 2 Minuten, in größeren Höhen etwas kürzer auf die Tierwelt ein.

Zimmermann (1979) fand einen ähnlichen Temperaturverlauf beim Abflämmen von Halbtrockenrasen im Kaiserstuhl. Um das Ausmaß der unterschiedlich hohen Oberflächentemperaturen flächendeckend kartieren zu können, wurden unmittelbar nach dem Feuer Infrarot-Aufnahmen der Böschungsoberfläche gemacht. Dabei wird die von der Böschung ausgehende Infrarotstrahlung in einem Wellenlängenbereich von 8 bis 13 Mikrometer erfaßt und die Flächen gleicher Temperatur durch bestimmte Farben auf einer

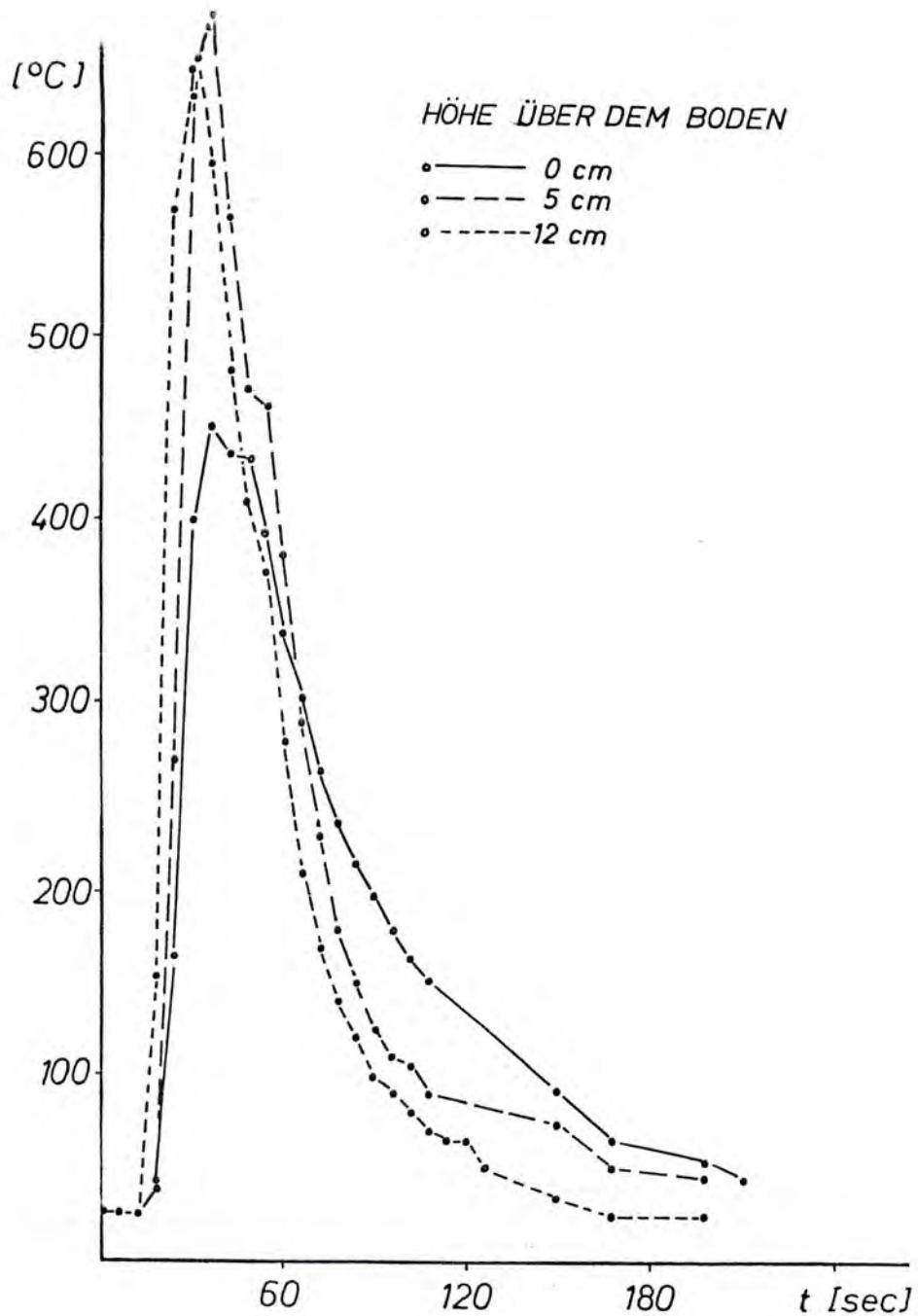


Abb. 2: Temperaturverlauf auf einer südexponierten Böschung am 23.2.1983.  
Relative Luftfeuchtigkeit: 45 %  
Lufttemperatur: 2 °C  
Wassergehalt der Streu (bezogen auf das Trockengewicht): 20 %  
Entzündung des Feuers am Böschungskopf

Polaroidaufnahme dargestellt.

Durch diese flächenhafte Kartierung konnte im Falle einer südexponierten Böschung fünf Minuten nach dem Passieren des Feuers ein Mosaik unterschiedlich hoher Oberflächentemperaturen nachgewiesen werden. Bei einer Lufttemperatur von 5°C traten auf Teilflächen noch Temperaturen von mehr als 125°C auf. Eine über die Fläche integrierte Messung mit einem Radiometer, das im Prinzip genauso arbeitet wie das Strahlungsthermometer für die Infrarot-Thermographie ergab eine Durchschnittstemperatur zum selben Zeitpunkt von 30°C.

Der Vergleich des geflammten und des ungeflammten Teils einer südexponierten Böschung 15 Minuten nach dem Abflämmen veranschaulicht das Mosaik von Oberflächentemperaturen, das lange nach dem Erlöschen der Flamme anhält. Die Farben der Polaroidaufnahme wurden auf einer Zeichnung in entsprechende Graustufen übertragen (Abb. 3).

#### EINFLUSS DES FLÄMMENS AUF VERTRETER DER VORWIEGEND EPIGÄISCHEN FAUNA

##### METHODE

Zur Erfassung der auf der Bodenoberfläche aktiven Tiere wurden Bodenfallen und Boden-Photoelektoren verwendet. Auf der Brandfläche und der entsprechenden Kontrollfläche (ungebrannt) befanden sich je vier Barberfallen mit einem Fallendurchmesser von 14,6 cm. Die Bodeneklektoren (Abb. 4) hatten einen quadratischen Grundriß, wobei zwei Seiten angeschrägt waren, damit die Spitze des Pyramidendaches auf den steilen Böschungen senkrecht nach oben ragte. Die vier Seiten des Daches waren mit Stahlgaze bespannt. Mit Hilfe von vier Bodenfallen (5 cm Durchmesser) konnten oberflächenaktive Tiere in der abgegrenzten Innenfläche erfaßt werden. Flugaktive Tiere wurden in Flaschen an der Dachspitze abgefangen. Mit je vier Bodeneklektoren auf den

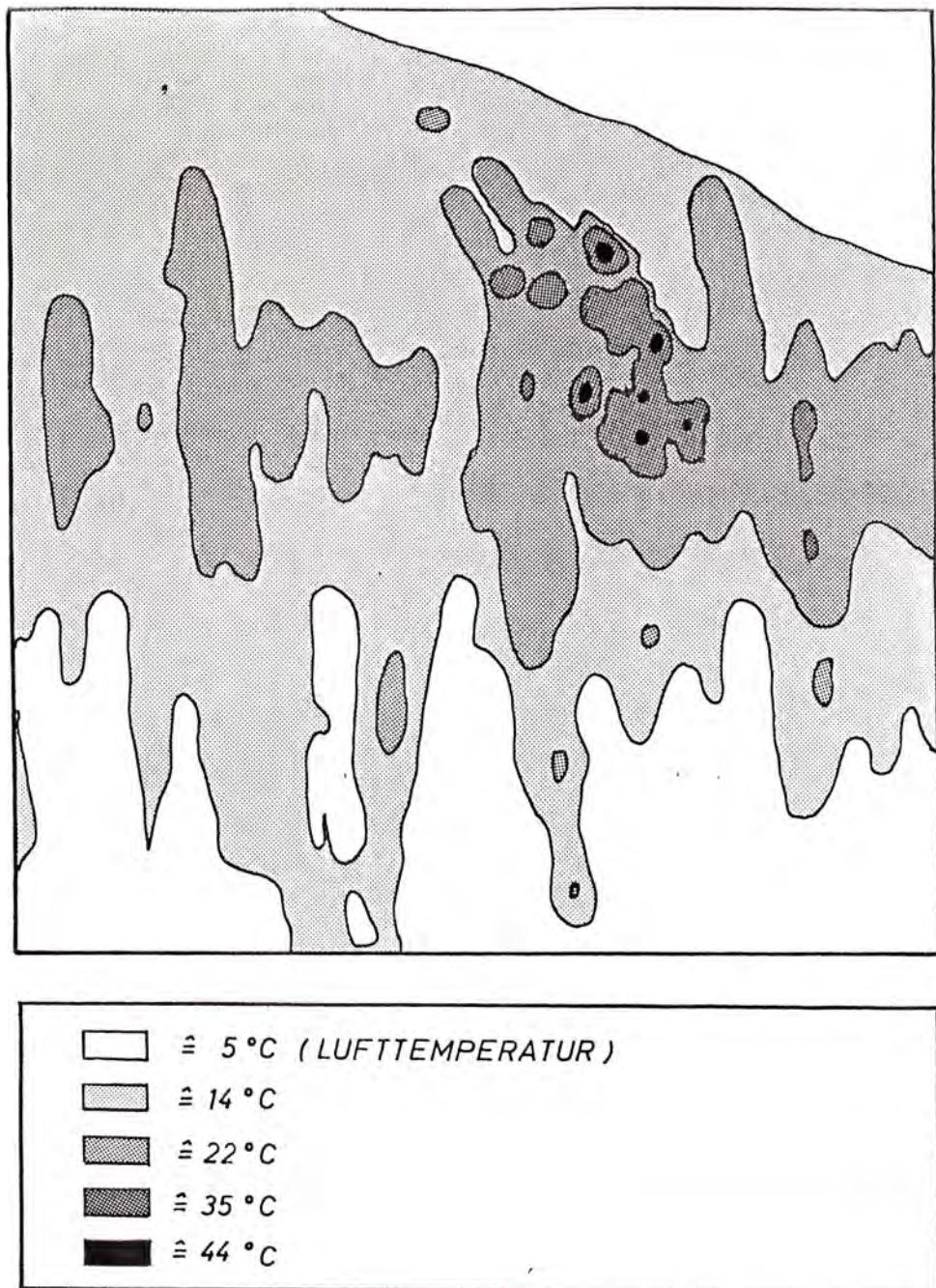


Abb.3: Infrarotaufnahme einer südexponierten  
Böschung, 15 min nach dem Abbrennen am  
23.2.1983. Links: Kontrollfläche, rechts:  
Brandfläche.



Abb. 4: Boden-Photoelektor auf einer geflammten Böschung.

Versuchsflächen konnten jeweils 2 qm Bodenoberfläche abgegrenzt werden. Als Fang- und Fixierflüssigkeit wurde Äthylenglycol verwendet. Die Leerung erfolgte monatlich.

Die hier dargestellten Ergebnisse beziehen sich auf einen Untersuchungszeitraum von zwei Monaten (März und April). Barberfallen und Eklektoren wurden unmittelbar nach dem Flämmen ausgebracht.

#### BARBERFALLENFÄNGE

Die Bodenfallenfänge ergaben für die Gruppen: Carabidae, Staphylinidae und Araneae keine deutliche Unterschiede zwischen der gebrannten und ungebrannten Fläche (Abb. 5). Die vorgefundenen Differenzen in den Artenzahlen zwischen Kontroll- und Brandfläche (Tab. 1) beruhen auf dem Vorkommen mehrerer Arten mit jeweils nur einem Individuum.

	Kontrolle	Versuchsfläche
Carabidae	22	16
Araneae	16	21
Gehäuse-Gastropoda	8	7

Tab. 1: Artenzahl in Kontrolle und Brandfläche für den Fangzeitraum März und April.

Bei den Carabiden dominierte in beiden Flächen die gleiche Art Harpalus tardus mit jeweils 28%, in der gebrannten Fläche erreichte noch Harpalus vernalis mit 16,5% einen hohen relativen Anteil an den Fangzahlen aller Carabiden. Ein ähnliches Bild ergab sich für die Spinnen: hier erreichte die Wolfsspinne Alopecosa accentuata in der gebrannten Fläche 66% und in der Kontrolle 59% der gefangenen Spinnen. Auffallende Unterschiede

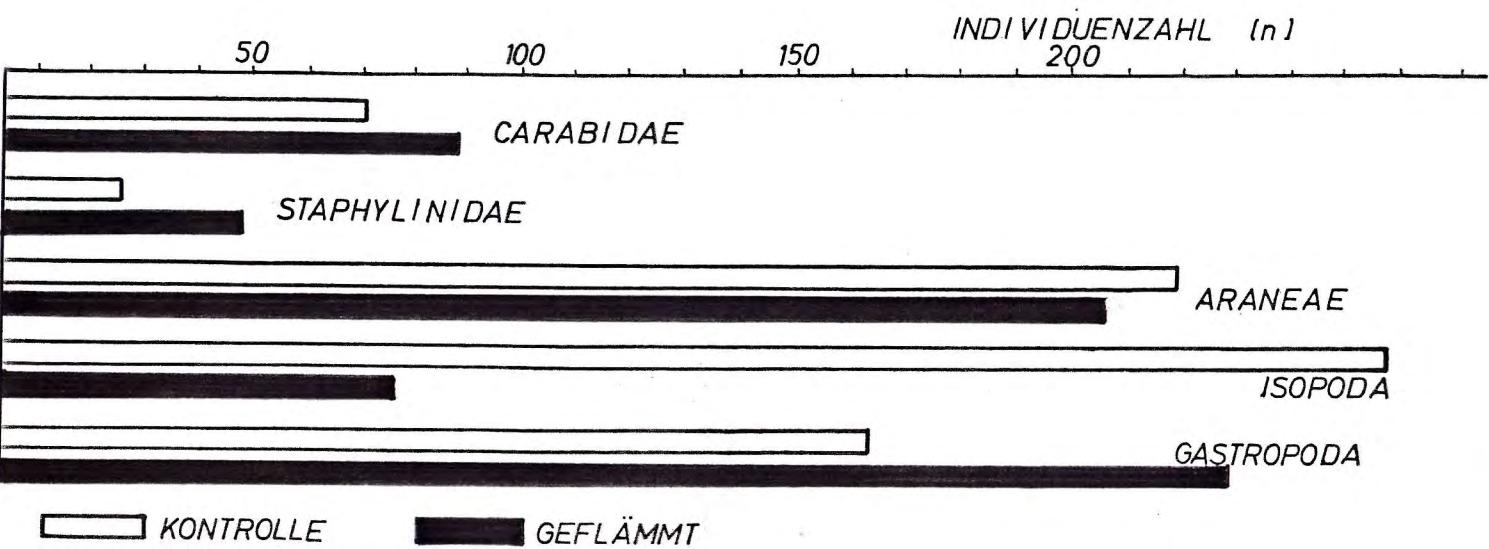


Abb. 5: Bodenfallenfänge: Gesamtindividuenzahl nach zweimonatigem Fangzeitraum (März/April 1983)

ergaben sich aber bei den Asseln, die in den Fallen der Kontrollfläche 3,4-mal häufiger gefangen wurden. Diese Differenz kam durch hohe Fangzahlen von juvenilen Asseln (Armadillidium vulgare) in der ungebrannten Fläche zustande.

Eine hinreichende Interpretation dieser Ergebnisse erscheint jedoch erst möglich, wenn weitere Daten über längere Untersuchungszeiträume vorliegen und nach der Artbestimmung weiterer Gruppen eine genauere Analyse möglich wird.

#### FÄNGE AUS DEN BODEN-PHOTOEKLEKTOREN

Um eine Einwanderung aus ungebrannten Flächen zu unterbinden, und um aus dem Boden und der Streu schlüpfende flugaktive Arthropoden wie etwa Dipteren auf der gebrannten und ungebrannten Versuchsfläche vergleichend zu erfassen, wurden Bodeneklektoren verwendet (Abb. 4). Hierbei zeigen die Fangzahlen der in Abb. 6 dargestellten Gruppen (Carabidae, Staphylinidae, Araneae, Isopoda, Gastropoda, Diptera, Hymenoptera) eine einheitliche Tendenz: Auf der Brandfläche wurden jeweils weniger Tiere gefangen. Die deutlichsten Unterschiede zeigen sich bei Laufkäfern und Gehäuseschnecken. Bei beiden Gruppen waren die Artenzahlen in Kontroll- und Brandfläche gleich.

Die höheren Fangzahlen der Carabiden in der ungebrannten Fläche ergaben sich aus dem häufigeren Vorkommen von zwei Arten (H. tardus, Amara aenea), die 40% und 19% der Individuen am Gesamtfang ausmachten. Bei den Gehäuseschnecken kommt die Differenz durch das Fehlen von Monacha cartusiana auf der geflammten Fläche zustande. Gegenüber der Bodenfallenmethode ergeben die Bodeneklektorenfänge zuverlässigere Ergebnisse über direkte Auswirkungen einer Feuerwirkung. Die Fangzahlen werden nicht durch eine Einwanderung aus ungebrannten Flächen verwischt (ein Eklektor befängt eine abgegrenzte Bodenfläche) und die Faktoren Aktivität und Raumwiderstand spielen zumindest für größere Arthropoden beim Vergleich beider Flächen keine

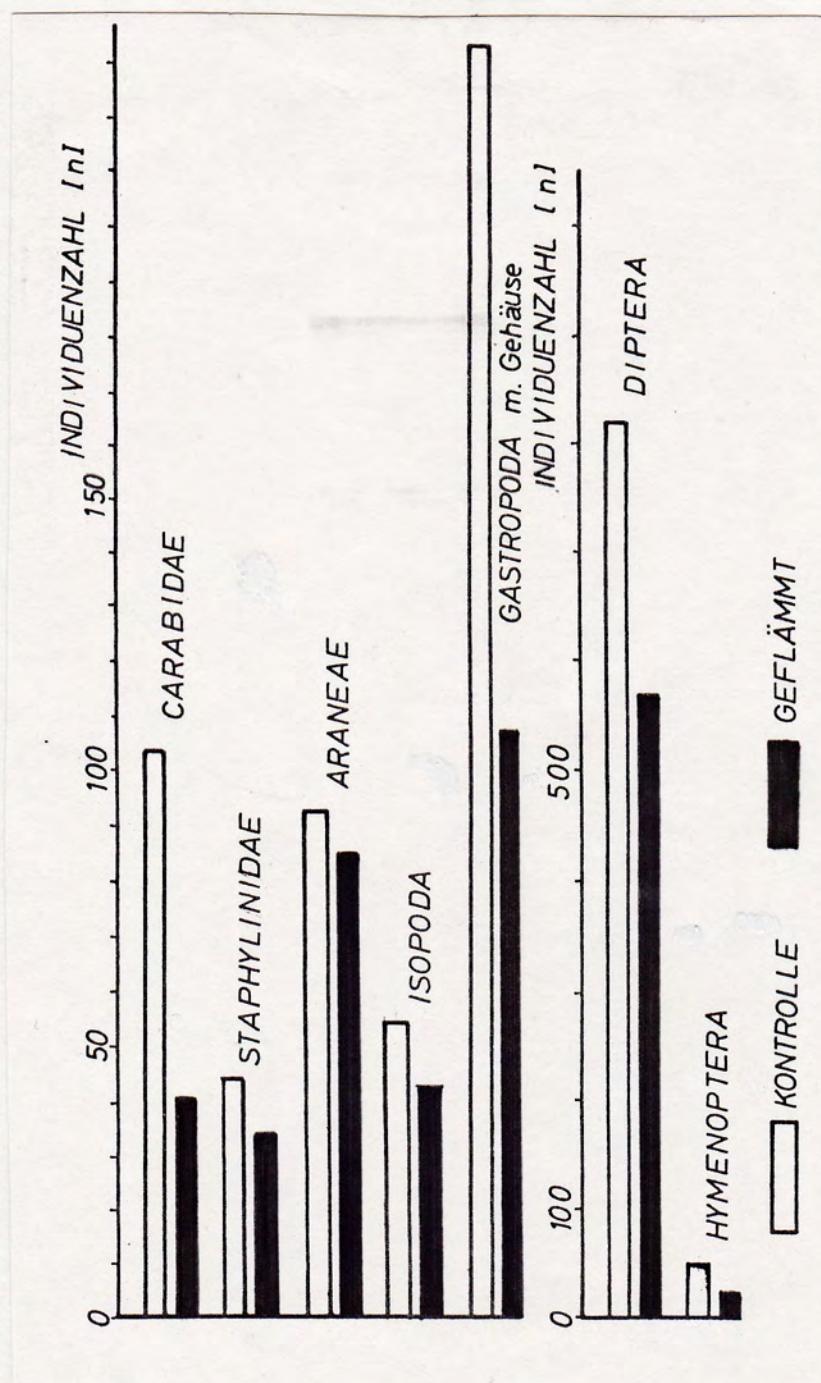


Abb. 6: Bodeneklektorenfänge: Gesamtindividuenzahl nach zweimonatigem Fangzeitraum (März/April 1983)

entscheidende Rolle.

#### EINFLUSS DES FLÄMMENS AUF BEWOHNER LEERER SCHNECKENHÄUSER

Eine Anzahl von Arthropoden benutzt leere Schneckenhäuser als Versteck und Nistplatz; dies gilt vor allem auf einer strukturarmen Bodenoberfläche. So sind z. B. einige Arten von Mauerbienen der Gattung Osmia auf leere Schneckenhäuser angewiesen, um darin ihre Brut unterzubringen (BELLMANN 1981). Im Kaiserstuhlgebiet kommen die drei heliophilen Osmia-Arten O.bicolor, O.aurulenta und O.rufohirta vor (KRATOCHWIL 1983).

Um die Bedeutung leerer Schneckenhäuser als Überwinterungsversteck für verschiedene Arthropoden im Untersuchungsgebiet zu ermitteln, wurden leere Gehäuse, vor allem von Zebrina detrita untersucht. Dies ergab, daß 52% der untersuchten leeren Schneckengehäuse Anzeichen einer ehemaligen und aktuellen Arthropodenbesiedlung aufwiesen, 20% davon waren von Dipteren mit Larven, Puppen und Imagines bewohnt, 10% von Salticiden (Heliophanus, Myrmarachne formicaria) und 2% von Drilus Larven und Weibchen. Drilus concolor (Drilidae) ist eine Käferart, deren Larven spezialisierte Gehäuseschneckenfresser sind. Larve und weiblicher Imago (deutlicher Sexualdimorphismus) überwintern in Schneckengehäusen (PLATE 1951, ZIEGLER 1981). Um quantitative Aussagen über eine eventuelle Feuerschädigung der Schneckenhausbewohner oder -überwinterer zu machen, wurden in Gehäuse von Weinbergschnecken (Helix pomatia) und Z.detrita Larven, Puppen und Imagines von Fliegen aus Laborzuchten (Phormia terraenovae und eine Art der Phaoniinae) eingebracht und auf einer Versuchsfläche exponiert. Nach dem Abbrennen der Flächen wurden diese wieder eingesammelt und im Labor die Schlupf- bzw. Überlebensrate ermittelt.

Unter Schlupfrate wird der prozentuale Anteil geschlüpfter Fliegen-Imagines an der Gesamtindividuenzahl der eingesetzten Larven und Puppen verstanden, die Überlebensrate ist

dementsprechend der prozentuale Anteil überlebender Imagines an der eingesetzten Gesamtindividuenzahl. Um ein Entkommen der Tiere aus den Schneckengehäusen zu verhindern, wurden diese mit Ton verdeckelt. Ein Vergleich der Schlupfraten von Fliegenpuppen in solchen verschlossenen und offenen Gehäusen ergab keine Unterschiede.

Aus den Helixgehäusen, die dem Feuer ausgesetzt waren, schlüpften von den jüngeren Puppen etwa 60%, von den älteren 10%, während Imagines und Larven nicht überlebten (Abb. 7). Aus den Gehäusen von Zebrina detrita, die mit Larven von Ph.terraenovae, Puppen von einer Art der Phaoniinae und Springspinnen versehen waren, schlüpften nur etwa 10 bzw. 2% der Fliegenlarven und Puppen (Abb. 8).

Die abweichenden Schlupfraten der Puppen und Larven (Abb. 7) deuten einmal auf eine unterschiedliche Toleranz der verschiedenen Entwicklungsstadien gegenüber Hitzeeinwirkung hin, zum anderen gab es bei dem mosaikartigen Verteilungsmuster der Temperaturen auf der Bodenoberfläche auch Bereiche, wo die Hitzeentwicklung unterhalb einer Schadensschwelle lag. Von den Springspinnen, die sich in den Gehäusen in ihrem Überwinterungsgespinst befanden, konnten keine lebenden Tiere mehr gefunden werden.

Auf den Versuchsflächen wurden einige Helixgehäuse gesammelt, in denen Osmien ihre Brutzellen angelegt hatten. Die Bienen der neuen Generation waren bereits entwickelt; die Tiere aus Gehäusen der geflammten Böschungen waren tot, was auf eine Hitzeschädigung hindeutet.

#### EINFLUSS DES BRENNENS AUF TIERE, DIE SICH WÄHREND DES FLÄMMENS IN DER VEGETATION BEFINDEN

Die meisten Tiergruppen verbringen den Winter inaktiv in unterschiedlichen Entwicklungsstadien an geschützten Stellen. In

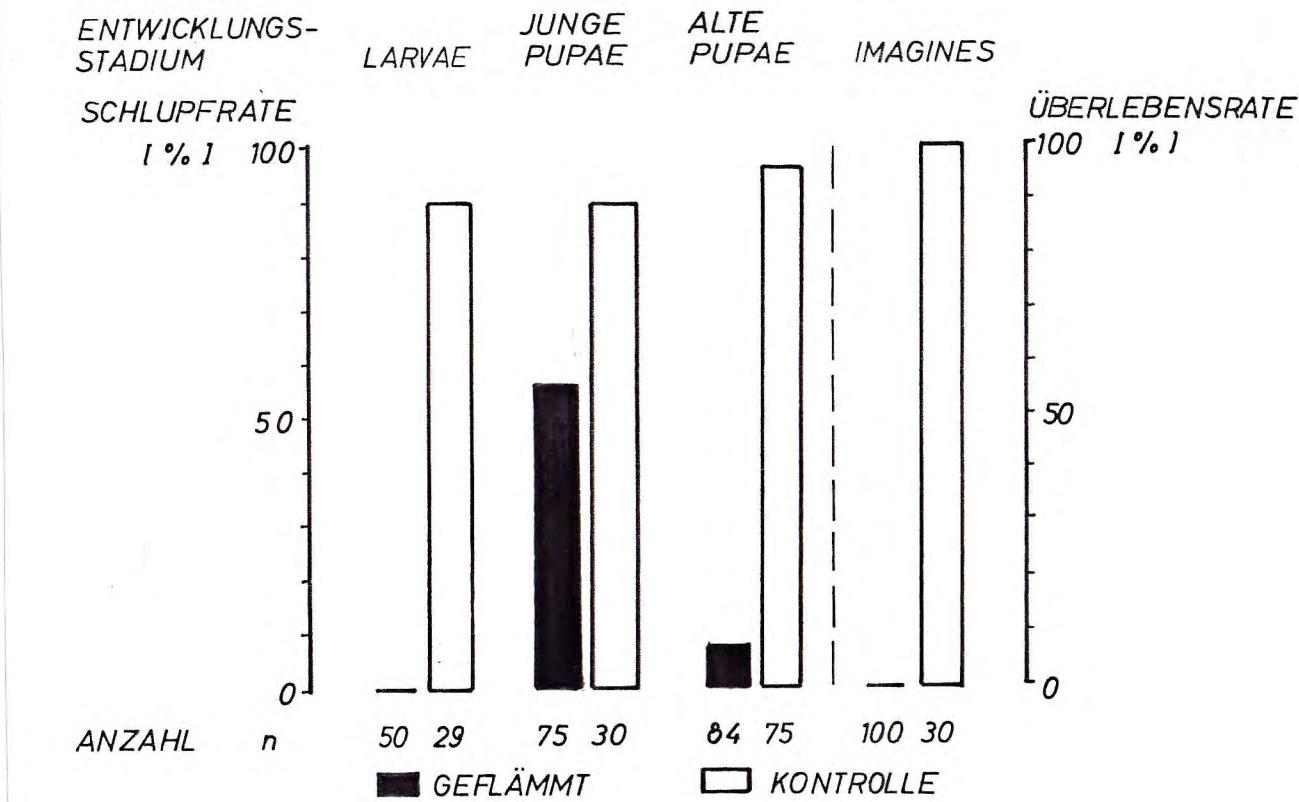


Abb. 7: Schlupfrate/Überlebensrate von Phormia terraenovae, die in Gehäusen von Helix pomatia während des kontrollierten Brennens in einer Versuchsfläche ausgebracht war ( 5 bis 10 Individuen pro Gehäuse).

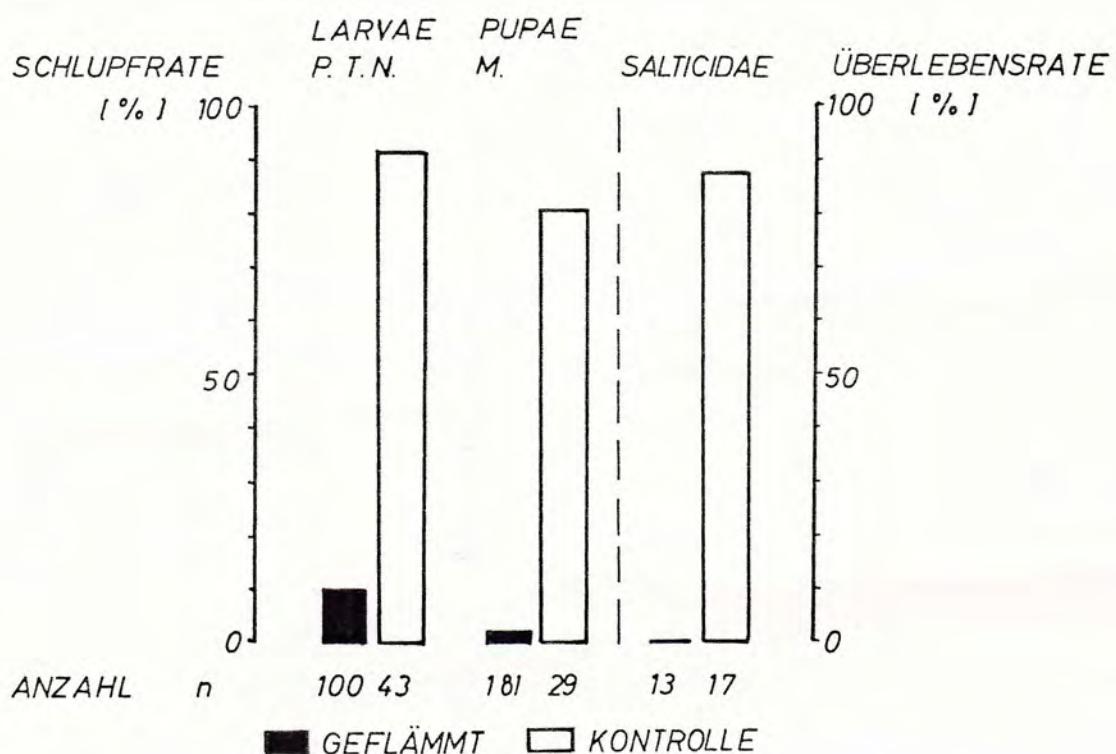


Abb.8: Schlupfrate/Überlebensrate von Fliegen (P.T.N.  
= Phormia terraenovae, M = Phaoniinae) und  
Springspinnen, die in Gehäusen von Zebrina  
detrita (1-3 Individuen pro Gehäuse) während  
des kontrollierten Brennens auf einer Versuchs-  
fläche ausgebracht waren.

der Vegetationsschicht verbergen sie sich hierzu in Pflanzenstengeln oder überdauern geschützt durch Gespinstkokons (Spinnen, Schmetterlinge), Mörteltöpfchen (Töpferwespen), Schaumgelege (Gottesanbeterin) oder andere Überwinterungsformen. Auf den Kaiserstühler Rebböschenungen findet man in den Herbst- und Wintermonaten die Schaumgelege der Gottesanbeterin (Mantis religiosa), die von den Weibchen im Spätsommer an Pflanzenteile ca. 10 cm über der Bodenoberfläche angeheftet wurden. In den Gelegen der Gottesanbeterin, den sogenannten Ootheken, die über 100 Eier enthalten können, entwickeln sich die Larven erst nach der Überwinterung im nächsten Frühjahr. Der Kaiserstuhl zählt zu den wenigen Gebieten Deutschlands, wo die Gottesanbeterin verbreitet ist. Da sie zu den faunistischen Besonderheiten zählt, ist der Erhalt dieser Populationen ein wichtiges Anliegen des Naturschutzes. Stellvertretend für Tiere, die sich während des Flämmens in der Vegetation aufhalten, untersuchten wir den Einfluß des Brennens auf die Gelege der Gottesanbeterin. Hierzu wurden Gelege von Brandflächen und von ungeflämmten Böschungen aufgesammelt, im Labor bis zum Schlupf der Tiere gehalten und die geschlüpften Larven gezählt. Obwohl die Ootheken nicht verbrennen, nur die äußeren Schichten werden angekohlt, wurden die Eier wohl durch die hohe Hitzeentwicklung letal geschädigt (Tab. 2).

	geflämmt	Kontrolle
Zahl der Ootheken	24	7
Zahl der Ootheken mit geschlüpften Larven	3	7
Zahl der durchschnittlich pro Ootheka geschlüpften Larven	3,1 (9, 12, 54)	120,1 (29, 83, 119, 121, 140, 169, 180)

Tab. 2: Zahl der geschlüpften Mantis religiosa aus Ootheken geflämpter und un behandel ter Flächen.

Von 24 Gelegen, die dem Feuer ausgesetzt waren, schlüpften aus nur drei Ootheken Jungtiere in geringer Zahl. Unbeeinflußte Glege zeigten entsprechend hohe Schlupfraten mit durchschnittlich 120 Larven pro Ootheka (die Gelege wurden im Labor zum Schlupf gebracht). Geht man davon aus, daß über längere Zeit großflächig und regelmäßig geflämmt wird, so hätte dies die Vernichtung der Mantispopulation der Rebböschungen zur Folge. Auf den frischen Brandflächen konnten eine Anzahl verkohlter Schmetterlingsraupen, die nur zum Teil bis zur Art zu identifizieren waren, gefunden werden. Es handelte sich dabei häufiger um die winteraktiven Raupen des Hausmütterchens (Noctua pronuba, Noctuidae), des Rostbären (Phragmetobia fuliginosa, Arctiidae) und Puppen von Noctuiden.

#### ZUSAMMENFASSUNG

Zielsetzung und erste Ergebnisse einer im Juni 1982 begonnenen Untersuchung über die Auswirkung des ortsüblichen Abflämmens der Weinbergböschungen im Kaiserstuhl auf die Fauna wurden vorgestellt. Eine Charakterisierung und Beschreibung des Feuers wurde durch die Erfassung des Temperaturverlaufes mit Hilfe von Thermoelementmessungen und der Darstellung der Temperaturverteilung an Hand von Infrarotthermographie vorgenommen.

Mit Bodenfallen konnten im Fangzeitraum zwei Monate nach dem Abbrennen keine bedeutenden Unterschiede der Aktivitätsdichte von Carabiden, Staphyliniden, Spinnen, Asseln und Gehäuseschnecken festgestellt werden. Mit Boden-Photoeklektoren wurden auf der Brandfläche geringere Fangzahlen gegenüber der Kontrollfläche erreicht. Da bereits in 1 cm Bodentiefe nur geringe Temperaturerhöhungen während des Abflämmens gemessen wurden, ist eine direkte Schädigung durch die Hitze für Tiere die sich zum Zeitpunkt des Feuers im Boden aufhalten nicht zu erwarten.

Die hohen Temperaturen auf der Bodenoberfläche (bis zu 400 °C)

haben größtenteils letale Folgen für die Tiere, die sich dort aufhalten; dies konnte für die Bewohner leerer Schneckenhäuser nachgewiesen werden. Alle Arthropoden, die sich zum Zeitpunkt des Flämmens in der Vegetation befinden, werden durch die große Hitzeentwicklung abgetötet (Temperaturen bis 800°C in 12 cm Höhe über dem Boden). Am Beispiel der Gottesanbeterin M. religiosa, einer schützenswerten faunistischen Besonderheit des Kaiserstuhls, wurde durch Vergleich der Schlupfrate von Gelegen aus Kontroll- und Brandflächen die letale Wirkung des Feuers in der Vegetation aufgezeigt.

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