FIRES

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1. Introduction

Evidence of fire in the world's vegetation throughout the past millions of years is abundant. Ancient charcoal in soils and in sediments of lakes and oceans, fire scars in petrified forests, and the characteristics of the prehistoric atmosphere contained in air bubbles embedded in glaciers and ice shelves reveal the prehistoric presence of fire. During an evolutionary time scale, lightning storms and volcanic activities have been the natural causes of these fires which had significant impacts on the development of vegetation on Earth.

About 1.5 million years ago early hominids began to tame and to use fire for hunting, cooking and heating, for socializing and warfare, and later on for opening and cultivating the unhabitable wilderness areas of the globe. The development of all human cultures was dependent on the free burning of vegetation and on the use of plant biomass to provide energy.

In the past ca. 20,000 years, with the start of expansion of humans throughout the continents, the habitability of the global environment has been affected by natural disasters

and climate changes. Forest fires and other wildland fires have been part or consequence of these disturbances. Numerous, uncounted human tragedies have been associated with catastrophic fires. In the long run, however, humans seemed to have coped with fire.

At the beginning of the 21st century, however, the global fire scene is changing dramatically. Rapidly expanding global human populations are causing more and larger-scale fires in shrinking forest and other vegetation resources than ever before. At the same time, human societies become increasingly vulnerable by wildfires.

This chapter aims at a global perspective of fire. Selected examples are given on the multifaceted aspects of fire in wildland vegetation.

2. Patterns of Fire: A Global Zonation of Fire

Recently the international community of wildland fire researchers has shown a great interest in quantifying the occurrence and impacts of fire at a global scale. One of the major reasons for this interest is the demand for reliable information on the share of emissions from vegetation fires in the total amount of global emissions of natural and anthropogenic "greenhouse" gases, particularly carbon dioxide and other radiatively active trace gases and aerosols.

Figure 1. Global vegetation fire map showing distinct regional fire patterns (fire regimes) which are classified primarily on the base of the vegetation cover type (see text).

Reliable statistical data on vegetation fires are available for a limited number of nations and regions. In the industrial countries of the Northern hemisphere fire statistics are collected annually by the United Nations, Economy Commission for Europe (ECE), within the ECE member states (Europe, countries of the former Soviet Union, USA, Canada).

Outside of the European Union (EU) and ECE regions respectively fire statistics are collected only occasionally and are often not published and otherwise accessible. Data on losses caused by forest and other vegetation fires (wildland fires) are only occasionally available. The main reason for the lack of reliable data is that the majority of both the benefits and losses from wildland fires involve intangible non-use values or non-market outputs which do not have a common base for comparison, i.e. biodiversity, ecosystem functioning, or erosion. The largest amount of burning of forest and other vegetation is taking place in the tropics.

A global vegetation fire map as presented in Figure 1 is not designed to provide the still missing data on the extent of fires (e.g. the total area of forest and other vegetation burned each year, or the total amount of plant biomass combusted). This map rather provides a classification of vegetation cover types with their distinct types of fire regimes as they are described in the following.

3. Vulnerable Ecosystems: Wildfires in Tropical Rain Forests

Figure 2. Traditional small-scale slash-and-burn agriculture fire in the lowland equatorial rain forest of East Kalimantan (Indonesia) (Photo: J.G.Goldammer).

The use of fire in the tropical rain forest is an old cultural practice of all human populations living in the equatorial zone (Figure 2). Traditional ***slash-and-burn agriculture*** or ***shifting cultivation***, practised by small-sized human populations, are potentially sustainable systems for utilizing the land and the fire effects (clearing, fertilization by the ash) for transitory production of crops on small and temporary sites. The present escalation of burning activities, however, is leading to an aggregation of burned forest patches. This causes manifold environmental problems, e.g. the loss of biodiversity, decrease of site productivity, heavy erosion processes and large-scale air pollution.

The wilful application of fire for forest conversion and other land clearing purposes (Figure 3), although causing environmental damages, at the first hand may not necessarily be defined as a ***disaster*** in the classical sense. However, the recently observed large-scale wildfires occurring in the wake of forest conversion activities show that more and more human-caused fires in the rain forests are getting out of control.

Figure 3. Effects of a forest-conversion fire after clearcutting in a lowland dipterocarp forest of East Kalimantan (Indonesia). Only a small part of the wood biomass is utilized, and the remainder is burned. Ignition and combustion of heavy logs under average conditions of humidity and fuel moisture content is extremely difficult. The logs, which were not affected by fire, decompose in the following years (Photo: J.G.Goldammer).

Figure 4. Surface fire in a lowland tropical rain forest of East Kalimantan. This forest became extremely dry and flammable during the 1982-83 and 1997-98 droughts caused by the El Niño-Southern Oscillation (ENSO)(Photo: J.G.Goldammer).

During the extended droughts of 1982-83 and 1997-98 which were caused by the El Niño-

Southern Oscillation (ENSO) event extremely large wildfires were recorded in South East Asia. These fire escaped from slash-and-burn cultivation and conversion fires, mainly in Sumatra and the Indonesian provinces on Borneo island. In 1982-83 about five million hectares (ha) of primary and secondary rain forest vegetation were affected by fires which had spread from numerous point sources throughout the island (Figure 4). In 1997-98 the total area affected by conversion burning and wildfires in Indonesia alone was in the range of 9 to 10 million ha. Such large-scale fire situations took also place in Africa and the Americas, particularly in Brazil.

The changing fire hazard in the tropical rain forest biomes is not only caused by the increasing number of fire sources. The alteration of the fuel complex leads to an increase of flammability of large forest tracts. Selective logging and opening of the rain forest by road networks, including trails constructed by forestry operations, leave behind combustible materials (downed woody fuels) which are not utilized. The "opening" of forests by this kind of activities enhances the penetration of sunlight and wind, thus changing the originally wet microclimate and leading to a faster desiccation of the forest fuels.

Local to regional anthropogenic climate changes in the wake of large-scale forest conversion have also considerable impacts on wildfire hazard. The destruction of the forest cover and its function as "water pump" of local water circulation (rainfall produced through the availability of aerial water surplus due to evapotranspiration) has dramatic impacts on local or even on regional decrease of precipitation.

The economic impacts of the rain forest fires are difficult, if impossible, to quantify. For instance, what is the monetary value of decreased biodiversity, of the extinction of plant and animal species occurring in the rain forest? What is the value of topsoil and humus washed away after fire and deposited in the rivers and finally in the oceans?

However, in some cases economic losses have been assessed. The evaluation of the fire damages of 1982-83 in East Kalimantan (the eastern province of Indonesia on Borneo) revealed that the total economic damage of the uncontrolled burning was ca. $US 9 billion. The economic and environmental damages caused the Indonesian fires and fire-generated smoke in 1997 were also in the range of $US 9-11 billion.

4. Woodland Fires in the Seasonal Tropics: Benefits Versus Destructiveness

With increasing distance from the humid equatorial zone the forests become more open and gradually develop towards *woodlands* or *tree savannas* and finally to *brush and grass savannas*. Tropical savannas cover an area of about 2.3 to 2.6 billion ha worldwide. Savannas typically consist of a more or less continuous layer of grass with interspersed trees and shrubs. There are numerous transition types between savannas and open forests. The surface fuels in these ecosystems are dominated by grasses and leaves shed during the dry season, and burn periodically at intervals ranging from one to four years. Fire frequency has increased in some regions as a result of increasing population and more intensive use of rangeland. The area of savannas potentially subjected to fire each year is up to several hundred million ha. As a result, savanna burning releases about three times as much gas and particle emissions to the atmosphere as deforestation burning. It is estimated that more than three billion metric tons of vegetative matter are burned in tropical savannas

annually.

The tree and brush species as well as the grass species in the *fire climax savannas* are well adapted to the regular occurrence of fires. Wildlife species living in these fire climax savannas are also well adapted to fire and take advantage of fire effects on vegetation.

The old burning practices of the indigenous human populations were all based on the empiric observations of the beneficial effects of fire, e.g. removal of the dead grasses to stimulate the growth of fresh shoots for grazing, elimination of undesired (economically less valuable) tree species, or facilitation of harvest of non-wood forest products like fruits, flowers, honey and cigarette-wrapping leaves.

Figure 5. Teak (Tectona grandis) plantation in the State of Uttar Pradesh (India) annually burned by surface fires. The fires leave the teak trees largely unaffected and eliminate all competing vegetation. The depletion of litter layer prevents humus layer formation and leads to heavy erosion processes (Photo: J.G.Goldammer).

Figure 6. Many of the tropical humid savannas are long-term stable fire climax ecosystems. The photographs show a humid "Guinean" savanna type in Côte d'Ivoire (West Africa) which are subjected to regular fire influence. The extreme fire tolerance of palms (here: Borassus aethiopum) is a pantropical phenomenon. All faunistic elements are adapted and even attracted to fire, e.g. the birds (here: Milvus migrans) which are feeding on insects and small mammals fleeing the fire (Photo: J.G.Goldammer).

With increasing human population densities, however, a pantropical increase of fires in these seasonal woodlands has been observed. Together with the effects of overgrazing and overcutting of trees, e.g for fuelwood use, the impacts of fire are becoming more detrimental. With the terms "savannization" and "desertification" processes of degradation are described in which all these factors interact and lead to further decline and finally to desertification. In the Sahelian savannas, for instance, former fire regimes are not found anymore because desertification has nothing left to burn.

5. Burning of Agricultural Residues, Control of Bush and Weeds on Grazing and Croplands

At global scale a substantial amount of agricultural residues, e.g. straw and stalks, is disposed of by burning. The magnitude of this practice is extremely difficult to quantify because of its distributed nature. No statistics are available, mostly because material of direct economic value is not involved. It has been estimated that between 800 and 1200 million metric tons of agricultural residuals are burned annually, making this practice a major source of atmospheric pollution, mainly in the tropics. By tradition fire is also a common practice to control bush and weed encroachment on grazing and croplands.

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