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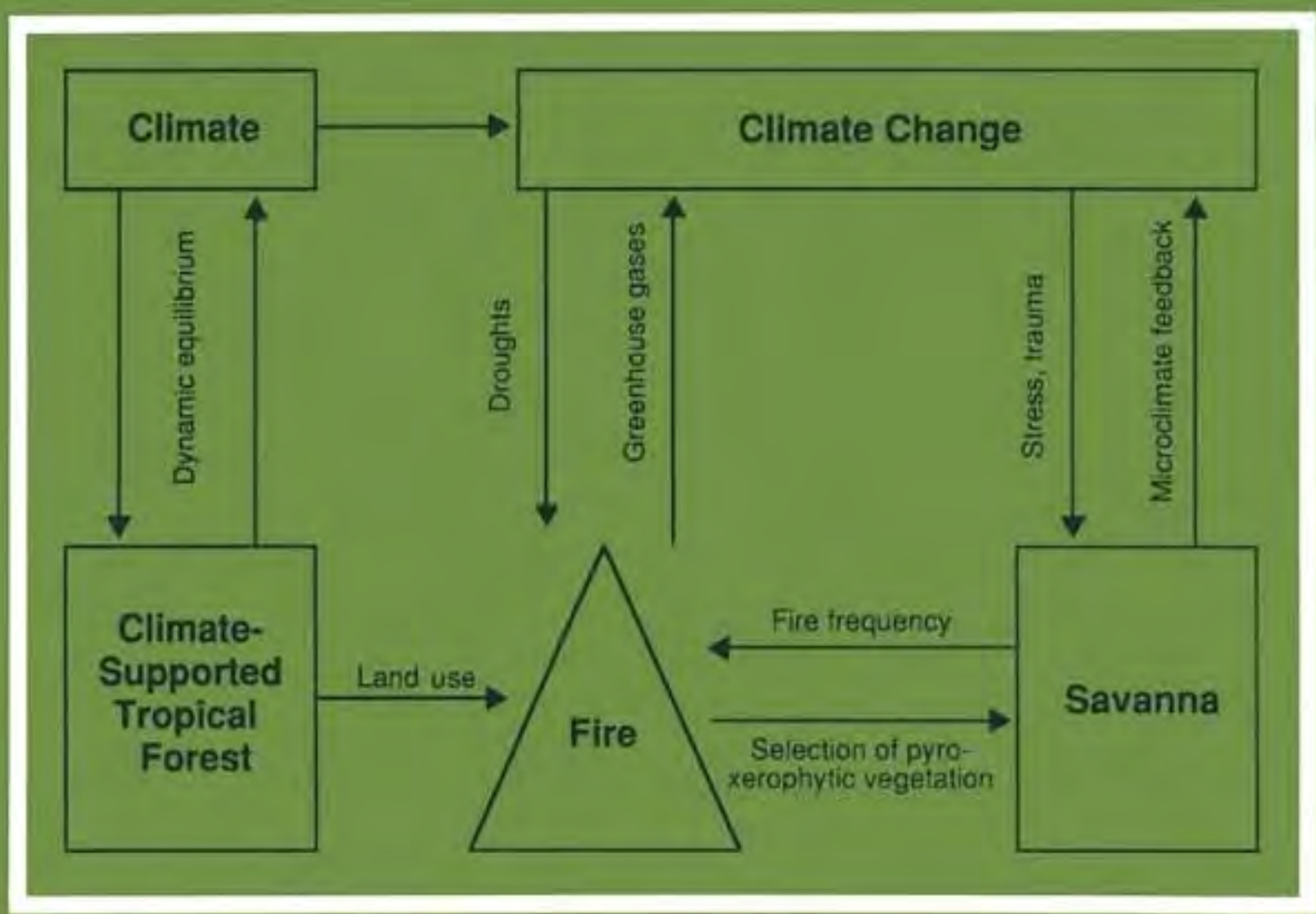
Fire in the Tropical Biota

Ecosystem Processes and Global Challenges

Edited by J. G. Goldammer



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Fire in the Tropical Biota

Ecosystem Processes and Global Challenges

With 116 Figures

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1 Fire in Tropical Ecosystems and Global Environmental Change: An Introduction

D. MUELLER-DOMBOIS[1] and J.G. GOLDAMMER[2]

1.1 Introduction

Fire has always been an important ecological stress factor in the seasonal tropics. The dry deciduous forest and the savanna grasslands, in general, have evolved with fire. The plant life forms of these tropical biomes can cope with fire through various adaptive traits (Budowski 1966).

No such categorical statement can be made about the humid or wet tropics. Under the present climatic conditions, fire plays a less important role in the year-round wet biome of the undisturbed equatorial rain forest. The permanently warm temperature, in combination with the continuously high atmospheric and soil moisture levels, has created a natural greenhouse climate which encourages high rates of decomposition. Sudden accumulations of organic waste on the forest floor can occur, but they are usually spotty, noncontinuous, and transient. Such accumulations are brought about by certain rain forest trees that drop their foliage during flowering and fruiting or through trees that break down and create tree-fall gaps. For this reason, fire, which could start naturally from lightning, has only a small chance of gaining access into primary rain forest.

There are, however, exceptions related to climatic oscillations and to larger-scale disturbances. Recent investigations have shown that climatic changes between the Pleistocene and today have created drought conditions that have favored the spread of forest fires in long-return intervals (Sanford et al. 1985; Uhl et al. 1988; Goldammer and Seibert 1989 this Vol.).

Certain rain forests, particularly in the subequatorial tropics (from 10 to 23° latitude), are frequently subject to hurricane damage. Such broader-area damage promotes the invasion of vines, which can contribute to foliar biomass accumulation on the soil surface in forest openings, particularly during occasional dry spells. Also some extreme soils, those with imbalanced nutrients and toxic elements, can slow or stall decomposer activity and thereby permit accumulation of spatially continuous fuel loadings that can lead to fires in tropical rain forests.

The spread of frequent fires into the wet tropics is a more recent development, attributable largely to human population pressures. During the last two decades, the use of fire has dramatically increased with the rapid

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3 The Role of Fire in the Tropical Lowland Deciduous Forests of Asia

P.A. STOTT[1], J.G. GOLDAMMER[2], and W.L. WERNER[3]

Each dry season from January onwards the litter on the jungle floor ignites spontaneously and creeping ground fires clear away old matted vegetation, making way for the new season's growth. Some of these fires reach considerable size and provide one of the most impressive of jungle sights when viewed from a distance on a dark night. Long, jagged fronts of flame advance across the black backdrop of hillsides, exploding into pyrotechnics as clumps of dry bamboo are engulfed by the everchanging scarlet patterns of destruction . . . .

A teak-wallah's description of forest fire in Northern Thailand (H.N. Marshall. Elephant Kingdom. London: The Travel Book Club. 1959. p. 133).

3.1 Fire: An Alien Ecological Pressure?

Throughout the lowlands of tropical Asia, in regions experiencing either a monsoon forest (Köppen's Am) or a savanna forest (Aw) climate, both natural and human-induced annual or biennial fires have long been a common ecological phenomenon during the dry season, which may extend from three to seven months. Such burns occurred quite naturally through a number of causes before the appearance, around 12.000 years ago, of agriculture in the region, but, with the advent of Neolithic communities, swiddening, and stubble burning, dry-season fires inevitably became much more frequent and widespread. In modern times, this fire pressure has grown even more intense, and the ecological role of fire is now a matter for serious debate, as it is seen to affect diminishing forest resources in closer and closer proximity to human settlements (Goldammer 1988). In Burma, for example, the total annually burnt area of forested land has been estimated at 3.5 to 6.5×10^6 ha yr^{-1} (Goldammer 1986). For Thailand, data collected from 1984 to 1986 show that fire affected 20.92% of the forested area or 3.1×10^6 ha yr^{-1} (Royal Forest Department 1988), while worldwide, for all ecosystems, a figure of 630–690 $\times 10^6$ ha yr^{-1} has been suggested by Seiler and Crutzen (1980), 98% of which occurs in the tropics and subtropics. In response to this, the clear temptation is for governments

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4 Fire in the Pine-Grassland Biomes of Tropical and Subtropical Asia

J.G. GOLDAMMER[1] and S.R. PEÑAFIEL[2]

4.1 Introduction

The genus *Pinus* is one of the most widely distributed genera of trees in the extra-tropical northern hemisphere (Critchfield and Little 1966; Mirov 1967). In the evolutionary history of its approximately 105 species two main centers of speciation are recognized. These are in southeastern Eurasia and southern North America, from where *Pinus* extends into the tropics. The range of extension of the pines in tropical South Asia has been described by Critchfield and Little (1966), Kowal (1966), Cooling (1968), and Stein (1978). Schweinfurth (1988) has compiled additional information and references on the distribution of pines in South East Asia provided by vegetation maps of the Himalayas, China, Cambodia, Viet Nam, Sumatra, and Thailand.

In tropical South Asia the biogeographical range of the genus *Pinus* is confined to the zone of lower montane rain forest and dry sites with a slight to distinct seasonal climate. In the perhumid equatorial rain forest biome of the lowlands of South East Asia the pines do not occur naturally. However, palynological data give evidence of *Pinus* occurrence in Northern Borneo up till the Pliocene (Muller 1972), thus reflecting the different climatic conditions at that time.

In a brief and general survey on the occurrence of conifers in tropical forests of Asia, Whitmore (1984) stated that the range of pines has been extended by anthropogenic and natural disturbances. The pines are pioneers (seral species) that easily colonize landslide sites and abandoned cultivation lands. Furthermore, pines are strongly adapted to and favored by fire. Both the flammability of the pine fuels and the various adaptive traits of pines to fire characterize most pine forest communities as a fire climax.

In tropical and subtropical Asia, most of the lands bearing pine forests are under increasing human pressure. Slash-and-burn cultivation extending into higher altitudes and steeper slopes, excessive fuelwood cutting, and grazing practices have brought an increasing frequency of man-caused fires into the mid-elevation forests. In many places the "fire-hardened" pine forests become more and more degraded because of shorter fire-return intervals and secondary

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12 Prescribed Fire in Industrial Pine Plantations

C. DE RONDE[1], J.G. GOLDAMMER[2], D.D. WADE[3], and R.V. SOARES[4]

12.1 Introduction

Industrial plantations of non-indigenous tree species (exotics) can be defined as even-aged stands established outside of their natural habitat. These plantations play a vital economic role in the developing countries of the tropics and subtropics. The ecological benefits of afforestation, however, go far beyond local and regional considerations: the increase in atmospheric CO_2 and its expected negative influence on the global climate may partially be averted through large-scale afforestation with fast-growing species (Maryland 1988). The take-up of carbon in woody matter could potentially balance the discharge of CO_2 from fossil fuel burning and from the vast amount of uncontrolled forest destruction and biomass burning in the tropical and subtropical biota. Although prescribed burning is itself an emission source of CO_2, its main function in plantation management is to increase stability and to protect against destructive wildfires, which are a much larger source. The same is true for particulate matter emissions. Thus, although at first glance it may seem contradictory, prescribed burning is indeed an important link in global fire ecology.

Of the estimated 9,968,000 ha of industrial plantations established in the tropics by the end of 1985, 41% were in softwoods (mainly pines) (Table 1).

Even though almost 60% of the industrial plantations are composed of hardwoods such as eucalypt and teak, most prescribed burning has taken place in pine stands. This chapter will thus be restricted to a discussion of fire in pine plantations. The information needed to plan and safely conduct prescribed fires beneath standing trees (referred to as underburning) and the ecological effects of these fires will be emphasized. The importance of fuel and weather parameters is explained, and techniques of setting fires and monitoring their behavior are described. Some facets of post-harvest burning are also discussed.

The major species used in pine afforestation activities are *Pinus caribaea*, *P. elliottii*, *P. patula*, *P. Pinaster*, *P. radiata*, and *P. taeda*. According to McDonald and Krugman (1986), the leading species are *P. elliottii* and *P. taeda*. They estimate that over 450,000 ha are planted to these two species outside their native

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21 Global Change: Effects on Forest Ecosystems and Wildfire Severity

M.A. Fosberg[1], J.G. Goldammer[2], D. Rind[3] and C. Price[3]

21.1 Introduction

Climate change, as a result of the greenhouse effect, is expected to take place within the next 100 years – a time span comparable to the planting-to-harvest interval of many commercial tree species. The predicted increases of temperature are expected to be comparable to those that have taken place since the end of the last ice age 15,000 years ago. The 5°C warming that occurred between 15,000 and 7000 years ago resulted in major changes in the location and abundance of North America's tree species (Bernabo and Webb 1977). The rate of temperature change predicted from the increase in greenhouse gases, that is 5°C in 100 years as compared to the rate experienced in the early Holocene, is unprecedented in history. There is thus a great need to determine the impact of this predicted change on North America's ecosystems and, in particular, on our forest resources.

Our concern is not only with global warming from the greenhouse effect, but also with the various stresses these ecosystems will experience as a result of changed precipitation patterns, trauma such as fire, insects, disease, and air pollution, ultraviolet radiation as a result of stratospheric ozone depletion, and from changes in the ability of all species, plants, animals, and microorganisms to compete for limited energy, water, and nutrients.

21.2 Scientific Bases for the Greenhouse Effect

The greenhouse theory is based on the energy balance between incoming solar energy and the energy radiated to space from the earth. If there is not a balance between the incoming and outgoing energy, then the earth would either warm or cool. The energy from the sun reaches the earth primarily as visible light. Some of this incoming energy is reflected back to space from clouds, a small portion is absorbed by the atmosphere, approximately 43% reaches the earth's surface, where it is absorbed. This absorbed energy warms the earth. A portion

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Appendix: The Freiburg Declaration on Tropical Fires

The Freiburg Declaration on Tropical Fires was released by the participants of the 3rd International Symposium on Fire Ecology held at Freiburg University, Federal Republic of Germany, 16–20 May 1989.

The Role of Fires in Tropical Ecosystems

Fires in the forest and other vegetation of the tropics and subtropics and the changing tropical land use have increasing regional and global impact on the environment. The smoke plumes from tropical biomass fires carry vast amounts of atmospheric pollutants, including CO_2, CO, NO_x, N_2O, CH_4, nonmethane hydrocarbons, and aerosols. Smog-like photochemistry produces ozone concentrations comparable to those found in the industrialized regions. These perturbations of the tropical atmosphere are on such a scale that they can be easily detected by remote sensing from space. Alterations of the hydrological regimes can have severe environmental and human consequences for the regions being burned and in neighboring regions. The consequences of biomass burning, such as the aggravation of the greenhouse effect, affect nontropical regions most strongly. The catastrophic fires on the island of Borneo in 1982/83 indicate the danger that possible climatic changes pose to the survival of the tropical forests themselves.

On the other hand, fires play a central role in the maintenance of many natural ecosystems and in the practice of agriculture and pastoralism. The various types of savannas are burned frequently both by human- and non-human-caused fires. Burning is used as a tool in maintaining tree plantations and natural forests, especially in the subtropics. Forests in the moist tropics have long been used in shifting cultivation to support low population densities of traditional agriculturalists without degrading either the forest or the productive potential of the soil. This situation has changed radically by accelerating shifting cultivation cycles under the influence of market economies and because of increasing population pressure, both from demographic growth and from reduced access to land. Nonsustainable slash-and-burn pioneer agriculture, without the long fallows of traditional systems, is practised by populations that are either attracted to or forced to migrate to tropical forest areas, or that are transported to these regions under government colonization or transmigration programs. Both shifting cultivation and pioneer farmers depend on burning to

produce crops at acceptable labor input intensities. Burning is also the key process in maintaining the cattle pastures that are replacing tropical forest in vast areas of tropical Latin America.

In the enormous areas of savannas – especially in Africa – where burning is a part of the natural cycle, the frequency of fires has greatly increased, and with this the impact of uncontrolled fires is more and more detrimental. The dual role of fire must be recognized, being both a natural agent of ecosystem maintenance and a potentially disastrous cause of ecosystem destruction.

Where Do We Stand?

Fire control has been the traditional fire policy in many parts of the world. An increasing number of countries have adopted fire management policies instead, in order to maintain the function of fire in removing the accumulation of fuel loads that would otherwise lead to damaging wildfires, and in order to arrest succession at stages that are more productive to humans than are forests that would predominate in the absence of fire. Frequently, inappropriate choices are made – often because decisions are influenced by other regions where conditions differ. Such influence may come through misguided international aid programs, through visiting consultants and researchers, or through the temperate-zone bias of local technical staff trained abroad. Researchers and policy-makers must be sensitive to the different functions of fire in each ecosystem and to the needs of the people who depend on it.

When current burning practices are correctly identified as damaging, as in the case of the recent explosion of deforestation and burning in lowland Amazonia, the measures taken are often ineffective. Prohibiting burning, and attempting to enforce this through inspection and punishment, is bound to fail. The motives for burning must be removed, such as land speculation, tax or other incentives, and land documentation criteria that reward deforestation. Migration of farmers to infertile rain forest areas must not be facilitated by highway construction and must not be augmented by policies that expel populations from other regions through land tenure concentration and through lack of employment alternatives. Sound policies to bring the use of fire under rational control must be based on an accurate understanding of why burning is done, what its costs and benefits are, and who enjoys the benefits and suffers the impacts of present and alternative practices.

An Action Plan

Both more research and immediate action are needed. Education must begin now to bring about long-term changes in attitudes towards fire and nature. Global monitoring systems must be expanded and coordinated. For example, the rain forests of the Congo Basin have so far been almost untouched by fire, but must be watched because the situation could change rapidly, as it has in other tropical areas. Temperate zone countries can contribute greatly to research efforts through financial contributions and by participating in intellectual exchange with tropical countries. The International Geosphere-Biosphere Programme (IGBP) offers a promising channel for international cooperation in fire research and the Intergovernmental Panel on Climate Change (IPCC), under the auspices of the United Nations Environmental Program (UNEP), will provide response strategies to these environmental threats. It is essential, however, that the IGBP focus its resources on the large ecosystems that play major roles in global geochemical processes. Tropical rain forest, for example, must be understood in the Brazilian Amazon and in Equatorial Africa rather than being studied primarily in isolated remnants of forest in Puerto Rico, Panama, Costa Rica, or Hawaii.

Without waiting for further results, much could be done to translate what we already know into action. These actions include reforming the policies of international lending institutions and development assistance programs to give greater consideration to the environmental impacts of policies that either provoke or eliminate fires. Recent increase in the environmental review capabilities of the World Bank is a hopeful sign, but it is only a tiny beginning.

Institutional mechanisms must be developed to distribute fairly – both within and between nations – the costs and benefits of changes in fire policy. The questions of "fire for whom?" and "fire control for whom?" must be answered clearly if sound and fair policies are to be formulated. Policies must respect national sovereignties. Fortunately, the interests of different nations almost always point in the same direction: limiting deforestation is not only in the long-term interest of the people of the tropical countries where forests are being cleared, but is also beneficial to other nations concerned by the loss of biodiversity and by the danger of atmospheric impacts in temperate latitudes.