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Rural land-use and wildland fires in the tropics

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Abstract. Tropical forest land is increasingly influenced by man-caused wildfires. The vast majority of the forested area burnt and cleared annually is in the tropics. The use of fire in rural land-use systems is the major cause of the wildfires. Five broad causative agencies of wildfires are presented, shifting cultivation, grazing, non-wood forest products, migration programs and the wildland/residential interface. Integrated concepts of prescribed burning and prescribed grazing may offer solutions to the tropical wildland fire problems.

Introduction

The tropical forests of the Americas, Africa and Asia in 1980 covered about $1{,}935 \times 10^6$ ha of which $1{,}200 \times 10^6$ ha were closed forest and 735×10^6 ha were open tree formations. In addition, fallow forest land accounted to 410×10^6 ha [FAO, 1985]. In most countries of the humid and dry tropics, forests are being cleared or degraded at a rapid rate, mainly to satisfy the basic subsistance needs of poor rural communities.

About 2,000 million people live in this zone, where the population is increasing at a net annual average rate of 2.6 percent. The increasing population is exerting pressure for the use of forest land for agricultural and settlement purposes. According to the estimates of the Food and Agriculture Organization of the United Nations (FAO, 1985) the deforestation rate of closed tropical forests and open tree formations has been estimated to be 11.3×10^6 ha yr^{-1} during the early 1980's, mostly due to transfer of forest land to agricultural use.

A great part of this forest depletion is due to shifting agriculture (slash-and-burn techniques) and the long-term effects of repeated and uncontrolled wildfires which accompany fuelwood collection, grazing and the harvest of minor forest products. The high frequency of wildfires in degraded vegetation types (savannas, bush and grasslands) is a major impediment to the

restoration of former forest types or the development of climax forest [Goldammer, 1986a]. It has been estimated, that the total area burnt or cleared (all ecosystems worldwide) amounts to 630–690 $\times$ 10^6 ha yr^{-1} [Crutzen et al., 1979; Seiler and Crutzen, 1980]. More than 98% of the burnt and cleared area is in the tropics and subtropics. The total forested area cleared annually for agricultural purposes in the tropics accounts for about 30–80 $\times$ 10^6 ha, with an average of about 50 $\times$ 10^6 ha. The burning of savanna and bushland amounts to approximately 600 $\times$ 10^6 ha yr^{-1}. Major single wildfires recently reported within the tropics sometimes exceed 3–5 $\times$ 10^6 ha [Malingreau et al., 1985; Goldammer, 1986b; see also para 4].

The role of natural fires (lightning fires) becomes less important compared to the increasing occurrence of man-caused fires [see also Mueller-Dombois, 1981]. The vast majority of wildfires follows in the wake of traditional agricultural practises and other deep-rooted burning habits of the rural population. The traditional fire cause classification used in the industrialized countries therefore is not applicable within the tropics because of this different socio-economic and cultural background.

In general, fire is used as a tool for clearing of vegetation, enhancing forage yield for livestock or wildlife, or to facilitate the harvest of non-wood forest products. The spread of these intentionally set fires into the surrounding wildland is generally not controlled unless valuable plantations or developed areas at the wildland/urban interface are threatened.

The material presented in this paper has been separated into five broad causative agencies of wildfires within the tropics.

1. Shifting cultivation

The term 'shifting cultivation' has been applied to a wide range of cropping systems. Following FAO convention [FAO, 1982] it refers to 'a system in which relatively short periods of continuous cultivation are followed by relatively long periods of fallow'. Long-fallow agriculture systems where the length of the fallow period is more than double the length of the cropping period, can be accepted as synonymous with shifting cultivation, and must be clearly separated from 'short-fallow agriculture' (or semi-permanent or stationary cultivation with fallowing) which characterizes farming systems [Lanly, 1985].

Shifting agriculture – also variously called slash-and-burn agriculture – involves the clearing of woody vegetation by girdling and felling trees at the beginning of the dry season. At the end of the dry season as much of the

Fig. 1. Silvopastoral practises and annual fires in the Terai 'Sal' forests (*Shorea robusta*) of southern Nepal frequently eradicate the natural regeneration. The Sal stands become decadent and moribund.

Photo: J. Goldammer

dead plant material as possible is burnt. After the burning the chosen area is used for a few years for crops. When the harvest yield declines, the site is abandoned and a new clearing is made.

It is estimated that shifting cultivation and its degraded forms involve about 500 million people and affect 240×10^6 ha of closed forest and 170×10^6 ha of open forest, or 8.3 percent of the tropical land area (equal to about 21 percent of the tropical forest area)[FAO/UNEP, 1982; Lanly, 1985]. Crutzen et al. [1979] and Seiler and Crutzen [1980] estimate that an average of 41×10^6 ha yr^{-1} of forest land are burnt and/or cleared due to shifting agriculture.

As a consequence of the diminishing forest reserves, the people practising shifting cultivation have been forced to reduce the length of the fallow periods they formerly observed [Ramakrishnan et al., 1981; Muthoo, 1985].

The increasing slash-and-burn pressure on the remaining forest land is associated with other disturbing processes causing the break-up and alteration of formerly closed forest land. Selective logging and the increased amount of logging residues as well as the invasion of understory vegetation

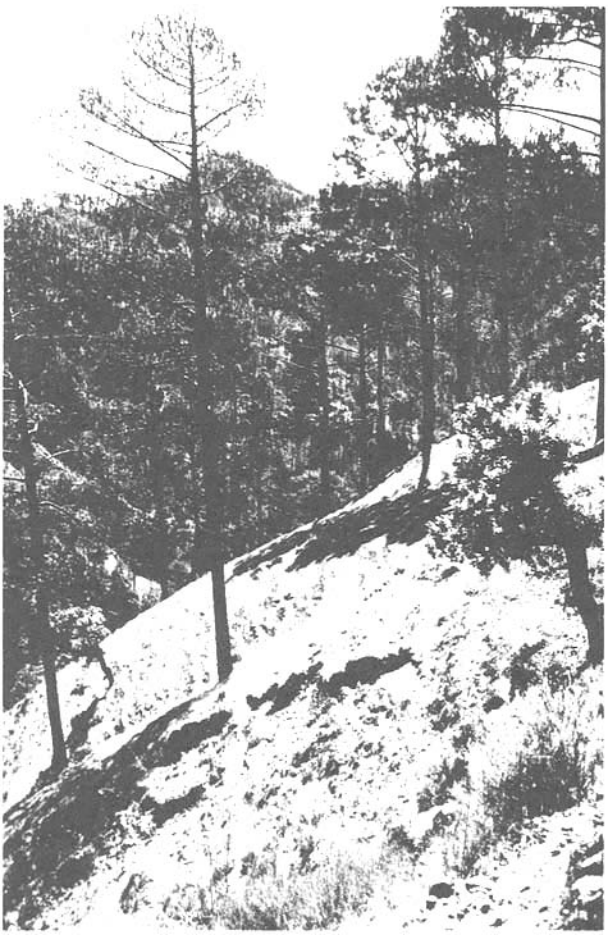

Fig. 2. The 'Chir' pine forests (*Pinus roxburghii*) of the Himalayas are burnt annually in order to remove pine needles which become slippery and dangerous to the cattle. Grazing and trampling effects acclerate the erosion process. Uttar Pradesh, India.

Photo: J. Goldammer

into the opened forests have considerable effects on fuel composition and the flammability of the forest. Grass species as *Imperata cylindrica* or *Themeda triandra* tend to occupy forest gaps or forest stands in which the canopy density has been altered by logging. Many of these tropical grasses are fire adapted and favour the uncontrolled and repeated spread of shifting cultivation fires into the surrounding forest land. Frequent fires lead to an overall removal of fire sensitive species. Dramatic alterations can be expected in most tropical rain forest associations which are generally characterized by thin-barked species. The mixed deciduous forest formations and the sub-

tropical and tropical hill forests, however, have developed remarkable adaptations to the periodic fires [Goldammer, 1986c].

Altogether this development of increasing slash-and-burn practices is resulting into a land-use pattern in which the impact of fire on soil and vegetation degradation, the fire regime, becomes a dominant factor. Alternatives to shifting cultivation, like the 'taungya' system, may offer a better control of the movement of the rural population and the reforestation planning, but they do not exclude the use of fire as a clearing tool and its uncontrolled spread into the surrounding forest lands.

2. Grazing

In farming systems of the tropics animals fulfil a role which is essential to the functioning and stability of rural economies. Livestock are kept primarily for production of milk, draft power, meat and manure. Grazing by all or some of the livestock on pastures outside the farm boundaries, more par-

Fig. 3. 'Tendu' leaves (*Diospiros melanoxylon*) for bidi wrapping are collected from coppices. Better and lush growth is stimulated by artificial injury or extensive burning. Maharashtra, India.

Photo: J. Goldammer

ticular in grassland-type savannas, is a traditional practice in many tropical countries.

These tropical savannas and grasslands which form a very large proportion of the semi-natural vegetation in all major tropical regions of the world, are no longer considered to be climatic or edaphic climax or zonal vegetation types [see Mueller-Dombois, 1981]. Savannas can be defined morphologically as vegetation types of scattered trees and/or shrubs, growing in a matrix of more or less closed herbaceous vegetation cover (usually composed dominantly of grasses). They are today the most widespread tropical vegetation types and, with few exceptions, generally characterized by periodic fire occurrence.

Intentional grassland burning has long been recognized as the major factor in maintaining balance in tree-bush-grass composition patterns of tropical savannas [Busse, 1908; Phillips, 1930; Skovlin, 1972]. In hunting, fire was used intentionally either to produce green grass to attract game, by burning moist areas towards the end of the dry season, or for driving game to provide a refuge in which game would concentrate to be hunted later [West, 1972]. Analyzing the use of fire in the management of natural pastures for livestock grazing Van Rensburg [1972] mentions four reasons:

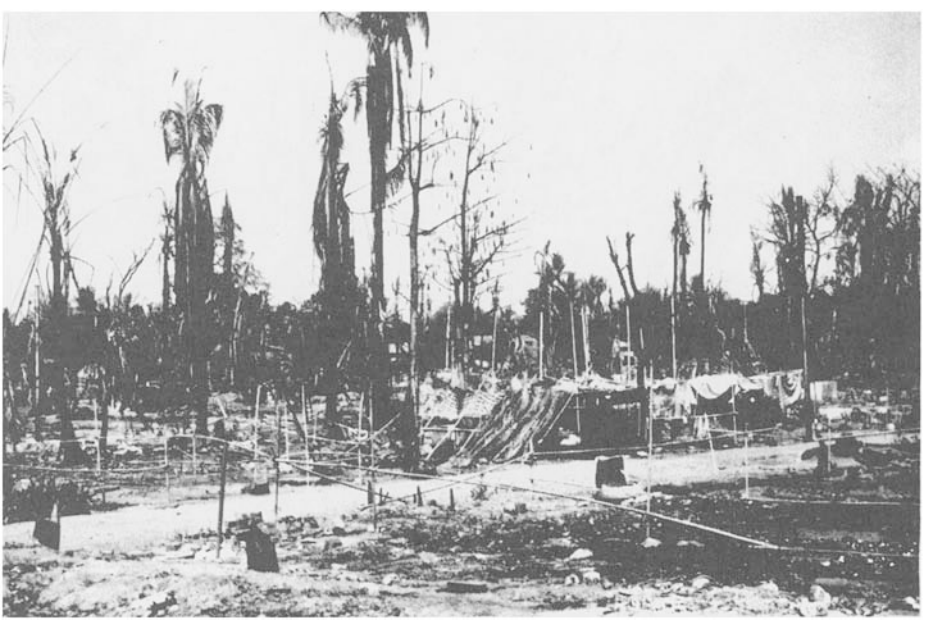

Fig. 4. Within the tropics extreme flammability of rural housing causes a considerable threat to human property and lives at the wildland-village interface. Kamayut township, Burma.

Photo: J. Goldammer

- to burn off the unpalatable growth left over from previous seasons growth which would not be touched by livestock and which, if not removed, would tend to become moribund and die out;
- to stimulate growth during the dry season and thus provide green food for stock at time when it does not occur naturally;
- to destroy parasites such as ticks which carry and transmit stock diseases, and
- to control the encroachment of undesirable plants.

The extension of cultivated land area is leading to a decrease in land available for grazing and a heavy reliance on grazing in forest areas. The uncontrolled silvopastoral practices involve the use of fire usually started by graziers, resulting into extended spread of wildfires into the forested land. This phenomenon can be observed in many forest types throughout the major vegetation zones of the world. It is most visible in the Southern Tropical Dry Deciduous Forests. These forest types occur largely in Latin America (Caatinga and Chaco type), Africa (mainly south of the equator) and the dry parts of the Subcontinent of India (*Shorea robusta* and *Tectona grandis* forests) and Central Burma (Indaing and Semi-Indaing forests), covering approximately 530×10^6 ha worldwide.

A great part of this forest land is exposed to frequent and almost annual sylvopastoral wildfires which have, together with the overlapping effects of grazing/browsing, lopping and trampling, significant influence on selection of fire tolerant species and forest/soil degradation. The frequent fires are a major impediment to the restoration (progressive development) of vast areas of degraded dry deciduous forest land. Browsing and fire mainly affect the natural reproduction and coppices, whereas old trees of the dry deciduous forest types (as well as pines) are not injured in general. As a consequence of the widened gap in age class distribution, the forests become overmature and moribund [see also Goldammer, 1986d].

Although most of these fires originated by the graziers are going unreported, some estimates may demonstrate the regional dimension of the grassland/forest area affected annually by fire: In India Srivastava [1985] reports that almost 1/3 of the Sal (*Shorea robusta*) forests, 1/2 of the hill pine forests (*Pinus roxburghii*) and 1/2 of other forests ('miscellaneous') are burnt every year. Goldammer [1986c] estimates that the annual area burnt in Burma may exceed 3.5×10^6 ha, mainly affecting the teak-bearing (*Tectona grandis*) mixed deciduous forests and the deciduous dipterocarp forests. Vareschi [1980] estimates that the annual fires set intentionally by graziers in Venezuela cover more than 27×10^6 ha yr^{-1} of grass savannas.

3. Other non-wood forest products

Forest products have customarily been divided into two groups, 'major' and 'minor'. The first category consists of timber, small wood and fuelwood; the second includes grasses, fruits, resin, oilseeds, bamboo, leaves, exudates etc. Because of the increasing economic and social significance of the second it has been proposed to use the term 'non-wood forest products' (NWFP) [Gupta and Guleria, 1982]. According to the authors, the share of NWFP's in the total net revenue accruing to the forestry sector in India has increased over 40 percent during the late 70's. NWFP's accounted for over 63% of the total value of forest based exports during the decade 1965–75, and for more than 70% of the total employment in the forestry sector in India.

Describing the forest utilization of the Southern Dry Mixed Deciduous Forests and the Dry Teak Forests in Maharashtra (India), Gandle [1985] mentions a large variety of NWFP users:

- Tendu contractors
  Leaves of 'tendu' trees (*Diospiros malanoxylon*) are collected for cigarette (bidi) wrapping.

Fig. 5. Fire management activities may offer considerable employment opportunities for the rural population, thus creating forest protection awareness and mutual confidence. Firebreak construction in central Burma.

Photo: J. Goldammer

Fig. 6. Integrating other land-use practises into plantation management may temporarily reduce the fire hazard. This 12-year old *Eucalyptus camaldulensis* plantation is regularly cleared by leave collectors. The leaves are used as cooking fuel. Saing Pyu Plantations, Burma.

Photo: J. Goldammer

- paper millers.
  Bamboo (*Deudrocalamus strictus*) is leased to paper millers

- Graziers

- Fodder collectors

- Thatching grass collectors

- Mineral prospectors
  The operators usually establish labour camps

- Fruit and flower collectors
  Edible fruits of a variety of trees are collected for fermentation and sugar production.

- Bark and leaf collectors
  Bark/leaves for tanning industry. Leaves for production of brooms, plates and cups.

- Rope makers
  Use of tree roots (e.g. *Butea monosperma*)

- Gum contractors

- Honey and wax collectors

- Silk cocoon collectors

- Medical plants
  Especially dried flowers of 'tendu'

- Bamboo craftsmen
  Production of bamboo mats, baskets, packing cases etc.

- Thorn collectors
  Thorn brush is collected for field fencing

- Betel vine growers
  Collection of bamboos, poles etc.

The permanent presence of people travelling through the forested lands itself provokes a high probability of accidental wildfires.[1] But the major threat of uncontrolled wildfires is caused by the widespread use of fire for facilitating and/or improving the harvest of the NWFP's. In India, the most striking example is the collection of 'tendu' leaves used for cigarette wrapping. The tree develops new shoots and tender leaves (or a bushy character) after being injured artificially by trenching, pruning or hacking. The same effect can be obtained by setting tendu bushes on fire, a very old practice for providing better flush and more tender leaves early in the plucking season. The costs are also significantly lower compared to the mechanical treatment for stimulation of coppicing. It was observed by Gupta and Guleria [1982] that uncontrolled forest fires spreading from the 'tendu' fires have increased

during the past years.

Besides the collectors of leaves and the graziers, the collectors of edible fruits are setting fires for removing forest litter in order to make visible the freshly fallen fruits and to facilitate collection. The use of fire by honey and max collectors is another traditional practice widely used by the aboriginal population in all continents [see also West, 1972].

4. Migration and land-settlement programs

In the sparsely populated and more or less undisturbed lowland tropical moist rainforests of South East Asia, the Amazon and Congo Basins, the manifold interactions between traditional land-use practices, fire and forest vegetation have not yet been established. However, during the recent years dramatic changes become more and more visible. The rapid alteration of the ecological conditions, as a consequence of organized (public) land-settlement projects and spontaneous migration, make vast areas of rainforest highly vulnerable to wildfires.

One case history, the East Kalimantan (Indonesia) wildfire in 1982–83, may be a striking example of mutual influence of regional development, forest alteration and wildfires. In Indonesia the transmigration scheme is one of the largest resettlement programs in the world [Spears, 1980]. The abolition of regional disparities and, in this context, the abolition of the disequilibrium in population distribution between Java (population density 691 persons $\times$ km^{-2}) and the outer islands is one of the major aims of Indonesian economic policy. In particular regarding transmigration, special significance is placed on the Province of East Kalimantan (population density 5 persons $\times$ km^{-2}).[2] During the 1979–84 period more than 70,000 families were resettled to Kalimantan, and the target figures for the 1985–89 period are about 320,000 families respectively [Kebschull, 1984].

The increase of the logging activities in East Kalimantan as well as the increase of peasant slash-and-burn forest cultivators, following in the wake of timber extraction, created conditions favourable to start and spread of forest fires. In mid 1982 an extreme drought, associated with the 'El Niño Southern Oscillation Event', struck the West Pacific/South East Asia region [see also Lennertz and Panzer, 1984; Johnson, 1984].

When farmers and settlers started to burn in preparation for the next planting cycle, fires ran out of control. Large tracts of logged-over and primary forests, peat-swamp and swamp forests were set afire. The turflike accumulation of organic matter of peat-swamp forests dried to a depth

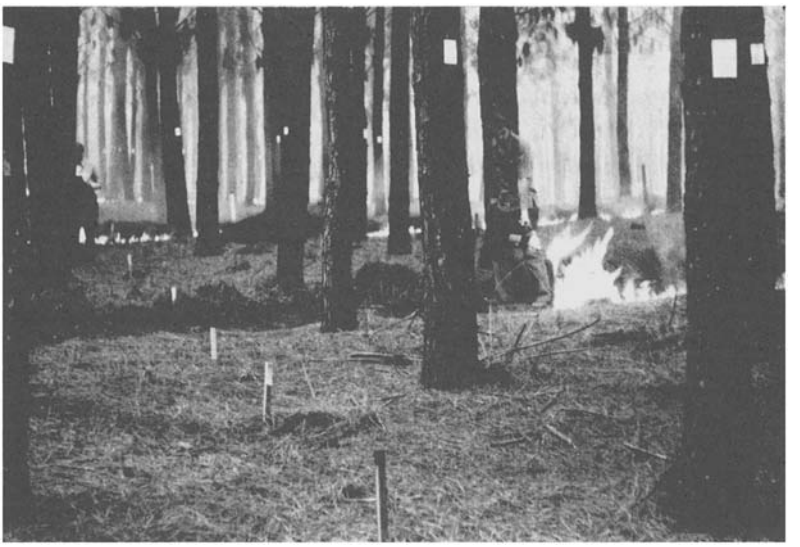

Fig. 7 and 8. Prescribed burning of surface fuels inside of pine plantations may create conditions suitable for prescribed grazing systems.

Left: *Pinus elliottii* plantation in Paraná, Brazil.

Right: *Pinus radiata* stand with livestock farming in Tikitere, New Zealand.

Photos: J. Goldammer

exceeding 0.5 m, and surface coal seams burnt until the return of the rains. The most extensive fires took place during August to October, 1982, and March to May, 1983. Fire and drought affected a total area of about 3.5×10^6 ha of forest land, thereof 800,000 ha primary forest, 1.4 million ha logged-over forest, 750,000 ha secondary forest, shifting cultivation and settlements, and 550,000 ha peat swamp and peat-swamp forests [Lennertz and Panzer, 1984].

The Kalimantan scenario was created by a coincidence of ecological and socio-economic factors which have favoured an extreme wildfire hazard condition in a forest type which would not burn under undisturbed conditions [see also Mueller-Dombois, 1981]. The size of this fire seems to be unique. Smaller fires, like the fire on 20,000 ha rain forest in Mindanao in 1983, however, remain unreported. Reports of the El Niño fires in Sabah/Malaysia which covered approximately the same amount of forest land like in East Kalimantan [Bruenig pers.comm.], were also not observed by the public.

5. Wildland/residential interface

The mutual interferences of wildland and village/urban fires are mainly influenced by

- fuel load and fuel continuity at the wildland-urban interface;
- type of material used for building construction;
- fire season and weather patterns;
- risk of man-caused fires, and
- safety precautions.

In the rural lands and even in many metropolitan areas within the tropics, houses are mainly constructed of cellulosic material: wood, bamboo, grass, reed or cardboard. Cellulosic structures gain and lose moisture in response to changes in relative humidity just as similar fuels do in the forest [Chandler et al., 1983]. Whereas the fuel moisture inside of big buildings is controlled by indoor relative humidity, the equilibrium moisture content of cellulosic material of the shanties of rural and poor urban population in the tropics is much more influenced by the external forces of sun, wind and precipitation.

The fire occurrence in residential areas therefore is highest during the dry season. Residential fire statistics of Burma, as shown in Table 1, are reflecting this seasonal effect. The amount of damage by such fast spreading structural fires can be tremendous. On 4 March 1986 a fire was raging through Kamayut Township, Rangoon/Burma. Within minutes more than 1,850 houses were burnt, making 18,000 people homeless.

The fire cause classification in Table 1 shows that forest fires play a considerable role in setting fire to residential areas. During the dry season of 1985 forest fires accounted for more than 5 percent of all cases, whereas during the wet season the importance of forest fires is comparatively low.

Vice versa, forest fires are also started at the edge of villages and settlements. Besides outdoor cooking, one of the major causes is the use of torches

Table 1. Township structural fires in Burma, 1985. Source: 4th Pyithu Hluttaw, 1st and 2nd Conference. Note: The dry season is between January and May.

Month	Number of fires	Cause of fires	
January	145	Negligence	81.43%
February	185	Spontaneous combustion	1.41%
March	215	Electricity	1.88%
April	153	Arson	4.58%
May	140	Insurgence	1.06%
June	14	Forest Fire	5.15%
Subtotal	852	Under enquiry	4.58%
July	45	Negligence	75.27%
August	50	Spontaneous combustion	1.41%
September	48	Electricity	3.94%
October	51	Arson	0.72%
November	64	Insurgence	0.72%
December	21	Forest fire	1.43%
		Under enquiry	3.59%
Subtotal	279		
Total	1,131		

by people walking between houses or villages during night time. Resinous pine wood sticks used in the subtropical/tropical hill forests contribute considerably to the frequent occurrence of forest fires [see also Goldammer, 1985 b].

Agroforestry systems: solutions to the wildland fire problems?

The wildfire scenario in the tropics and its sociological background are so manifold that a direct approach to a strict 'fire out' (fire control) policy seems to be highly unrealistic. The increasing ecological impact of the fire interactions at the interface between wildland and the various land-use systems and residential areas, on the other hand, requires a direct response. Fire management strategies and technologies as developed in North America and Australia can hardly be transferred to the tropical countries due to financial and educational restraints.

Tropical wildand fire management therefore needs to be adapted or integrated into local land-use systems or vice-versa. Since there is no short- or medium-term perspective of eliminating man-caused fires in the tropical lands the main emphasis must be laid on fuel management. Fuel management for wildfire hazard reduction is the modification or treatment of wildland vegetation to

- reduce the flammability of vegetation
- slow down or stop the spread of uncontrolled wildfires
- facilitate the access to a potential wildfire scene
- reduce fire intensity and facilitate fire suppression on the ground

A variety of fuel modification practices can be applied to establish fuel breaks – the permanent conversion of vegetation on strategically located areas which separate fire endangered land-use systems from each other. The application of herbicides for fuel treatment cannot be recommended due to environmental considerations and financial constraints. Methods of mechanical treatment of wildland fuels as mowing, mulching or shredding without utilizing the biomass can also be regarded as overexpensive and energy-wasting processes.

The most realistic and economic approach to reduce the wildfire risk *in toto* or to establish and maintain fuelbreak systems is the applications of prescribed burning and prescribed grazing practices.

Prescribed burning is the controlled application of fire to wildland fuels in either their natural or modified state in order to attain planned resource

management objectives. Reducing the hazardous fuels and minimizing the risk of high-intensity wildfires is one of the major and common goals in fire management of various forest types. Extensive literature on prescribed burning objectives and burning techniques is available [see Goldammer, 1978; Chandler et al., 1983].

Silvopastoral practices or forest farming are commonly designed to combine different land-use systems and to increase their ecological and economical stability. The use or planting of widely spaced trees for farming livestock on the understory has been successfully applied in various regions [New Zealand Forest Service 1982; Penaloza et al., 1983]. Since understory grazing may lead to an overall reduction of potential wildfire fuels it can be concluded that controlled grazing may have similar effects on understory fuels and thus on fire hazard reduction as prescribed fire.

In general wildfires and uncontrolled grazing practices have detrimental effects on tropical forest development. Prescribed fire – if properly applied – may contribute considerably to reduce the wildfire risk and to increase the stability of various forest types. Accordingly 'Prescribed Grazing' – a new term proposed in analogy to 'Prescribed Burning' – may have a similar effect and additionally generate significant secondary income. Furthermore the combination of both treatments may increase the stabilizing effect. A unique and striking example of this kind are the experiment and the long-term observations designed by Liacos [1986]. His findings show that the highly fire-prone mediterranean pine forests can be managed successfully by a combined treatment of prescribed burning, grazing and high quality timber production.

These ideas of prescribed burning and grazing are not contradictory to the problems of forest degradation described in this paper. They show that the time – space relationship is the most crucial element in both fire and grazing management. Young trees are highly vulnerable to fire, grazing and browsing. Mature forests may be dependant on periodic surface fires in order to reduce the high-intensity fire risk but become moribund if grazing and burning continues beyond the age of maturity. This also refers to all other fire climax communities.

Integrated concepts of agroforestry and wildland fire management may offer a new and reliable opportunity in protecting natural resources within the tropics – a challenge for tropical agroforestry and wildland fire research.

Conclusions

The interactions between rural land-use and forest fires are manifold. Fire is used as a traditional and cultural tool by a large variety of ethnic groups

throughout the tropics. Long-term influence of man-caused fires had considerable effects on the composition of many vegetation types. In the tropical world, the increase of rural population has resulted into an alarmingly increasing wildfire pressure on the forest land. In general the forest degradation processes become accelearated. Integrated concepts of prescribed burning and silvopastoral practices may offer a new approach toward solving the fire problems at the interface between wildland and other land-use systems.

Notes

1. Smoking may be an important factor locally. In Burma, for example, the rural population usually smokes 'cheroot' cigars while working or travelling in agricultural and forested lands. Most 'cheroot' types consist of a mixture of tobacco leaves and stem particles. The solid particles may glow for a considerable time and act like sparks. They can be regarded as a major wildfire cause (Goldammer, 1986c).
2. According to the last census carried out in 1980.

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