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Forest fires and fire management in Sweden; a comparison with Spain

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APPENDIX

1.- INTRODUCTION

The concept of “fire history” has two meanings. The common sense interpretation is that it describes the history of fires, fire practices and fire regimes. The second sense refers to the study of fire as a means of better understanding human experience. Thus fire histories differ, even among regions that share similar environmental characteristics, and those differences both reflect and reveal characteristics in the human societies that reside on them. In this way fire history resembles a dialectical torch that, like itself, both breaks down and binds.

Fire is the single most dramatic natural event in many terrestrial ecosystems. Within minutes it alters the conditions for plants and animals, and the effects are usually evident for many years. The destructive impact of fires on organisms is obvious, but it is less well known that some species need fires to survive.

2.- OBJECTIVES

With this project, I want to review the current situation in the fight against forest fires in two different regions within Europe, the Boreal and the Mediterranean regions.

For the Boreal zone, the main example used is Sweden, a traditionally forestry country. In the case of the Mediterranean region, the country selected is Spain, the country with the longest and largest database related to forest fires.

3.- METHODOLOGY

The methodology used to do this project includes the search for information in books and different journals of libraries. It is also included the search for information through the Internet, and the interview to several professors by e-mail.

4.- FOREST FIRES IN THE BOREAL REGION. SWEDEN

4.1.- Background

No system of land use in northern Eurasia can survive unless it recognizes the ancient and enduring power of fire. In some areas, fire is useful; in others, necessary; and still in others, essential and inevitable.

According to Arno (1998), fire history in Sweden is comparable to that of the nonlethal and mixed severity fire regimes of North America. Globally, humans have used fire for more than one million years. When the first tribes of hunters and gatherers migrated into Scandinavia after the last glaciation 10,000 years ago, fire was the oldest, and together with the axe, their most important technology. Little information seems to be available, however, about the pioneer hunter and gatherer's use of fire. That they both intentionally and unintentionally ignited and burned large areas seems obvious. More uncertain is whether they also used fire in forested environments as part of the actual hunt, or to enhance herbivore populations of typical "fire followers" such as moose and roe deer.

Tactical use of fire has even been mentioned in certain places in Sweden in the north, for instance in conflicts between Saami reindeer herders and colonizing agriculturists.

Another example of the widespread use of fire along the coast is the burning of pastures, which has created extensive areas of *Calluna* heaths. These are purely fire-induced, man made ecosystems developed for year-round animal grazing.

Historical analyses using fire-scarred trees have shown that the situation was drastically different in earlier times (Granström, 1998). The northern Scandinavian Peninsula was until the late 1600s inhabited by a small population of semi-nomadic Saami, subsisting on fishing, hunting and small-scale reindeer herding (Niklasson, 2000). The 17th century was an extremely cold period. This period falls within the “Little Ice Age”. During the 1700s and 1800s, an increasing number of homesteads were established. In the mid 1800s, the lumber industry gradually expanded into the area, and today the main land use is forestry. As late as in the mid 1800s, on average more than 1% of the forested area in northern Sweden burned per year. Probably the situation was much the same further south, although less is known from there. The annually burnt area dropped steeply over the last decades of the 19th century and during the last 100 years there has not been any really large fire-years. The slump in area burnt coincides with the expansion of modern forestry. It is assumed that the rural people gradually abandoned old fire practices (such as burning for improving grazing conditions in the forest) and started to attack lightning ignitions aggressively as well. The contribution of man to the fire regime of the old days is not fully clear, but it most certainly varied from region to region and over time. The interior of northern Sweden was settled by farmers (mainly depending on cattle) only since the late 1600s. There is evidence that prior to this, fires were relatively few but some of them covered many thousand of hectares. With an increased number of settlements, the number of fires increased but their size went down. Therefore, the resulting area burned did not increase as much as might be expected. Instead, the most substantial change in the fire regime came with forestry towards the late 1800s, as outlined above (Granström, 1998). The industrial revolution came to Sweden in several ways, but the most dramatic involved the development of industrial logging. The whole structure of land use changed, particularly in Norrland. The spectacular commercial success of the timber industry encouraged the belief that the boreal environment was better suited to silviculture than to agriculture. The national fire load plummeted. Of course, there were spectacular wildfires from time to time, specially where large volumes of logging slash littered the ground. There were great outbreaks in 1868, 1878, and 1888, almost in lock-step with the marching timber industry. The last bust, however, came in 1933. What really diminished was the background count of burning, the quality of land that remained too remote for active manipulation, and the regimen of agricultural fire. Gradually industrial combustion replaced the fire assisted technologies and land usage that had defined the Swedish past. Fire loads shrank but did not vanish. By 1903 Sweden enacted the first of it modern forest laws, one that required that harvested woods be replanted, and in this way began the process of converting farms from the production of wheat and barley to pine and spruce. For much of the century, forest products have accounted for half of Sweden's export income – ample incentive beyond a commitment to Germanic "clean floor" silviculture. By 1990 a series of ever more prescriptive laws had effectively transform Sweden's forests into a vast tree farm. All this influenced the country's fire environments. This process persisted until the 1950s when Europe's post-war reconstruction and subsequent economic boom intensified pressures on Sweden's forests. Until then, at least in the north, forestry had sought to transform rather than abolish traditional burning. To regenerate pines it adapted swidden agriculture to a swidden silviculture, modifying slash and burn farming to forestry, a practice known as "*hyggesbränning*". But forestry, like agriculture, experienced a green revolution that condemned traditional practices and began to substitute controlled combustion and the product of fossil hydrocarbons for them. Land not only remained forested but former wastelands were converted and new lands created to support further planting – Sweden's heaths, for example, all but vanished, and much of its mires were drained. In the north, domestic reindeer increased to unprecedented numbers, browsing off many surface fuels. Over time forests edged into a due-culture of pine and spruce, the two most valuable commercial species. This highly intensive management demanded roads, which broke up fuel complexes and provide ready access to fires. Less than 2% of Sweden was committed to parks, and much of those extended in the "*fjell*" over the timberline. In addition, forestry institutions, public and private, both sought to control wildfire. Fire no more belonged in the cultivated woods than in a wheatfield. By the mid 1980s Sweden no longer kept statistics on wildland fires.

In recent years, however, interest has grown regarding the preservation of natural and traditional landscapes, and in studying environmental philosophies, even those biocentric ethics that seek to decentre humanity from a privileged status in the cosmos. Nature reserves are growing in number, though they remain small in area. Fuels are beginning to build up, selectively but inexorably. The Swedish Riskdag is proposing to revise the forest law to accommodate matters like biodiversity. Fire history and fire ecology have found footholds among Swedish academics, and as something more than biotic archaeology. It is likely that the pressures for some kind of re-introduction of fire will increase.

4.1.1.- Number and size of fires

The proportion of area burned per time unit is the product of two variables: the number of fires (ignitions) per unit area per unit time, and the size of the individual fires. The same area burned can thus result from either a large number of small fires or a small number of large fires, which complicates the interpretation of fire history from records of area burned.

There are difficulties in describing past fires with sufficient spatial and temporal resolution. Analysis of charcoal in lake sediments or peat stratigraphies can provide records over millennia, but they do not provide spatial detail. Fire histories from tree ring chronologies usually cover shorter time spans, but have the potential to resolve spatial patterns. (Niklasson, 2000)

The general picture emerging is of an early period ending in the 1600s with relatively few fires in the landscape, some of which were very large, followed by a period of greatly increasing numbers of fires that were progressively smaller in size. Finally, from around 1870, there was a dramatically decreasing number of fires. The cause behind these long-term changes in the fire regime could potentially be climatic, anthropogenic, or both. Climate change could act on both, the number of fires (through an altered density of lightning ignitions) and on the size of individual fires (through different weather conditions prevailing during the burning sessions), both of which would influence the proportion of area burned per unit time. (Niklasson, 2000)

Documented changes in the human population and utilization of the area coincide better with the observed trends in the fire regime than does the climate.

4.1.2.- Fire return intervals

The fire regime of an area depends on several variables, the most important of which may be fuel characteristics, landscape structure, climate and ignition frequency. Although the importance of lightning ignition density for shaping natural fire regimes is obvious, few data have been published.

Swamp forests have a greater spatial variability of microhabitats, and therefore moisture levels, than forest in drier sites, so it could be expected that the fire pattern is more patchy in swamp forests. (Hörnberg, 1995)

Although it has long been assumed that fire has had an impact in most Sweden's forest regions, fire regimes of earlier times in Sweden are still little known. Fire history studies have only been carried out in the boreal forest in the northern part of Sweden, covering mainly the last 500 years. These studies indicate that the fire rotation before active fire suppression started in the mid 19th century, was ca 100 years, with average fire return intervals ranging from around 50 years on nutrient-poor dry-sediment soils to more than 150 years on mesic soils. Fire return intervals were essentially the same, even in the earliest period analysed, before the agricultural expansion in the interior of northern Sweden started. Thus lightning should have been a principal source of ignition.

Later research on fire in Scandinavia has concentrated mainly on fire history and variations on fire frequency. A few paleoecological records that show a long-term influence of forest fires have been published from different parts of Scandinavia. For the boreal part of Sweden, a more detailed account of forest fires in the last few centuries is provided by a number of dendro-chronological studies. Forest fire has varied considerably with vegetation type, topography and region, with a range in fire return intervals from around 50 years on dry sediment soil to over 150 years in moist environments. For the majority of forested land in northern Sweden, the available data suggest an average fire return interval of around 100 years before active fire suppression started towards the end of the last century. (Schimmel, 1993)

For southern Sweden, virtually nothing is known about the occurrence of natural fires. The cultural use of fire has not been well quantified either. However it is clear that anthropogenic burning both intentional and unintentional, has greatly affected the fire regime of central and southern Sweden, where extensive areas of dwarf shrub dominated heathlands were earlier kept open by burning on a rotation scheme of less than 10 years.

4.1.3.- Fire Causes

According to Granström (1998), most fires are caused by people, directly or indirectly. In example, in 1994, arson was assumed to have caused 6% of the fires, smokers 2%, carelessness with fire (camp fires, refuse burning etc) 13% and various accidents 14%. An additional 30% of the fires were presumably human caused although the exact agent was unknown. That year lightning accounted for 35% of the fires, which is a very high figure in comparison with statistics from the period 1945-1975. It is probable that the summer of 1994 was unusually conducive to lightning ignitions. Most of these fires occurred in July, at the height of a long drought.

If we have into account the statistics for 1994 to 1998, humans are assumed to cause more than 50% of the fires; arson implies 6% and negligence 49%. The natural causes, mainly lighting ignitions, cause 9% of the fires, but some years with extreme conditions this rate can be increased to 30%.

4.1.3.1.- Lightning ignition

Quantitative estimates of the number of past fires per unit area and time should help distinguish between anthropogenic and lightning ignited fires, by offering a comparison with present day lightning ignition densities.

Generally, the weather conditions which prevail during summers with many forest fires have been described as “dry anticyclonic with dry electric storms”. (Engelmark, 1987)

Analysis of fire statistics revealed that there are steep gradients in the distribution of lightning caused fire ignitions in Sweden. The highest ignition density was found in the southeastern provinces of Kalmar and Ostergotland, ca 0,23/1000 ha/yr. From there, densities generally declined both to the north and to the west, with a density average ca 0,05 in the six northernmost provinces, and equally low density in the southwestern province of Halland. (Granström, 1993)

Lightning ignitions peaked in early July, but in the south the season for ignitions started 2-3 weeks earlier and ended 2-3 weeks later. (Granström, 1993)

The geographical gradients in lightning ignition density correspond to the average precipitation during summer. The patterns of lightning ignitions density may also indicate gradients in natural fire frequency. This hypothesis is supported by the distribution of certain plant-adapted species.

4.1.4.- Forest fires legislation

Sweden and Finland were the first countries where forest conservation laws came into effect, in 1886 and 1903 respectively. These laws stipulated that felled areas were to be reforested. However, planning and growing large areas of forest was not sufficient. In the wake of rationally managed forests, criticism of monoculture and, after the Second World War, the adverse effects of large-scale operations grew. In time, self-criticism also increased and research was able to show other adverse trends with regard to certain flora and fauna. This was a result of highly production-oriented forestry and forestry policies.

However, nearly a hundred years ago, a special Forestry Act stipulated that Swedish timberlands could no longer be freely exploited. Instead, sustainable forestry would provide the basis for future operations. Replanting, good forest management and long-term planning have subsequently led to a very large increase in timber supplies. This made possible a steady expansion of logging operations. Today's timber stock is 50% larger than it was when detailed measurements began in the 1920s. Since the 1992 UNCED meeting in Rio, the concept of sustainability has broadened. This is reflected in the revised Swedish forestry policy that went into effect in 1994. Today sustainable forestry must not only ensure a reliable yield of timber and the multiple use of forests, but also preserve biological diversity.

Legislation has been changed so that the environment and conservation are now considered to be as important as production. Moreover, forest industry companies have taken the initiative in developing new methods - which go beyond their legal obligations - to effectively preserve biodiversity.

Both Sweden has subsequently supplemented and renewed the forestry legislation. This has occurred in tandem with new research findings and by consistently setting new objectives for forestry.

There are no separate provisions in the *Forestry Act* regulating forest protection. Damage resulting from fire is viewed similar to a potential insect problem and is dealt with under Section 29, the Insect Damage clause.

Fire preparedness plans, fuel management plans or specifications for reducing fire hazards, except for wood removal provisions mentioned in the Insect Damage clause, are not required by the *Forestry Act.*

4.1.4.1.- Section 29

The Government, or public authority designated by the Government, may issue regulations for combating insect infestation in forests, for the processing of damaged trees, for the removal or storage of timber, and for other measures necessary to inhibit insect breeding grounds.

Forest owners are responsible for ensuring that such measures are carried out. Other parties benefiting from forest and timber are also responsible for preventive measures in connection with felling and storage.

4.2.- Fire use

To facilitate regeneration, prescribed burning on clearcuts and seed-tree stands was used primarily during two periods, 1920-1940 and 1950-1970. This method was replaced by scarification in the 1970s. (Zackrisson, 1997)

The previous fire influenced old growth dominated forest landscape was transformed by human activities into a regulated production forest in the course of one century.

The earlier all-aged stands with regeneration patterns linked to recurrent forest fires have also been altered into forest stands with uniform age-classes.

The major factor shaping the forest landscape before the arrival of commercial logging and forest management was recurrent forest fires.

In the periods 1920-1940 and 1950-1960, prescribed burning was introduced to facilitate regeneration and influenced up to about 1% of the area annually during peak years. Although fire influence during these years almost reached the average "fire perturbation percentages" found in the 19th century, the total fire impact on the landscape during the 20th century has been very limited. The reintroduction of fire as a tool for regeneration was beneficial from a conservation stand point, e.g., for fire dependent insects. Examination of the survey information reveals however, that prescribed burning was performed mostly in late successional forest stands with a raw humus beds at higher altitudes between the rivers valleys. A large proportion of the prescribed burning was performed to establish regeneration on previous residual stands after intense high grading and with poor natural regeneration. The forest stands that previously were frequently disturbed by fire were seldom treated by prescribed burning because they usually already contained abundant natural pine regeneration established after fires in the 19th century. Prescribed burning thus did not help to maintain a previous natural disturbance pattern in the landscape. On the contrary, prescribed burning was just another method to manipulate the forest to produce Scots pine in late successional or even nonpyrogenic spruce-dominated sites with low capacity to sustain Scots pine regeneration. Fire has also been used recently by modern forestry to regenerate clearcuts. (Zackrisson, 1997)

4.3.- Present fire regime

In contrast to many other countries within the boreal and subboreal region, Sweden today has very small problems with forest fires, despite the unusual size of the fires of 1994. In fact, fire protection has been successful to such a degree that the lack of fire creates problems for nature conservation. (Granström, 1993)

In recent decades, Scandinavian forests have experienced only minor amounts of wildfire and prescribed fire is used relatively little (Granström, 1996). Although fire suppression is highly effective today, it acts only on the size of the fires and not in their numbers. In fact, the number of fires is much higher today (often in the order of 10- to 20-fold) than in natural state (Niklasson, 2000).

Yet, fire is not considered a serious problem today. The area burnt annually is minute in comparison with most other boreal regions. In fact, authorities did not even bother to collect fire statistics after 1975. The worst fire year this century was in 1933, with approximately 30,000 ha burnt (Goldamer, 1996). There was also a special survey for the summer of 1994, which was unusually dry and hot. That summer 3500 ha burned in 2200 fires, the highest figure since 1959, when 9000 ha burnt. Most fires were thus very small; only 37 were larger than 10 ha. This indicates a relatively benign situation and several factors may contribute. To begin with, high winds are rare during dry summer periods. Of the fires in 1994, only 11% started during days with noon wind speeds higher than 5 m per second and only a handful started during days with winds higher than 10 m per second. In addition, the well developed network of forest roads allows very fast access to fires with pumps and hoses. It is very rare that fires burn for more than a few hours. In the southern half of the country the average distance in the forest to a navigable road is below 400 m and in the northern half of the country around 500 m. These roads have been put in primarily for timber hauling, but they most certainly also serve to reduce losses due to forest fires. (Granström, 1998)

The result is that fire fighters today usually have little experience with forest fires, and particularly big ones. They rely exclusively on water, delivered from hoses or from helicopters, which may present problems once a fire grows big. (Granström, 1993)

4.4.- Consequences of present fire regime

According to Zackrisson (1997), an important effect of the elimination of fire influence is probably most easily observed among strongly fire-adapted organisms. Many fire-dependent insects have declined in population size and some may have disappeared from Fennoscandia[1]. The decline of boreal fire-dependent tree species like *Betula pendula, Salix caprea* and *Populus tremula* may have far-reaching consequences for long term ecosystem functions, since deciduous

[1] *Fennoscandia*: term for Finland and Scandinavia (including Denmark and excluding the Northern Atlantic islands).

trees are considered keystone species in boreal ecosystems supporting a large number of lichens, mosses, wood fungi, insects and birds. (Arno, 1998)

Today there is a consensus among environmentalists and forestry people that the present fire situation is historically unprecedented and possibly unhealthy for biodiversity in the long run. Therefore, some measures have been taken to increase the amount of fire in the landscape. Many forest companies have resumed the old tradition of burning felled areas. This is then used as an alternative to mechanical soil scarification (Norberg, 1997). Still the area treated with fire is small (probably less than 2000 hectares during the last year) but it is increasing. On these areas there is often a residual stand which may serve to seed the area afterwards and increase the structural complexity of the future stand (dead wood, old living trees). There have also been some efforts to use fire in the management of forest reserves, although very little has been accomplished so far. (Granström, 1998)

Quantification of past fire regimes is important because they indicate under what conditions organisms have lived and survived historically. On the other hand, they don’t tell us what happens under an altered fire regime.

There is today a rising awareness also among forest managers and conservation biologists about the role of ecological disturbance by fire.

Too long a fire free time might prove disastrous for organisms that have evolved adaptations to frequent disturbance by fire, for example seed bank species that possess heat-triggered germination. Several seed bank species seem capable of surviving at least a 100 years in forest soil, but the upper limit for survival is not known. There are also indications that several pyrophilous insects are endangered in Sweden today.

According to Zackrisson (1997), fire should be reintroduced as an ecological tool to recreate biological values associated with multi-storey Scots pine stands. This might not necessarily mean that timber production will decrease.

4.5.- Fire effects and vegetation response

According to Schimmel (1993), under natural conditions, fires occur on average every 50 to 200 years in boreal forest. Fires may have existed as long as there has been vegetation on earth, and have presumably had a great impact on the evolution of terrestrial species. Therefore, one can expect to find fire adaptations enabling organisms to survive fire in situ, and also to exploit early post-fire successions.

The main prerequisite for the start and spread of any forest fire is a continuous bed on the ground of dry enough fuel particles of suitable size and packing in which the fire can propagate The flame front will spread by continuously heating the fuel ahead of it to ignition temperature, usually > 300° C, and in order to persist the fire front must be constantly moving to recruit unburned fuels. The rate of spread will thus be greatly influenced by the chemical and physical properties of the fuel, specially fuel moisture and fuel packing and arrangement, but also by wind speed and slope. (Rothermel, 1972)

Many variables determine the effect of a fire. The intensity, most commonly defined as a rate of energy output per unit length of the fire front (Byram, 1959), the depth of burning in the organic soil layer, the time elapsed since the last fire, known as fire frequency, and time of the year when it occurs. Seen over a long time period and over a large landscape, these variables may be summarized as a fire regime. (Granström, 2001)

According to Granström (2001), the attempts to describe past fire regimes in Fennoscandia have been relatively few, and have concentrated on only one variable: fire frequency.

Fire frequency is important per se because it determines the successional age, and therefore composition, of the vegetation at the time of fire. For example, very long intervals may lead to the local extinction of tree species which has a limited life span and which regenerates only on burnt ground (Granström, 2001).

However, moderate differences in the average fire interval are not likely to have major consequences for the biota. Other variables may be more immediately important, such as fire intensity, which directly controls tree mortality and thus species composition and stand structure (Granström, 2001).

Differences in the fire frequency between regions are typically much larger than between forest types within a region. Thus, past fire frequencies cannot be deduced from the present vegetation types (Granström, 2001).

There maybe stronger or weaker links between several fire regime variables which could affect biodiversity, but they have not yet been well documented for the boreal forest.

4.5.1.- Fire intensity effect

The large variation in fire intensity will be directly reflected in the survival of trees, and thus it also will influence the establishment of a new tree generation. Decreased canopy shelter and specially decreased seed supply are likely to lower the establishment of tree seedlings at sites where mature trees are killed extensively.

The common tree species of northern Sweden show different resistance to fire due to differences in morphology, especially bark thickness. Picea abies is likely to survive only fires of quite low intensity while Pinus sylvestris will also survive fires of medium to quite high intensities. High fire intensity with total tree killing will probably favour the common deciduous species *Betula spp.*, *Populus tremula* and *Salix spp.*, all of which have very small seeds that can spread over large distances. These patterns of tree survival and seedling establishment in relation to fire intensity will strongly influence the species composition in a landscape frequently burned.

According to Engelmark (1993), after the fire first *Picea abies* established in the shade of dead trees and the subsequent shift to recruitment of *Pinus* was favoured by reindeer browsing of Betula in combination with a thinning of the tree layer. This pattern may also be found in other fire disturbed forest stands in Fennoscandia because dead trees still provide shade shortly after a forest fire and reindeer browsing has occurred for at least 1000 yr.

4.5.2.- Plant colonization after fire

Among plants two major strategies for the recolonization of burned areas can be recognized:

- Recolonization from buried seeds, spores or rhizomes in the ground.
- Establishment by seeds or spores brought into the burned area from a distance.

The first category includes the most common rhizomatous forest species in northern Sweden, *Vaccinium myrtillus*, *Vaccinium vitis-idaea* and *Deschampsia flexuosa*, and the seed bank species *Luzula pilosa* and *Calluna vulgaris.* Different species within this group show highly variable patterns in relation to fire severity, and these differences can be attributed mainly to the depth distribution of their seeds and rhizomes. For example, *D. flexuosa* has its bud bank slightly higher in the mor-layer than the *Vaccinium* species and is thus favoured by a slight disturbance, but it is killed off by fires of quite moderate fire severity. Seeds of *L. pilosa* and *C. vulgaris* are found comparatively deeper in the soil profile than the rhizomes and should thus be fairly well protected from the fire. Seeds of *L. pilosa* cannot germinate from depths over ca 3 cm and quite high fire severity might be needed for good establishment of this species. An even higher fire severity might be needed for good germination of seed bank species that possess heat-triggered germination. In *Anthyllis vulneraria* and three species of *Geranium* exposure to 45-95° C for 10 minutes was needed for good germination. This might clearly be seen as an adaptation to germinate during favourable conditions immediately after fire. Compared to *L. pilosa*, these species have large seeds that can germinate from large depths. In soils with thick mor-layers, however, also *Anthyllis vulneraria* and *Geranium* species should require high fire severity for good germination due to the temperature requirement of the seeds. (Schimmel and Granström, 1996)

Species differ in their ability to respond to fires differing in depth of burn. These differences are due principally to variations in the position of seeds and rhizomes in the soil and to the colonizing habit of the plants (Schimmel and Granström, 1996). These relations are summarized in a simple model depicting the initial response of three different groups of species: rhizomatous sprouters, early successional seed bank species, and seed dispersers. Sprouters will generally decrease in importance with increasing depth of burnt, although there are interesting differences within the group depending on vertical position of the rhizomes and aggressiveness of growth. By these sites, *Deschampsia flexuosa* was able to profit from mild disturbance. Seed bank species, on the other hand, will have advantage after relatively deep burning fires that kill off some competitors and expose the buried seed bank. Fires consumpting most of the mor layer will, however, kill a substantial part of the seed bank. For seed dispersers, there will be a more direct positive relation between depth of burning and initial success. (Schimmel and Granström, 1996)

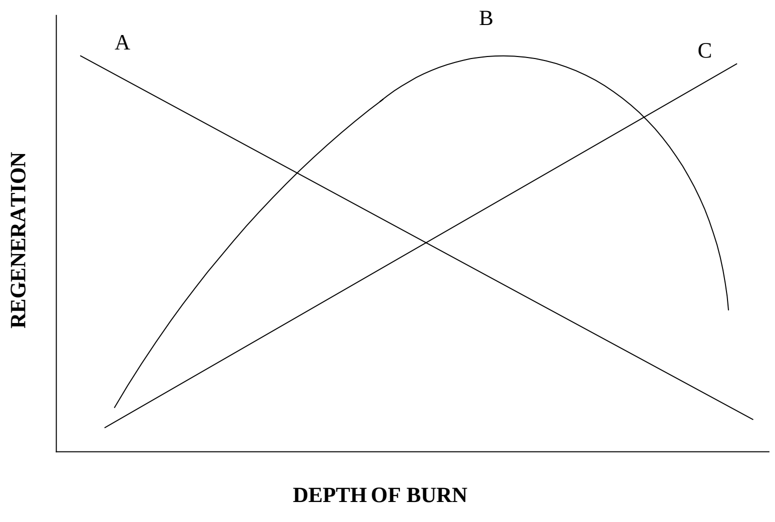

Figure 1: Hypothetical model of the regeneration of different categories of plants in relation to depth of burn (mor consumption): (A) rhizomatous species; (B) seed bank species; (C) species that depend on postfire seed dispersal. Source: "Fire severity and vegetation response in the boreal Swedish forest". Schimmel and Granström, 1996.

4.5.2.1.- Recolonization from buried seeds and rhizomes

According to Schimmel and Granström (1996), fires in boreal forests can vary considerably in their below ground effects, and this is important for the colonization process after fire. In these forests, depth of burn is a more important variable than fire front intensity for the understorey vegetation, in contrast to the situation in ecosystems with little accumulation of organic material on the mineral soil.

According to Schimmel (1993), boreal forest ecosystems are characterized by cold climate and slow decomposition rates, which often lead to the accumulation of a distinct organic soil layer, here referred as the mor-layer. Due to the compact structure of the mor-layer, it is not involved in the flaming combustion of the spreading fire front. If this layer burns, it is instead slowly consumed by glowing combustion, which mainly occurs after the fire front has passed. The degree to which the mor-layer is consumed is therefore more or less independent of the fire intensity. Instead the glowing combustion in the mor layer seem to be controlled especially by its moisture content which in turn will depend in the length of the drying period before the fire. Thus it seems probable that shorter drying periods should lead to al lower consumption of this layer in northern latitudes.

There are differences in the ability to survive fires between the dominant gloundflora species in northern Sweden. Three of the most common understorey species in the field layer of Swedish forests are *Vaccinium myrtillus, Vaccinium vitis-idaea* and *Deschampsia flexuosa*. These species recolonize a burned area mainly from subterranean runners that survive underground and are able to produce sprouts after fire (Schimmel, 1989). Different survival between species is principally due to variations in the positioning of the rhizomes, but morphological and physiological differences can also be of importance. There are also differences between plants of the same species at different sites. These are mainly effects of different thickness of the organic material but differences in nutrient status are probably also important. (Schimmel, 1996)

The important variables for survival of these runners or rhizomes are depth of burn in the mor and the soil temperature profile, which is related to fire duration. (Schimmel, 1996)

Normally the main fire front passes the ground quite quickly, consuming only the upper centimetres of the mor layer. The rest of the organic material, if it burns at all, is consuming by smouldering and/or reburnings, after the main front has passed. Therefore, the depth of burn depends rather on moisture content throughout the organic layer, than on surface fire intensity (Schimmel, 1989). A moist humus layer acts as an excellent insulator during the fire. According to Uggla (1957), a “sweating zone” is continually formed immediately after the fire. Before the fire can penetrate further down in the humus, moisture must be evaporated. Humus with a moisture content below 25-30% (dry weight basis) is generally considered to burn independently of woody fuels.

Duration of flaming combustion over a unit area is another variable that has a very significant effect on living vegetation and heat penetration into the soil. The fire duration of burn-out time for a given amount of fuel is mainly a function of fuel particle size. Fine fuels burn faster than heavier. Moisture content of the fuel is of less importance (Schimmel, 1997).

Boreal forest soils are usually podzolised and the majority of seeds and rhizomes are located within the organic soil layer and in the uppermost part of the mineral soil. This will make them potentially vulnerable to the impact of fire, particularly if the mor layer is so dry that smouldering combustion starts to eat into it (Schimmel, 1996).

There is virtually no information for the boreal flora on heat tolerance and specific responses to fire such as release from dormancy.

According to Schimmel and Granström (1993), the lethal temperature has been usually between 55 and 65° C after about 10 min exposure. Lethal temperatures are inversely related to exposure time, and over a broad temperature range there seems to be a linear relation between lethal temperature and the logarithm of time. Another important factor for heat tolerance is the moisture content of the tissue. Soil temperatures during burning are effectively dampened by the moist humus layer and differences of several hundred degrees Celsius, between surface temperatures and soil temperatures at a few cm depth are normal. So the drier the tissue, the longer time or the higher temperature that is required to kill the tissue.

There are a number of reports of heat-triggered germination, mainly within the plant families Leguminosae, Proteaceae, Malvaceae and Cistaceae. The critical level for release of dormancy is generally around 60° C, and this has usually been assumed to be an adaptation to fire as an agent of disturbance. This phenomenon has not been well studied for plants within the boreal zone. There are two Geranium species which have been reported to possess heat-triggered germination, but there is no quantitative information on their responses to heat exposure (Granström, 1993).

During forest fires the temperature gradient in the organic soil layer is very steep (Uggla, 1957). The depth distribution of seeds and rhizomes in the soil should therefore be more important for survival than the relatively small differences in heat tolerance observed between species, with the exception of Leguminosae and *Geranium* (Granström, 1993).

Geranium bohemicum and *Geranium lanuginosum* are annual species that emerge nearly exclusively after forest fires. Their distribution is largely Mediterranean, but they also occur in the hemiboreal zone in Scandinavia. *Geranium bicknelli* is also an annual plant and is distributed over much of boreal North America. It has been reported from fire areas, but also from eroding riverbanks. *Anthillys vulneraria* is a short-lived perennial specie. A race indigenous to the European boreal zone has been noted from some burnt forest sites. Thus, the occurrence of these species in the wild suggests that the observed release of dormancy by exposure to high temperatures is indeed an adaptation to disturbance by fire (Granström and Schimmel, 1993).

Heat triggered germination seem to be restricted mainly to taxa where the seeds are impermeable to water during storage in the soil.

According to Granström and Schimmel (1993), differences in the temperature tolerance between species are not likely to be a decisive factor in their post fire colonizing success, with the exception of species with water impermeable seeds, some of which may even require fire for dormancy release. The majority of below-ground plant structures will, however, be killed at high fire severity, and thus the post-fire vegetation will be dominated by species of the second strategy. Also, the most important tree species northern Sweden spread their seeds onto the burned ground after a fire and their success in seedling establishment is strongly correlated with the degree of fire severity/depth of burn.

4.5.2.2.- Bryophyte flora colonization

Post fire vegetation development in north Swedish forests obviously can vary in its initial condition depending on the behaviour of the fire. However, viewed, over a long time scale, there are some general patterns apparent in the succession of ground vegetation in *Vaccinium myrtillus*-type forests. (Schimmel, 1993)

In the field-layer very little replacement species occurs. Ericaceous dwarf-shrubs that are dominating before the fire will mostly return to pre-fire levels within a couple of decades at the latest.

The bryophyte flora in the bottom layer shows a more classical mode of succession, with species replacing each other in sequence. Already one to two years after fire the cover of acrocarpous mosses is substantial in the burned area. 20-30 years after fire acrocarpous mosses in the bottom layer are of great ecological importance since it may influence several processes; e.g., tree seedling establishment. (Schimmel and Granström, 1996)

Since pleurocarpous mosses constitute the most important fuel in these ecosystems, the change in moss species composition also induces a gradual change in flammability. Estimates of fire intensity in stands of different ages suggest that for the first 10-20 years after fire, stands are not liable to burn. After this initial period, the fire intensity gradually increases, above all due to a gradually deeper and less compact fuel bed as the cover of pleurocarpous mosses increases.

From around 50 years after a fire, there is a more or less steady state fuel condition, which suggests no decisive shift in fire behaviour in older stands. Such a shift is, however, likely to occur as *P. abies* becomes prominent some 80-100 years after fire, since saplings and lower branches of spruce, unlike pines, are often involved as fuel in the propagation of a fire. At this point the mean fire intensity will increase, as will spread rate, and in particular so will the chance for long-rate spotting from torching spruce trees, thus overcoming firebreaks such as streams and mires. (Schimmel and Granström, 1996)

Variation in fire severity/depth of burn can influence significantly the distribution and composition of plant communities in the Swedish boreal forest, and should thus be an indispensable element of the fire regime concept. (Schimmel and Granström, 1996)

There is an abundance of different factors that might govern the fire regime in a certain area, but probably the most important are ignition density, fuel characteristics, landscape structure and climate. Estimates of fire behaviour in different stands suggest that the amount of fuel and especially the structure of the fuel can greatly influence the fire regime of an area. Spatial and temporal patterns of build-up cause differences in flammability and fire behaviour, which in turn might influence the areal extent of individual fires. (Schimmel, 1993)

4.5.2.3.- Fuel succession and fire behaviour

Earlier studies carried out by Schimmel and Granström (1997), have shown that there are profound changes in the species composition of mosses and lichens over the first decades after fire in boreal forests, and it would seem likely that changes in potential fire behaviour are linked to these successional processes.

It is suggested that there are three phases in post fire succession with respect to fire propagation and surface fire intensity:

1. Up to about 20 years after fire, no or marginal fire spread.
2. Between years 20 and 50 a progressive rise in potential fire intensity.
3. From around year 50 a steady state in potential fire intensity.

By setting a limit for the shortest possible fire intervals this pattern of fuel accumulation might have a significant effect on fire frequencies in the landscape.

According to Schimmel and Granström (1997), the consequences of these relations at the landscape scale are difficult to assess, but there are at least three mechanisms that may be operating:

1. Ignition from lightning or other causes occurring within young fire areas would tend to be extinguished because of lack of suitable fuels, which would lower the number of successful ignitions on the landscape.
2. Fires in young stands, if able to propagate at all, will have a low intensity because of a low rate of fuel consumption. They will therefore cover less area in a given period of suitable burning weather and be more easily stopped by minor firebreaks.
3. Recent burns can act as firebreaks.

Although still not analysed on a large scale, it is clear that long fire intervals were not necessarily followed by stand-replacing fires.

4.5.3.- Fire-adaptive traits. Pyrophilous species

Organisms that are conspicuously favoured by fires are called pyrophilous, Greek for fire-loving, and exist among fungi, plant, and animals. Vascular plants comprise most of the known pyrophilous species in regions with frequent fires, such as South Africa, Australia, Mediterranean Europe and southern USA. In contrast few plants, but many insects and fungi, are listed as pyrophilous in boreal forest. This taxonomical bias could be because of insects and fungi have been less studied in warmer regions. However, it may also have an ecological explanation because fires act differently on energy and nutrient availability in differing biomes the more. In cool and wet climates, such as boreal forest, nutrients often accumulate in the humus layer. Fires may activate the decomposition and liberation of nutrients, such as nitrogen, is often lost through combustion. Pyrophilous fungi and insects are mainly decomposers, and may take advantage of the increase in nutrient availability after fire in boreal forest.

The unpredictable occurrence of fires and special habitat characteristics of recently burned forest will, however, pose special demands on organisms that depend on fires for their long-term survival.

Pyrophilous plants and fungi may survive fire, or long fire-free intervals, by resistant vegetative or reproductive structures. In insects, long-lasting, dormant stages that are able to respond to environmental cues in a similar way as in plants and fungi is unknown. Instead, pyrophilous insects have to track fires in time and space by actively searching and dispersing over large distances. Smoke and heat can guide pyrophilous insects to burning areas from great distances. Unique receptors capable of sensing long-distance infrared radiation emitted from forest fires have evolved in the Holartic beetle genus *Melanophila*. (Wikars, 1997)

In northwestern Europe about 40 insect species, mostly beetles, are regarded as pyrophilous. Their populations have declined the last century as a consequence of the development of modern forestry and the subsequent elimination of natural fire dynamics. A majority are to be found on the national red-lists of threatened species. Pyrophilous insects form a surprisingly heterogeneous group, both from a systematic and ecological point of view. They are found among bugs, beetles, moths, and flies. Most develop as larvae in fire-killed trees or in burned ground where they feed on such varied items as fungi, phloem and sapwood of trees, and prey.

Fires have a stochastic occurrence on both a seasonal and annual basis. To have long adult life-spans would enhance the chance for pyrophilous insects to find a fire. Another strategy would be to spread the emergence of the offspring to increase the chance that at least some individuals find a fire. This has been indicated for *Melanophila acuminata*, which may emerge over several years despite simultaneous ovoposition. (Wikars, 1997)

Insects dependent on ephemeral resources or habitats must have a large dispersal and reproductive capacity. When reaching the burned habitat this has to be used quickly by pyrophilous species due to its inevitable deterioration. Anecdotal evidence suggests that pyrophilous insects have an exceptional dispersal capacity. Several have repeatedly been found along seashores far from their breeding habitats. The simultaneous need for a great dispersal and reproductive capacity may be problematic in animals, such as pyrophilous species, because resources devoted to dispersal may decrease the fecundity.

The characteristics of recently burned forest may pose special demands on species that live there. Daytime temperature is increased due to successive mortality and leaf-shedding of trees, and by increased water-loss through evaporation from the upper soil surface. This may cause mortality in species which are not drought resistant. Fires may also cause increased predation because hiding places become fewer and generalist predators may actively disperse to burned areas. (Wikars, 1997)

Several boreal pyrophilous insects, such as *Henoticus serratu*, *M. acuminata*, and *Microsania spp*., swarm from April to October, and are thereby able to find fires throughout the season.

A proximate reason for fire dependence could be the habit of many species to aggregate around glowing fires. This might have become an important behaviour in some pyrophilous insects to facilitate mate finding. However, the ultimate reason for fire-dependence in these species is presumably the special characteristics of the post fire habitat.

4.6.- Disturbances and biodiversity

Disturbances, such as forest fires, act on the species diversity of organisms largely in two ways:

- Firstly, they affect the distribution of habitat in time and space by creating patches of different successional age, thereby usually increasing the between-patch heterogeneity. A large part of the natural habitat variation in boreal forest such as stand structure and tree species composition is the result of fires.
- Secondly, within patches, a disturbance turns the clock back, which does not favour established and dominant species but favour fugitive, or stress-resistant species which are usually less competitive. Disturbances may therefore prevent competitive exclusion by promoting nonequilibrium conditions. However, too frequent or intense disturbances eliminate species without giving time for re-establishment. This reasoning led to the intermediate disturbance hypothesis, which predicts that moderate disturbances maintain high species diversity within a habitat.

For several years there has been more and more talk about the need to start using fire as a management tool in nature reserves that had been structured earlier by repeated fires, but nothing has been done so far on the ground. Forest managers on the other hand are eager today to adjust forestry practices to the former patterns of natural disturbance. The use of prescribed fire is one of the ways to achieve this. Until the late 1960s prescribed fire was extensively used for site preparation, but today most of the experienced people have gone. (Granström, 1993)

We know that fire specialists, so-called pyrophilous species, such as Cranesbill (*Geranium bohemicum*) and Pill-headed sedge (*Carex pilulifera*), which are almost exclusively dependent on fire for survival. The number of invertebrates associated with scorched and charred substrates, dead wood and other resources in burned areas is considerable. An example is the fire beetle, *Melanophila acuminata*, whose larvae develop in freshly burnt wood. Among the vertebrates, "fire followers" such as the moose (*Alces alces*), roe deer (*Capreolus capreolus*), woodpeckers and even the Ortolan bunting (*Emberiza hortulaua*) occur. (Wikars, 1997)

Today, fire suppression is so effective in Fennoscandia that the average annually burnt area has been reduced to less than 0,01% of the forested land. The lack of fire may have negative effects on biodiversity and ecosystem function. At first, this discussion was centred on management of reserves. Nowadays, however, the need to incorporate fire and to consider past disturbance regimes also within commercial forestry has been acknowledged by both researchers and land managers. (Granström, 2001)

Throughout the boreal region, various models have been proposed to link past disturbance regimes to modern land-use with the aim of conserving biodiversity. These models are usually built on the following assumptions:

1. Biodiversity within forest landscapes is a function of past history, particularly disturbance history.
2. Harvesting operations are (or can be made) equivalent to natural disturbances.
3. If harvesting is carried out so that the "natural" proportions (or in some models a particular fraction thereof), structure, and spatial patterns of various age classes are maintained then biodiversity will be maintained.

In Fennoscandia, the active use of fire has also been advocated under the program of forest certification; forest companies in northern Sweden are presently scheduled for about 4000 ha of prescribed burning per year (5% of the cut area on dry and mesic forest land, evened out over a fire-year period). This is a fairly large commitment considering the slim and highly mechanized field organizations of today's forest industry. (Granström, 2001)

In the long term, fire suppression in the overall landscape may result in a less diverse flora and fauna. It has been suggested that management plans for forest reserves should, to a much greater extent, include management practices that in some way maintain the natural disturbance regimes. (Granström, 2001)

Organisms with good dispersal potential might still find these small patches of burnt substrate and maintain their population above extinction. In Sweden, the amount of burnt substrate is certainly only a minute fraction (perhaps 1%) of what a "natural state" would offer (Engström, 2000). On the other hand, dispersal distances between substrate abundance between years may also be less. It is worth noting that the specialized fire fauna that utilizes freshly burnt substrates is still relatively intact, at least regionally, despite a tremendous decline in the amount of burnt forest. Organisms in the boreal forest that are highly specialized to exploit recently burnt areas must, in their evolutionary past, have been under extreme selection for dispersal in time or space, which makes them resilient even with today's effective fire suppression. Large distances between burns was typical in the past and there was no guarantee that fire would occur each year within a particular region, as is still the case in remote parts of Canada and Russia. (Granström, 2001)

When lightning is the only source of fire, long periods with virtually no fire can occur, and these periods are synchronized over relative large regions. This exerts a strain on fugitive insect species. Likewise, fire-dependent plant species, which rely on seed or spore-banking, would need exceptional longevity in their propagules, because extreme fire free intervals will sooner or later occur at point scale. (Granström, 1993)

Species which move around the landscape from one burn to the next, such as the pyrophilous beetles, can make use of new habitat patches wherever they appear, provided they offer the right substrate in sufficient amounts and are at a reasonable distance from the source population. Therefore, wildfires or prescribed fires, which appear randomly on the landscape today, can allow survival even in the long term. Although the total area of burnt forest is much lower than in the past, the same may be true for late successional elements such as deciduous stands with a fire origin (*"lövbrännor"*) and the particular set of species associated with these. A site can become densely covered with deciduous trees after fire regardless of its previous history provided that conditions are appropriate. (Granström, 2001)

Other elements (organisms and structures) can be viewed as more or less sessile, and for these it is necessary that fire returns to the same site repeatedly. Examples are multi-stored stands with fire-scarred trees, seed-banking plant species, and fire influenced soils. Today, these features are slowly eroding from the landscape and will continue to do so as long as burns are randomly located. The return time for fire at point scale is inversely proportional to the fire frequency and will most probably be too long.

	Early successional	Late successional
Mobile	Coleoptera	Senescent deciduous stands and their fauna
Sessile	Seed banking plants Fire-shaped soils	Multi storied pine stands

Figure 2: Example of early successional and late successional elements uniquely associated with fire in the boreal forest. For maintenance of the "sessile" elements, fire must return to the same site within a reasonable time. Sessile is here used to separate species without long-range dispersal and forest structures and site qualities which develop only over a very long time (several hundred years). Source: "Fire management for biodiversity in the European boreal forest". Granström, 2001.

Today, fire frequency, including prescribed fires, is so low in Fennoscandia that fire return intervals are in the order of 1000-10000 years. Although there are no estimates of maximum longevity, for example, the seed bank of *Geranium bohemicum*, these periods would probably be too long. (Granström, 2001)

The present goal for forest companies, as expressed in their policies and in the forest certification criteria, is to burn a specific amount of land. It is likely that in the future, emphasis will shift towards obtaining maximal ecological gains with the aid of fire. To achieve such targets in the long term at both the stand and landscape levels, long-term commitments to particular sites for several forest generations to come is needed for sessile elements, whereas mobile elements might benefit from a geographic concentration of burning activities. (Granström, 2001)

Fire should be reintroduced as an ecological tool to recreate biological values associated with multi-storey Scots pine stands. This might not necessarily mean that timber production will decrease.

4.7.- Forest certification

In Sweden, forest is certified by two different systems: the Forest Stewardship Council (FSC) and the Pan European Forest Certification Council (PEFC). Certified forest area in Sweden: FCS - 10,12 million ha (accessed 07-04-2002) and PEFC - 1,97 million ha.

The Swedish PEFC process started in June 1999. The FSC process in Sweden started in 1996, but some initiatives were taken already in 1992.

Large-scale forestry and State forests are certified in accordance with the national FSC standard, while the forest owners' associations together with purchasing sawmills have chosen to offer certification to the Swedish PEFC standard, which was adopted by the European PEFC Council in May 2000. Now in Sweden a proposal for a bridging document for the Swedish PEFC and FSC standards has been prepared. The project is called *"Skogsduvan"* (The Stockdove).

4.7.1.- Forest Stewardship Council

Forest Stewardship Council (FSC) is an international, independent membership organization. FSC provides a framework of global Principles and Criteria for a sustainable use of the world's forests, which is constantly completed with national and regional standards. FSC was founded in 1993 in Toronto on initiative from representatives from environmental organizations, forest owners, indigenous peoples organizations, and environment certification organizations from 25 countries. The main objective was to support environmentally appropriate, socially beneficial, and economically viable management of the world's forests. Actually FSC counts more than 500 member organizations including environmental NGO's, forest companies and its customers and social stakeholders like indigenous people. Up until now, there are members from 60 countries.

The head quarter is located in Oaxaca, Mexico. The FSC standards are about consideration of nature and environment as well as right of indigenous people's and other local communities and a sustainable, economic viable production. Sweden was, in 1998, one of the first countries with a national FSC standard. Today more than 23 million hectares of forests and plantations are FSC certified in 48 countries all over the world (as of November 2001).

Products certified according to the FSC-standard must come from forests managed in a responsible environmental, social and economical manner.

The base for FSC certification are national standards that are created by each country's FSC Working Group. As a result the standard is balanced between different stakeholders' demands, consideration is taken to environment and nature, local people's rights, the benefit of indigenous people and to a sustainable and economically viable production.

FSC certification is by its nature dependent on the market place, and the demand for FSC products turns out to be large and growing, especially in some countries, e.g. UK and Germany.

FSC is based on voluntary participation; each forest owner can apply for the forest being certified. The performance standard that has to be fulfilled embraces most aspects of forestry. Some examples are: five percent of the forest shall be set aside for pure biodiversity purpose. The forest shall to a certain part consist of broadleaf trees and naturally dead wood has to be left on ground or standing (because of its great importance to many threatened species.) It is not allowed to ditch forest wetlands. The use of exotic species is prohibited, other than in exceptional cases.

FSC certification works equally well for all land owner, small forest owners as well as big companies. Specialized "umbrella organizations" are responsible for group certification which makes it easier - and less expensive - for the smaller land owners.

4.7.2.- FSC in Sweden

The FSC was established in Sweden through the formation of an FSC working group on 15 February 1996. The task of the working group was to develop a proposal for the Swedish FSC standards, which was finally approved on 8 May 1998.

After the intensive work involved in creating the national standards, the working group was restructured to form the smaller Swedish FSC Council, on 24 September 1997, which now officially represents the FSC in Sweden. The Council consists of two members each representing environmental, social and economic interests, as well as a secretary. The tasks of the Council are to deal with matters concerning the Swedish FSC-standards, disseminate information on the FSC and support certifiers in their work to apply the standards. The Swedish FSC Council also handles contacts with the international FSC. The Swedish FSC Council is currently financed through donations.

The Interest Group is coupled to the Swedish FSC Council. It consists of 100 or so companies, organizations and private persons who have declared their support for the FSC certification of forestry.

So far, Sweden is the world's number one among FSC certified countries, with more than 10 million hectares of productive forest land certified. This has been accomplished through the devoted effort of SSNC and other players. On this area (which is some 45 % of the Swedish forest), much of the biodiversity crises and other problem issues in the Swedish forests could be solved, step by step. All the larger forest companies, some 70 cities and communities, and hundreds of smaller land owners are FSC certified by now. This is really an important landmark for the forest with its inhabitants and of course for the forestry.

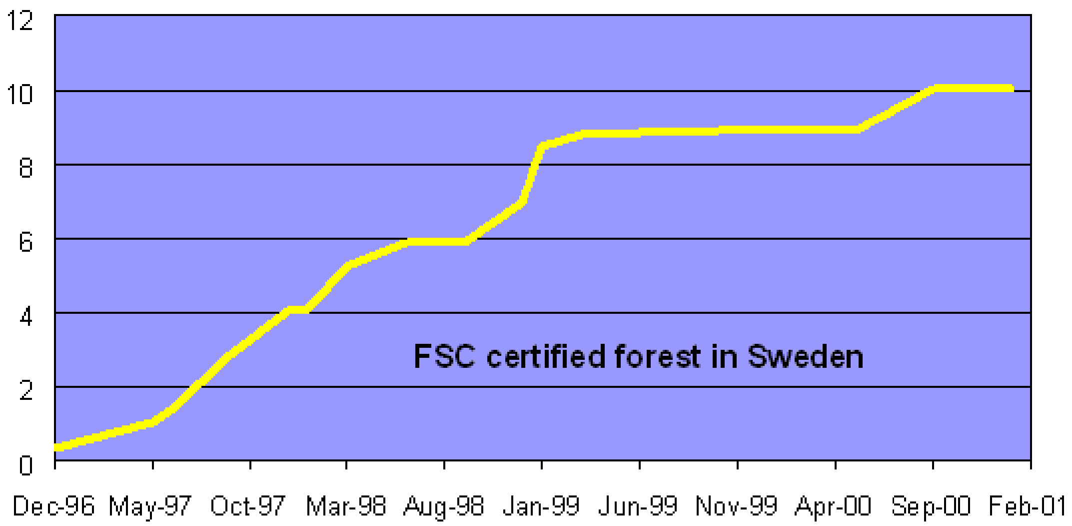

Figure 3: Forest Stewardship Council certified forest in Sweden (million hectare). Source: Svenska FSC-Rådet, 2001. (www.fsc-sweden.org)

4.7.3.- Swedish FSC standard

The FSC's Principles and Criteria constitute an overall framework for the development of a national suitable standard. They are not intended to be employed as the sole basis for certification. National standards are developed to comply with local ecological, social and economic conditions, while simultaneously embodying the FSC's fundamental Principles and

Criteria. When a set of standards has been approved by the FSC, all local and international certifiers must apply these standards as a minimum requirement in their certification processes.

Prescribed burning is required for forest certification through the Chapter 6.4.4 of the Swedish FSC Standard for Forest Certification:

"Owners of larger landholdings are to take all reasonable measures to burn an area corresponding to at least 5% of the regeneration area of dry and mesic areas during a 5 year period. Preferably, earlier fire-affected land should be chosen. Naturally-burned forest and forest burned for conservation purposes may be included here. Felling and burning are to be planned so that fire-dependent species are favoured. In areas with high nitrogen levels, the leaching of nitrogen into water courses shall be minimized. Where the appropriate conditions exist, natural regeneration shall be used."

5.- FOREST FIRES IN THE MEDITERRANEAN REGION. SPAIN

5.1.- Background

Fire is the main cause of forest destruction in the countries of the Mediterranean basin.

Forest fires, regardless of their extent, have different typologies that depend in particular on the biomass exposed to fire (tons per hectare) and the density and distribution of the combustible material (Bovio, 1990). It is advisable in the planning stages to predict the characteristics of the possible fires that may occur. This prediction is based above all on a floristic analysis of the species that are most liable to spread the fire. The quantity of combustible available and the actual vegetable species are the main factors determining heat emanation in the event of a fire.

The spreading of the fire front, on the other hand, is affected by the density and the distribution of the fuel. In order to determine the probable behaviour of a forest fire, special attention must also be paid to the horizontal continuity of the vegetation, i.e. the distance between the foliage of the individual trees that create the forest coverage.

It is also necessary to know the vertical continuity of the vegetation, which is determined by the distance between the lowest levels of the tree foliage and the shrub level of the ground cover. It will thus be possible to estimate if the fire is likely to spread at ground level, only burning the ground cover, or if it will succeed in reaching the foliage of the trees.

Knowledge of the typology of the combustible is necessary for the realization of planning measures. (Bovio, 1990)

5.1.1.- Climatic factors

Mediterranean weather, with its long and dry summers and average daily temperatures higher than 30°, decreases the moisture of dead plant material to less than 5%. With these conditions, a fire can be started with a little source of heat. (Vélez at al., 2000)

Summer winds, for example tramontana, sirocco, levante, etc, are characterized by a high speed and drying power. Atmospheric moisture can decrease to below 30 % and contribute to spreading fires and carrying pieces of ash long distances.

Winter cold and dry winds also can cause forest fires due to small fires made by farmers and may spread to the forest.

5.1.2.- Forest vegetation as a fuel

Botanic composition of Mediterranean forests includes species that need the fire during its reproductive cycle. The reason for this is the summer long droughts that characterize the weather conditions. Pine groves are the most extensive forests. The main species are *Pinus halepensis, Pinus pinea, Pinus pinaster, Pinus nigra* and *Pinus brutia*. All of them are characterized by physiological mechanisms that link the natural reproduction to the fire. Often they contain a high percentage of resins and essential oils that are highly inflammable.

Other evergreen species, such as *Quercus genus*, have developed mechanisms to survive the fires as the presence of a high number of buds. This ensures the production of sprouts if the aerial part of the plant is attacked by a fire. This adaptation does not imply permanent protection. After several fires the trees are replaced by a woody brush typically pyrophilous, as is the case of Cistus.

To this natural evolution of vegetation, it is necessary to add the variations due to artificial restoration of degraded zones. This restoration is usually made with pioneer species, such as pines. Therefore, the risk of big fires is increased due to the easy spread of fire through the highly inflammable and continuous fuel in these plantations. (Vélez at al., 2000)

5.1.3.- Socio-economic conditions

Socio-economic develop of a region can cause of grazing to be interrupted, as well as the extraction of firewood and brush. Consequently, combustibility of the forest has increased. This is an important problem in private property forests. Due to its low profitability, forests are often neglected until the felling of the trees.

Another cause of fires has been the rural exodus. Large extensions have been abandoned and colonized by brushes and, sometimes, natural pine groves.

According to Vélez et al. (2000), the current situation in the European Mediterranean countries can be characterized by the following facts:

- Rural exodus looking for higher economies in urban zones.
- Give up traditional uses of land in rural areas.
- Tendency for a downward trend of forest use as a raw material producer.
- Tendency of traditional uses of land (grazing, firewood extraction) to disappear or remain a residual crop.
- Upward trend of recreational use (hiking, hunting and fishing).
- Constant increase of urban-forest interface.

5.1.3.1.- Rural interface conflicts

1) Persistence against the breaking of land

This conflict is due to the use of fire to eliminate forest vegetation so land can be cultivated. Currently, this conflict is disappearing, because there is no demand for more land to be cultivated.

2) Drift from the land

This conflict is a consequence of the end of rural activities in bad lands. This drift originates the invasion of forest species and, within a short period, the light fuel load is high, so the fire can spread with a high speed and intensity. There are policies that provide subsidies to regulate the change from agricultural to forest use, but it is a long process that makes it aggravating.

3) Grazing and use of fire

Sometimes fire is used to maintain the herbaceous vegetation and eliminate woody vegetation. Normally, the use of fire is forbidden in woodland. Outside a permission from the Forest Service is necessary. On the contrary, there are some regulations for the protection of mountain populations due to the steady reduction of the number of shepherdesses. The current tendency is to promote controlled burning.

4) Burning of agricultural remains

The current tendency has been to increase burnings to eliminate the remains of the crops and to prepare the land for new sowings. There are educative policies and promotions of controlled burnings, so this conflict can be treated efficiently.

5) Declaration of special protection zones

The problem is the limitations that these declarations imply for the local communities. These limitations try to conserve and restore the natural resources. Sometimes the limitations go against the costumes of the local communities. The political tendency is to recognize these conflicts and arbitrate compensatory measures. However, the bureaucracy of the compensatory systems, necessary to avoid frauds, keeps this conflict opened.

6) Forest crops

The problem of forest crops is the continuity of the fuel models. This is very dangerous in the first stages and prone to big fires later if there is not a proper preventive silviculture. The consequence of the debate around forest crops has been the ending of reforestation programmes within large regions. The tendency is to integrate the principles of the preventive silviculture in the reforestation programmes.

5.1.3.2.- Urban interface conflicts

1) Change into urban use

This conflict is due to the quick development of urban areas, extending first to the agricultural zones and later to the further forestlands. The limitative legislation in the change of use can be the reason for the fire if the existence of forest vegetation is what determines the use. Actually, it is not like this in any Mediterranean country. If the vegetation is lost in a fire, it has to be restored, so it is not admitted the change of use. The conclusion is that this conflict should be investigated.

2) Increase of the recreational use in the forest

In recent years there has been an increase in the recreational activities such as hiking, hunting and fishing. The increasing amount of people in the forest results in a higher probability of fires caused by negligence. Bonfires are regulated as agricultural fires. Throwing a lighted cigarette is forbidden. The current tendency is to make these regulations effective, intensify the vigilance and limit the transit of people through the forest.

3) Rubbish dumps maintained with the use of fire

The importance of this conflict is increasing due to the increase in the amount of garbage originating from urban areas. In small to medium sized towns, they still accumulate the garbage and eliminate it using fire, but this can cause a leak fire. The only measures to solve this conflict are economic aids to treat the garbage, but it needs more attention from the local authorities.

5.1.3.3.- Conflicts non directly related to the use of land

1) Revenges

It could be revenge against people or against the society. The former can be due to a private motivation, and the latter can be very variable, for example, a hunter can be angry because he didn't get a hunting place and could burn the forest in anger. In all the cases, the arson is an offence.

2) Crime

In this case, the fire is used to hide another offence or help to do it. There are many examples: fires to bring about future investments in reforestation, fires to distract the police in smuggling operations, fires to hide poaching.

5.1.4.- Motives for the forest fires

Regarding to what has been said before, we can consider the next main motives (Vélez et al., 2000):

1. Frequent motives in all the regions:
    - Agricultural fires
    - Grazing fires
    - Rubbish fires
    - Revenges and vandalism
    - Recreational activities (bonfires, barbeques, smokers)
2. Frequent motives in some regions:
    - Protest against use limitations in protected areas
    - Labour market
    - Hunting conflicts
    - Resentment against old reforestations
3. Infrequent motives:
    - Smuggling and other criminal activities
    - Changes in the land use to urbanize it
    - Wood market

5.2.- Defence against forest fires

The database of forest fires is an important tool for the analysis of causes and the design of prevention and extinction policies. Spain possesses the longest and largest database about this problem in Europe, started in 1968, and maintained with forest criteria since then.

5.2.1.- Prevention

The most crucial infrastructure items to be developed for fire prevention are the creation of forest roads (which allow rapid intervention and act as fire-breaks), the provision of water supplies in the event of a fire and the establishment of firebreaks.

5.2.1.1.- Environmental education

This section can be divided in the next points (Vélez et al., 2000):

- Information through the media.
- Publicity (posters, adhesives, information boards, prevention campaigns).
- Raising public awareness.
- Vocational training.

5.2.1.2.- Preventive silviculture

Preventive silviculture is a group of rules included in general silviculture, with the aim of reaching certain vegetation structures with a lower degree of combustibility, meaning a higher resistance to fire spread (Vélez et al., 2000).

The spread of a fire depends on the moisture content of the dead fuel over the soil and on the structure of the vegetation. This can be classified according to a fuel model system. Preventive silviculture aims to modify that structure to reduce fires spreading through linear actions and general actions creating discontinuities and transforming the fuel models.

Prevention tries to stop fires starting through actions over the agents that cause the ignition. Taking into account the impossibility of avoiding some fires, prevention tries to reduce the spread of the fire over the fuels through previous actions that prepare the forest to resist the spread of the fire. Therefore, there is a need to analyse what fuel is burning in a forest fire and how the fire is spread over it to find a formula that makes the fuel less combustible and hinders the fire’s spread. (Vélez at al., 2000)

The forest resistance to the fires can be considered in two senses: the first is fire resistance of forest species; the second is the resistance to the fire spread over the forest vegetation.

Forest species resist the fire in two ways:

- Passively, thanks to thick barks which protect the cambium or the presence of sleeping sprouts that recover the dead aerial part from the fire.
- Actively, due to intense disseminations after the fire, recovering the individuals killed by the fire.

Most of the species living in Mediterranean ecosystems resist fire, sometimes both ways, as a consequence of genetic selection by repeated fires.

The Mediterranean environment is so altered that it is difficult to identify any zone with a natural existing equilibrium between fire and forest floristic composition. In most cases there is no natural equilibrium, instead this equilibrium is induced. Human burn more or less frequently every zone and vegetation responses as it was said before. Resistance to the spread of a fire depends on the horizontal and vertical continuity of the fuels. (Vélez at al., 2000)

The follow principles can be enumerated:

1) Preventive silviculture aims to modify the structure of the vegetation in the forest to make it difficult for fires to spread.

2) This aim can be reached through the diversification of species, establishing linear disruptions in its perimeter and along paths, watercourses and dividing lines. This is the same way as conserving or favouring the alternation of species.

3) Diversification should take place with a care for the landscape, as well as the wildlife habitats included in it.

Regarding to the extent of the actions, they can be:

1. **Linear actions**: Linear actions consist mainly of firebreaks. The firebreaks separate the forest from agricultural zones, pastures, urbanizations, rubbish dumps, industry, communication lines, etc. Inside the forest, the firebreaks will be maintained along roads, tracks and paths, along watercourses and to leeward of dividing lines
2. **Stand actions**: Stand actions try to diversify the vegetation, avoiding monospecific large surfaces and creating differences in the inflammability that slow down the fire. In the case of copping wood, it is convenient to save the strong sprouts and cut the others in order to change from copping wood into a forest. In the high forest, it is interesting to reach the closed canopy with the aim of changing into less dangerous forest fuel models, limiting the development of the understorey vegetation. The felling plan should be organized in such a way that the patches formed do not contribute to speeding up the fire. For this reason, the felling direction should be against the wind, in a way that the stand remaining stops it. Regarding the species, there has to be favour to the ones with low

inflammability, however this will not be possible in most of the cases due to ecological and economical factors. It is convenient to favour the mixture of species or, unless, the presence of patches of different species, which contribute to modify or break up the continuity of the forest fuel models. In particular, every spot with enough humidity, mainly watercourses, should be used to plant species that can take advantage of this humidity. It is known the existence of species belonging to typical genus of arid zones (Atriplex, Tamarix, etc.) with high salt content, which burn badly and could be experimented on in some places.

To decide the location of these actions, it is known that normally fires have their origin in predictable activities, so the zones closed to these plots will be the ones that require more attention, and where the stand structure modifications should be more intense. Other preventive infrastructures

Other important infrastructures are:

- Forest trails: which have a multiple use against forest fires, as a quick access to the forest by firewatch groups, fire engines or brigades, and also as a defence line.
- Water spots: places to store water for fire engines or aerial means.
- Protection of housing states, encampments and recreational areas inside the forest.

5.2.2.- Extinction

5.2.2.1.- Detection systems

To guarantee that damage produced by fires and the extinction costs are at a minimum, an efficient detection system is needed within the program of fire fighting.

The currently used systems are the following (Vélez et al., 2000):

- Terrestrial detection
- Terrestrial mobile detection
- Aerial detection
- Others

5.2.2.2.- Extinction methods

Depending on heat production, fire-fighting operations may consist of direct or indirect attacks. These attack may be by land or by air, and frequently can be simultaneous. (Bovio, 1990)

There are three methods for fire extinction: direct attack, indirect attack and counterfire.

Normally, the counterfire is not included as an extinction method, but it is included as an action of the indirect attack. Taking into account that for certain types of fires, such as the crown fire, the counterfire is often the only option to control the fire, moreover its application requires a previous actions, a technique and a control of time, it seems more appropriate to include the counterfire as one of the extinction methods (Vélez et al., 2000).

1. Direct attack

If the fire is in its beginning or its characteristics allow us to work at head quarters, or there is water and means to throw it, there can be a direct attack to the fire in order to suffocate the flames.

In this method, there is an act mainly against two of the components in the triangle of fire (heat and oxygen), and leads to the cooling down of the fuel and reducing the air close to it. (Vélez at al., 2000)

The methods of action are numerous and they vary according to circumstances. For the same reason various types of equipment are commonly used, as fire-beater, fire-rake and shoulder-held, manual or motor pumps to direct powerful jets of water on to more violent fires. (Bovio, 1990)

2. Indirect attack

Fire should be combated according to this method when the fuel type, fire intensity and its spreading (crowns) so recommend it. Always that there is danger for the personnel working in the extinction, or when present and foreseeable dynamics of a fire, easiness to walk and topography so advise it.

The indirect attack consists in isolating the fuel from the flames, establishing defence lines to a distance at the front, so that the control lines circumscribe one or more perimeters that complete the control phase. (Vélez at al., 2000)

This method acts mainly over the fuel, removing it in strips (defence lines) or spreading chemical products that impregnate the fuel and avoid or hold up its combustion (chemical firebreaks).

3. Counterfire

Counterfire means to use the fire in order to extinguish it. There should always be controlled burning, because the fire is prescribed to spread in a certain direction according to the determining factors that act on its behaviour: fuel, topography, climate. There are limitations due to security reasons and the damage that can be made to different goods. The person responsible to order a counter fire is the extinction director. (Vélez at al., 2000)

According to Rodríguez de Velasco (2002), the use of counter-fire needs the strict performance of the three following conditions:

1) To guarantee that the safety of the experts or any other possible users of forests are not endangered with the use of fire.
2) To use the appropriate techniques to the conditions that are to determine the fire behaviour and the counter-fire.
3) To analyse the opportunity of its starting moment, adjusting the foreseeable development of the counter-fire to the advancing and geometry of the front.

5.2.3.- **Application of new technologies**

Fighting against forest fires needs numerous data about countryside knowledge, massive information about the fire state and experience. Nowadays, different computer systems are being used in order to help when taking decisions.

New technologies and materials appear constantly and, although they are not a solution for the problem, sometimes are very useful tools for helping against some difficulties of the defence against forest fires, both in preventive and fight aspects.

Normally, these technologies are linked to the quick development produced in recent years in the fields of telecommunications and computing. The application of these technologies to the forest fires has lead to the Prevention and Extinction Services incorporating modern Operation Centres. Here, the data consulting, digital cartography and the exchange of digital information play a very important role. The utilities provided by these technologies constitute an invaluable help for a more documented decision-making process. (Vélez et al., 2000). The utilities include:

- GPS technical applications
- Location and monitoring of terrestrial and aerial means
- Location of mobile platforms
- Transmission of real time images
- Infrared fire detection
- Fire simulation (CARDIN, FARSITE, FIREFOC, FEOT programs)
- Fire behaviour prediction (BEHAVE system)
- Satellite fire detection (SISTEMA FUEGO)

The use of Geographic Information Systems (GIS) for the management of the data accumulated has became common for the planning against forest fires. At the same time, remote sensing is used to know the danger evolution in large areas and to evaluate the fire impact.

6.- CONCLUSIONS

Forest fires have been an influential disturbance on the flora and the fauna both in the Boreal and in the Mediterranean regions. Through this project, it has been shown that this problem is very different from one region to the other. In the Boreal region, there is a lack of forest fires due to the intense and efficient fight against them, which may result in a less diverse flora and fauna. In the Mediterranean region the forest fires burn every year a large surface, sometimes even jeopardizing people's lives.

This enormous difference is mainly due to climatic and socio-economic factors. In Boreal regions, the main cause for forest fires is lightning ignition, while in the Mediterranean region it involves just a low percentage of the total forest fires; most of them are caused by men, with a high incidence of arson due to different conflicts.

Once that the forest fires are not any longer a problem in the Boreal region, the use of prescribed burning has received a renewed interest. By mean of this, it is tried to favour the different fire-adapted organisms and to create favourable conditions for forest regeneration. Different studies have shown the benefits of the forest fires for the regeneration of several species. The present goal for forest companies, as expressed in their policies and in the forest certification criteria, is to burn a specific amount of land. It is likely that in the future, emphasis will shift towards obtaining maximal ecological gains with the aid of fire. The problem of fire management is not to abolish fire but to establish its proper proportion, to reconcile fire use with fire control. What this means specifically will vary with the specific purposes of specific lands.

Within the Mediterranean region the current situation is completely different. Despite all the efforts made and all the money invested, forest fires keep on being a serious problem. The number of forest fires is increasing every year, although the total area burnt is slightly decreasing. Even though a big effort is being made throughout this entire region, forest fires still spread over large surfaces every year. Throughout this project, I have also gone through the different ways of fighting forest fires, from the prevention to the extinction, and some of the new technologies that are already being used.

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APPENDIX

Table 1.- Total number of forest fires (number)

Year	Finland	Norway	Sweden *	Spain	Italy	Portugal
1989	617	390	...	20593	9669	20155
1990	571	578	...	12474	14477	18507
1991	287	976	...	13531	11965	13118
1992	852	892	...	15955	14641	14954
1993	286	253	...	14254	14412	13919
1994	1054	471	2500	19263	11588	18104
1995	1031	181	1100	25827	7378	28044
1996	2349	246	6240	16772	9093	28626
1997	2595	108	8434	22319	11612	23497
1998	557	14	5258	22338	9540	35102
1999	1528	?	4694	18237	6932	25477
2000	805	?	4650	24117	8595	34109
2001	751	?	4774	19547	7134	27067

* Sweden: The collection of statistics was discontinued in 1980. Data for 1992-1997 are based on estimates (applies also to other tables).

Sources: Corpo Forestale dello Stato (Italy), Timber Bulletin (UNECE/FAO publications), Dirección General de Conservación de la Naturaleza (Ministerio de Medio Ambiente, España), Swedish Rescue Service Agency.

Table 2.- Total area of forest fires (hectares)

Year	Finland	Norway	Sweden *	Spain	Italy	Portugal
1989	516	992	...	426568	95161	126235
1990	433	87	...	202825	195319	129839
1991	227	530	...	260306	99860	182486
1992	1081	1370	5808	105278	105692	57012
1993	580	224	1000	89331	203749	49963
1994	1575	232	3100	437635	136334	77323
1995	643	113	400	143468	48884	169612
1996	827	514	2181	59814	57988	88867
1997	1467	870	6386	98503	111230	30535
1998	205	300	2989	133643	155553	158369
1999	609	?	1326	82217	71117	70613
2000	352	?	1553	187026	114648	159604
2001	161	?	1253	93298	75212	111850

Table 3.- Number of fires by known and unknown causes (number)

	Year	Finland	Norway	Sweden	Spain	Italy	Portugal
TOTAL	**1994**	...	471	2500	19263	8669	18104
	1995	...	181	1100	25827	6225	28044
	1996	2349	246	6240	16772	9093	28626
	1997	2595	108	8434	22319	11612	23497
	1998	557	14	-	21970	9540	35102
KNOWN CAUSES	**1994**	...	372	1687	14734	6850	12492
	1995	...	112	512	21003	4717	18509
	1996	1904	246	3718	13852	7506	18607
	1997	2196	77	5661	18522	8552	...
	1998	434	8	-	...	6137	...
UNKNOWN CAUSES	**1994**	...	99	813	4529	1819	5612
	1995	...	69	588	4824	1508	9535
	1996	445	-	2522	2920	1587	10019
	1997	399	31	2773	6797	3060	...
	1998	123	6	-	...	3403	...

Table 4.- Number of fires by known causes (number)

	Year	Finland	Norway	Sweden	Spain	Italy	Portugal
TOTAL HUMAN CAUSES	1994	...	169	798	13909	6731	12311
	1995	...	75	447	20041	4643	17948
	1996	1815	244	3634	13181	7434	18034
	1997	1731	34	5154	17857	8468	...
	1998	378	8	-	...	6041	...
TOTAL NATURAL CAUSES	1994	...	203	889	825	119	181
	1995	...	37	65	962	74	561
	1996	89	2	84	671	72	573
	1997	465	43	507	665	84	...
	1998	56	-	-	...	96	...

Table 5.- Number of fires by human causes (number)

	Year	Finland	Norway	Sweden	Spain	Italy	Portugal
ARSON	1994	...	25	151	...	4853	6366
	1995	...	5	75	17047	3300	8413
	1996	401	144	299	11006	5263	9160
	1997	384	17	496	15624	6135	...
	1998	102	5	-	...	4837	...
NEGLIGENCE	1994	...	140	647	...	1878	5974
	1995	...	70	372	2994	1343	9535
	1996	1414	100	3335	2175	2171	8874
	1997	1347	17	4658	2233	2333	...
	1998	276	3	-	...	1204	...

<u>Table 6</u>.- Number of fires by cause (percentage). Average years 1994-1998.

COUNTRY	TOTAL (NUMBER)	UNKNOWN	KNOWN				
			TOTAL	NATURAL	HUMAN		
					TOTAL	ARSON	NEGLIGENCE
Finland	1833.7	17.6	82.4	11.1	71.3	16.1	55.2
Norway	204.0	25.1	79.9	34.9	52.0	19.2	32.4
Sweden	4568.5	36.6	63.4	8.5	54.9	5.6	49.3
Spain	21230.2	22.5	80.2	3.7	76.5	68.6	11.6
Italy	9027.8	25.2	74.8	1.0	73.8	54.0	19.8
Portugal	26674.6	31.4	62.0	1.6	60.3	29.9	30.5