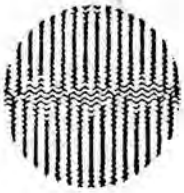

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Limitations and Needs in Maintaining or Restoring Prescribed Fire Regimes in Natural Forest Lands and Plantations

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SUMMARY

The developments of a variety of degrading forest ecosystems in the lower latitudes are influenced by non-planned anthropogenetic fire regimes. Short return interval fires are a characteristic feature in maintaining a fire climax (subclimax) stage of vegetation development. When converting non-planned fire regimes into prescribed fire regimes, the negative impacts of fire on the site and the surrounding environment have to be considered.
The main problem connected with fire are invasion of undesirable endemic/exotic species, interactions with pests, erosion and air pollution. Contemporary planning of prescribed fire regimes requires the temporal and spatial stratification of the fire environment and the search for alternatives to prescribed burning.

RESUME

L'extension en zone tropicale d'écosystème forestiers dégradés est en relation avec les feux non planifiés liés aux activités humaines.
Une grande fréquence des feux entraine le développement d'une végétation en équilibre avec le feu.
Lorsque les feux contrôlés remplacent les feux non planifiés, les aspects négatifs de l'impact du feu sur le site et son environnement doivent être pris en considération.
Les principaux problèmes liés à l'emploi du feu sont l'invasion d'indésirables espèces endémiques ou exotiques et les intéractions avec les dépradations, l'érosion et la pollution atmosphérique.
Une planification moderne des feux contrôlés exige la stratification du milieu dans le temps et dans l'espace, et la recherche de solutions de rechange au brûlage contrôlé.

1. INTRODUCTION

By the end of the 20th century it becomes more and more visible that the world's forests of all vegetation zones are undergoing a major change. Long-range and short-range transport of industrial emissions are causing severe problems and damages to the terrestrial and aquatic ecosystems of the northern circumpolar, boreal and temperate zones.
In the mediterranean subtropical and tropical regions (the "South") the stability and sustainment of forests and forestry is highly endangered by the increasing amount of fires in forests and wildlands which are following in the wake of altered and expanding land-use systems. The interactions between degrading forest ecosystems and the hydrosphere-atmosphere on global climate and "global change" are being recognized.

By successively better understanding of global ecological processes it is possible that policies of contemporary forest and wildland fire management may face a fundamental crisis : the shift from the fire control policy towards Integrated Fire Management seems to swing back due to environmental constraints.
Are the ecologically based concepts of Integrated Fire management and prescribed burning becoming questionable at the very moment in which the European foresters begin to reflect about restoring fire into forest ecosystem management ?

A hypothetical development of forest ecosystem management and fire management policy as shown in figure 1 may result into a post-modern fire control policy. This paper does not intend to proof whether this hypothesis is realistic or not. A critical look, however, is given to the limits and needs of prescribed burning and prescribed fire regimes and the alternatives to prescribed burning.

2. NATURAL AND ANTHROPOGENETIC FIRE REGIMES AND PRESCRIBED BURNING

The kind of fire history that led to the development of an ecosystem can be summarized as its fire regime (HEINSELMAN 1981).
According to KILGORE (1981) the characteristic features of a fire regime are such factors as fire frequency and intensity (HEINSELMAN 1978, SANDO 1978), season (GILL 1973), pattern (KEELEY 1979) and depth of burn (METHVEN 1978).
KILGORE (1981) proposed a modification of the fire regimes described by HEINSELMAN (1978) for use in forests and scrublands of the Western U.S.A. He distinguished six kinds of fire regimes based on the impact of fire frequency and intensity on the vegetative structure :
* frequent, low-intensity surface fire, 1 to 25 year return intervals,
* infrequent, low-intensity surface fires, more than 25 year return intervals,
* infrequent, high-intensity surface fires, more than 25 year return intervals,
* short return interval, stand-replacement fires, 25 to 100 year return intervals,
* variable regime : frequent, low-intensity surface fires and long return stand replacement fires 100 to 300 year return intervals,
* very long return interval, stand replacement fires, more than 300 year return intervals).

GOLDAMMER (1986) designed a model of seven types of fire regimes in tropical/subtropical vegetation. The fire regimes are characterized by the degree of disturbance (degradation) and site stability, under a generalized framework of anthropogenetic and ecological factors (figure 2).
When developing a fire management policy or a prescribed burning program it is essential to define the ecological and anthropogenetic characteristics of the prevailing or desired fire regime.
BARNEY (1975) defined fire management as "the integrating of fire related biological, ecological, physical and technological information into land management to meet desired objectives". BORROW (1977) proposed that "fire management activities should be governed by resource management objectives and both beneficial and damaging aspects of fire should be considered".

The most crucial question in developing a "prescribed fire regime" is whether the fire regime is likely to be a natural one or an answer to anthropogenetic disturbance of vegetation and the problems created by man-made forest ecosystems (plantations).

Intensive forest management will not permit to restore natural fire regimes such as the types 3 to 6 of the Heinselman-Kilgore definition ; the same refers to the extremely used forests and wildlands of the developing countries on which the population exerts increasing pressure and is dependant on by utilizing a large variety of wood and non-wood forest products. Those types 3 to 6 will be restricted to natural parks or to vegetation types under "wilderness management" and forests and wildlands in remote and non-managed lands.

Integrating (= restoring, maintaining or introducing) fire into forest management of the densely populated countries of the Old World and the tropical/subtropical regions may be restricted to fire regime type 1 or, to a lesser extent, type 2.
This type of regime is characterized by short return fire intervals and low-intensity fires and generally maintains a serial sub-climax (fire climax) stage of vegetation development. Such frequent fires are common in a variety of forest and shrubland communities within the lower latitudes.
The ignition of the fires is mainly man-caused and not planned. It follows often in the wake of extensive forest-land use, particularly grazing practices (see GOLDAMMER 1988).

The process of vegetation degradation depends highly on the frequency of burning. Le HOUEROU (1974) has shown that the mediterranean *Quercus ilex* forest degradation varies in respect to the fire regime and the soil and geological conditions.
On the other hand some forest communities as pine (*Pinus spp.*), eucalypt (*Eucalyptus spp.*) or teak (*Tectona grandis*) forests and a variety of dry deciduous and semi-deciduous forests may show remarkable tolerance to frequent surface fires.
However, most of the fires are started accidentally or intentionally by traditional land treatment practices. Thus, the existing frequently burnt plant communities are generally not the result of a "prescribed fire regime" in which all ecological interactions are considered.
Consequently almost all unplanned fire climax forest associations are not in a stable, dynamic equilibrium. They are rather subjected to long-term degradation processes which become visible only after generations.

Maintaining a desirable and probable already prevailing-forest type by prescribed fire requires both a spatial and a temporal stratification of the fire environment (prescribed fire regime) in order to avoid site disturbance. This corresponds to the negative effects of uncontrolled silvopastoral (grazing) techniques which may be overcome by "prescribed grazing" management (GOLDAMMER 1988).

However, the development of a fire management program must not take into consideration only the use of prescribed fire but also the alternatives in fuel treatment and the possible or preferable advantages of fire exclusion.

The commonly practiced objectives of prescribed fire, as discussed in this workshop, embrace :

* fire hazard reduction	fuel treatment
* habitat management	wildlife, livestock, pest control
* site preparation	planting, natural reproduction
* species composition	competitive/desired vegetation
* accessibility	recreation, aesthetics
* preattack planning	buffer zones, fuel breaks

Most of these short-term goals may be easily reached by developing appropriate prescribed burning techniques. However, the long-term impact of fire may be detrimental.

A variety of examples show that other goals of environmental management may be jeopardized.

3. LIMITS OF PRESCRIBED BURNING

3.1. Invasion of undesirable species, change of species composition

Frequent burning leads often to the invasion of endemic plant species which are adapted to the post-burn conditions and/or to the fire itself. In addition, introduced exotic species may also become very aggressive on repeatedly burnt land. This invasion process becomes especially problematic if the fire-followers tend to occupy the site completely and replace the ground vegetation.
The following examples refer mainly to anthropogenetic fire regimes characterized by short return interval surface fires :

* *Pteridium aquilinum*
The bracken fern is a common aggressive fire follower in many vegetation types of the world. A site occupied by bracken fern becomes useless for livestock grazing and impedes the natural regeneration of forest stands. Bracken fern becomes a problem even in tropical submontane fire climax communities, e.g. in the pine lands of Sumatra/Indonesia (*Pinus merkusii*) and in neighbouring countries.

* *Imperata cylindrica*
This grass is one of the most aggressive colonizers of burnt land in the tropics and subtropics. It usually follows after slash-and-burn agricultural practices and forms dense carpets which are not suitable for grazing and extremely difficult to re-convert into forested land. It spreads into almost all degrading plant communities of the tropics by establishing a short fire cycle, unsuitable for any fire-sensitive plant. In Indonesia alone more than 16.10^6 ha of former rain forest land is occupied by *Imperata* fields (F.A.O. 1981).

* *Eupatorium odoratum* and *Lantana spp.*
Eupatorium is a weedy colonizer of disturbed sites and is found throughout continental South and South East Asia (e.g. India, Burma, Thailand).
A similar problem is created by the fast spreading *Lantana* spp. which may become a serious wildfire problem during drought periods.

* *Melaleuca quinquenervia*
Melaleuca is not endemic in North America. Its introduction early this century into South Florida ecosystems causes severe problems by replacing the natural vegetation. *Melaleuca* is highly fire adapted and occupies already extensive land area within South Florida.

* *Schimus terebinthifolia*
Brazilian pepper is another naturalized exotic evergreen shrub species which threatens South Florida's native vegetation.

* *Serenoa repens*
Saw palmetto, an endemic species, is also extending its range within Florida. Following after fire the palmetto now dominates many sites formerly occupied by pine, often to the extent that such areas are called "palmetto prairies" (WADE & al. 1980, WOODALL 1983).

Fire selection induced by prescribed fire and the overall tendency towards a vegetation type dominated by fire resistant plants is often discussed controversially. In Australia the debate is still going on whether prescribed burning is advantageous or not because conservationists feel that the endemic flora and fauna needs to be protected by the impact of fire selection (SHEA & al. 1981, JOHNSTON & al. 1982).

3.2. Interactions with secondary pests

The interactions between forest fire, insect attack and host tree are not yet well understood. It is known that a variety of insects is attracted by freshly burnt stands, orienting themselves by infrared or CO_2 sensors.

A new phenomenon has been described in the Philippines. GOLDAMMER (1987, 1988 in prep.) found that the exotic *Ips calligraphus* is highly attracted by freshly burnt (prescribed or accidentally) stands within the extended fire climax pine lands (*Pinus kesiya*) of Northern Luzon.
Since its introduction during the second World War, the beetle has aggressively extended its range and represents now the major threat to the forest ecosystem this insect problem may jeopardize all efforts towards integrated forest fire management.

The fire-caused physical damage of trees may also create considerable problems. In Australia it was found that fire scars are a significant point of entry for termites (e.g. *Coptotermes acinaciformis* and *Mastotermes darwiniensis*) invading living eucalypts and causing structural weakening (STOCKER and MOTT 1981).

3.3. Erosion

There are numerous findings available on soil denudation and erosion following prescribed or natural fires. This problem becomes especially severe in forest stands which have a short return interval fire cycle. Extended areas of fire climax forest and tree savanna communities such as pine lands and all kind of dry deciduous and semi-deciduous forests are burnt annually.
Erosion is particularly severe on the slopes of the submontane and montane pine belts. In the tropical dry deciduous forest and the tropical pine lands fires usually burn at the end of the dry season. The braking rains hit the bare soil.
This erosion process is often not visible because the trees of the old stands are generally not affected by the fires. However, within an extremely fire-adapted teak plantation (*Tectona grandis*) the loss of topsoil may exceed 2000 m^3/ha throughout a 30 year period (GOLDAMMER 1987b).

3.4. Air quality

Considering the emissions of smoke is not a new aspect in fire management. In the USA extensive research efforts have been invested into this subject. Local/regional smoke management plans and prescribed burning limitations (restrictions) are more and more enforced.
From a supra-regional point of view it is being recognized that the emissions from biomass burning are a considerable source of atmospheric gases, in particular CO_2, CO, CH_4 and other non-methane hydrocarbons, COS, N_2O and NO_X.
Deforestation and forest degradation in the tropics and biomass burning is regarded as one of the major causes of atmospheric/climatic change (see: International Geosphere - Biosphere Program, NATIONAL ACADEMY PRESS 1986).

4. NEEDS OF FIRE PRESCRIPTIONS

In many countries of the world fast growing exotic species are used for plantation establishment. In the afforestation programs of most tropical countries fast growing exotics as *Pinus* and *Eucalyptus spp.* are reforested. They are brought from a natural/anthropogenetic fire environment to a management system which generally excludes fire as a management tool. Particularly pine plantations in the tropics are characterized by fast growth and high litter production, thus creating extreme wildfire hazard.

Some first steps in using prescribed fire in exotic pine plantations have been undertaken in Australia, Brazil, Chile and South Africa. They are mainly related to *Pinus radiata* and *Pinus elliottii* (FORESTS COMMISSION VICTORIA, unpublished reports 1979 to 1982, GOLDAMMER 1983, SOARES 1979, JULIO 1975, Van LOON and LOVE 1973, de RONDE 1980, 1982, 1983).
The most crucial problem in pine plantations is the high litter load (surface and aerial fuels) which create extreme difficulties in developing prescribed fire techniques. However, the fuel moisture regime inside the densely stocked stands and especially inside the needle layers offer a good chance to be used as prescription indicators (see also HARRINGTON 1987). A pronounced moisture gradient allows the partial burning of the all layer and the draped and aerial fuels without exposing the mineral soil (GOLDAMMER 1983).

The most challenging task in prescribed fire research is the question of the limits of fire intensity and its relation to expected fire damage. The search has to look for reliable indicators which go beyond needle/crown scorch or cambium damage. Such tree stress indicators should focus on the interactions between host tree and forest insects. The existing methods of determining tree stress by o.e.p. (oleoresin exudation pressure) and water potential are not completely satisfactory (GOLDAMMER 1983).

5. ALTERNATIVES TO PRESCRIBED BURNING

The function of prescribed fire in ecosystem management and the problems created by fire are manifold. Fire exclusion, a turn back to the fire control policy, seems unrealistic in a world in which the wildfire scenario turns out to be more and more anthropogenetic. Mechanized and chemical treatment technologies are often energy wasting and uneconomic and may also cause environmental problems.

One of the more interesting alternatives is prescribed grazing : silvopastoral techniques which are to be stratified in time and space, as prescribed fire.
Prescribed grazing requires a planning process similar to prescribed burning. The grazing targets, however, are different and restricted to the palatable fuel. Perpetuating forest land suitable for grazing requires often the combination of treatments such as prescribed burning and grazing.
LIACOS (1984, 1986) has recently summarized his experiences and concepts of livestock grazing in mediterraneam warm coniferous forests. Completing this valuable information by the experience of forest farming systems as developed in Chile (PENALOZA et al. 1983) and New Zealand (NEW ZEALAND FOREST SERVICE and MINISTRY OF AGRICULTURE AND FISHERIES 1982) it is obvious that silvopastoral practices offer an economic alternative to the traditional fire management practices.

6. CONCLUSIONS

At the end of the 20th century fire regimes of many types of forest and other land are increasingly influenced by man's activities. Population growth and the demand for more forest products and land suitable for agriculture, residential purposes and recreation exert increasing pressure on land. Degrading forests become more flammable and subjected to more frequent fire occurrence.
The change from natural and pre-settlement fire regimes towards contemporary anthropogenetic fire regimes require consequent adaptation of fire management planning. The expected negative impact of fire in degrading forest ecosystems as well as the interactions with the environment on regional and even global level have to be beared in mind when developing prescribed fire regimes or alternatives.

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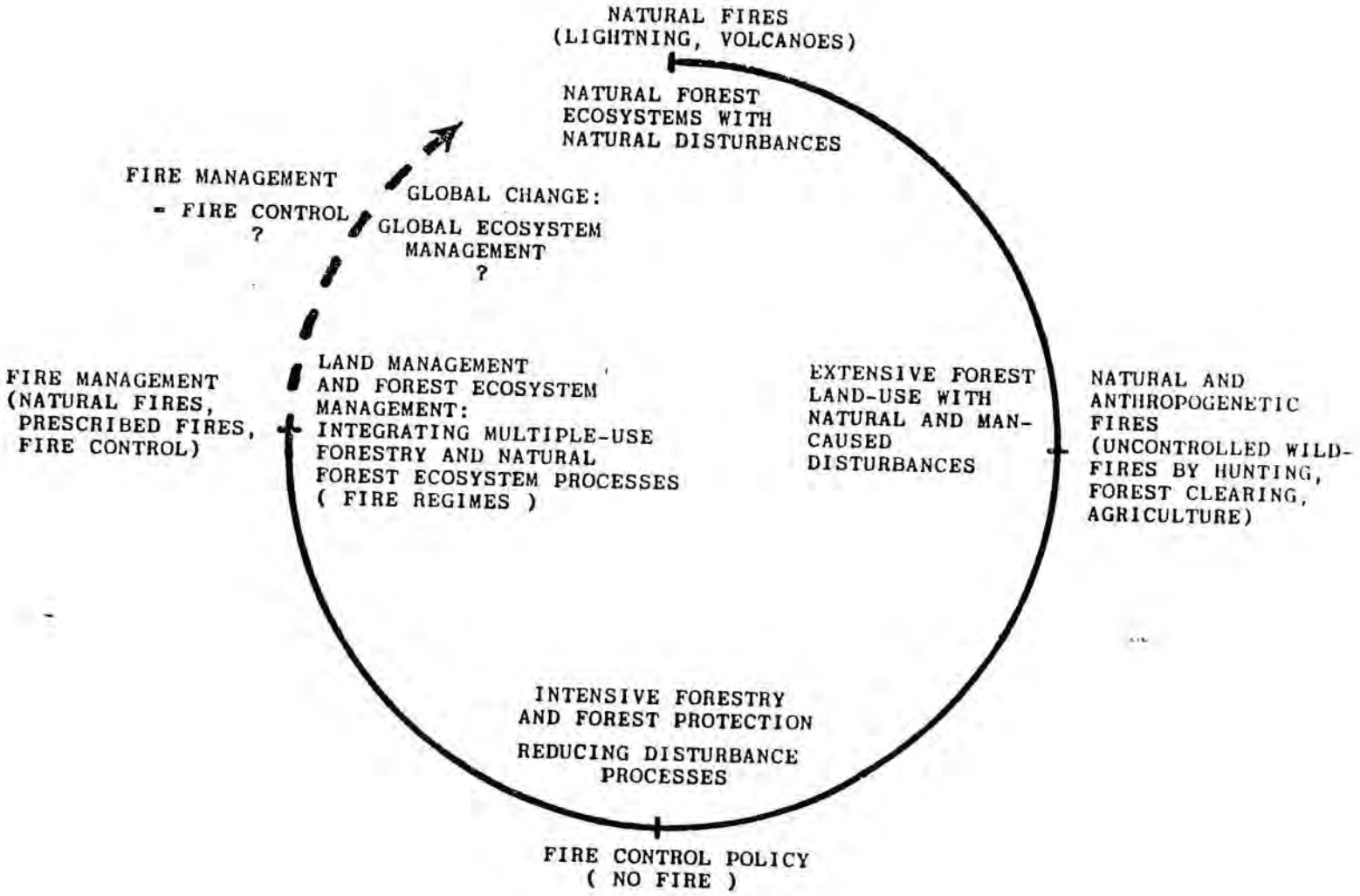

Figure 1

Hypothetical development of post-modern forest ecosystem and fire management policy

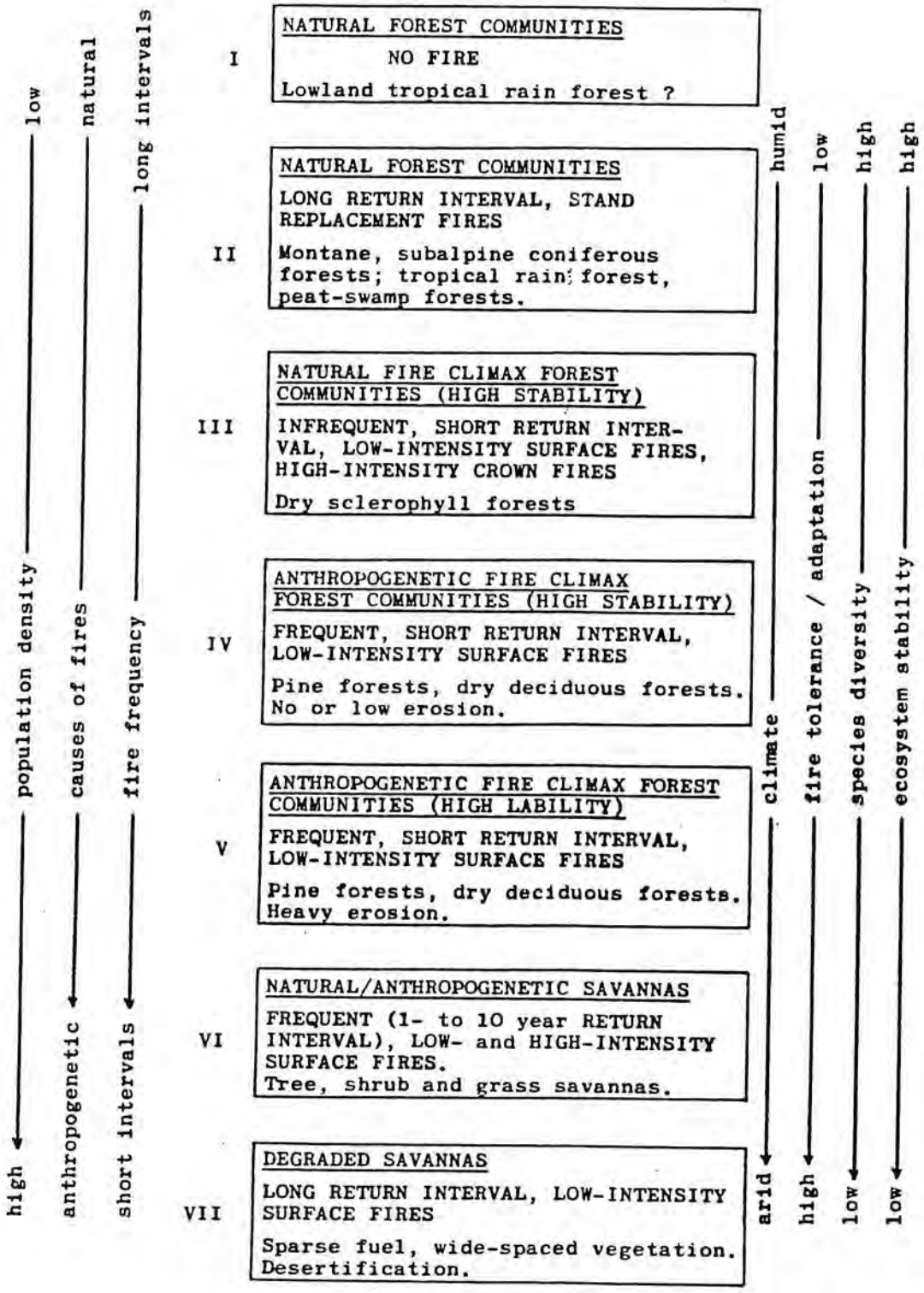

Figure 2

Types of tropical/subtropical fire regimes under a generalized framework of ecological and anthropogenetic influences (modified after GOLDAMMER 1986).