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J. Burke DUPL.

Development of a

National Fire Policy and Guidelines on Fire Management in Namibia

by

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Southern African Development Community (SADC) 1996. Wildfire management project proposals for Southern Africa. SADC Forestry Technical Co-ordination Unit, Lilongwe, Malawi, 51 p.

Tall Timbers Research Station (ed.) 1972. Fire in Africa. Proc. Ann. Tall Timbers Fire Ecol. Conf. 11, Tallahassee, Florida, 516 p.

Tothill, J.G., and J.C. Mott (eds.) 1985. International Savanna Symposium 1984. Commonw. Agr. Bur., Canberra, 384 p.

Trapnell, C.G. 1959. Ecological results of woodland burning experiments in Northern Rhodesia. J. Ecology 49, 129-168.

Trigg, S. 1997, Fire monitoring in the Caprivi. Report. Environmental Profiles Project, Directorate of Environmental Affairs, Ministry of Environment and Tourism. Namibia.

Trigg, S. 1998, Fire scar mapping in Northern Namibia. A Report on Forest Fire Control Component of the Namibia-Finland Forestry Programme, Directorate Of Forestry. Report dated 10 May 1998 (mimeo, with satellite-derived maps).

van Wilgen , B.W., C.S. Everson and W.S.W. Trollope 1990. Fire management in Southern Africa: Some examples of current objectives, practices, and problems. In: Fire in the tropical biota. Ecosystem processes and global challenges (J.G. Goldammer, ed.), 179-215. Ecological Studies 84, Springer-Verlag, Berlin-Heidelberg-New York, 497 p.

van Wilgen, B., M.O. Andreae, J.G. Goldammer, and J. Lindesay (eds.) 1997. Fire in Southern African savannas. Ecological and atmospheric perspectives. The University of Witwatersrand Press, Johannesburg, South Africa, 256 p.

van Wilgen, B.W., and R.J. Scholes. 1997. The vegetation and fire regimes of Southern Hemisphere Africa. In: Fire in Southern African savannas. Ecological and atmospheric perspectives (B.W. van Wilgen, M.O.Andreae, J.G. Goldammer, and J. Lindesay, eds.), 27-46. The University of Witwatersrand Press, Johannesburg, South Africa, 256 p.

Weiss, K.F., J.G. Goldammer, J.S. Clark, D.A. Livingstone, and M.O. Andreae. 1996. Reconstruction of prehistoric fire regimes in East Africa by lake sediment analysis. In: Biomass burning and global change. Vol.I (J.S.Levine, ed.), 545-551. The MIT Press, Cambridge, MA.

management capabilities in Namibia will assist the government of Namibia to meet the targets set by the IDNDR.[5]

2.6 Other relevant UN Initiatives (non-binding)

In 1996 the UN FAO/ECE Team of Specialists on Forest Fire[6] convened the international conference "Forest, Fire, and Global Change" (Shushenskoe, Russian Federation, 4-9 August 1996). Besides the ECE Member States the conference purposely invited non-member states in order to come up with recommendations that would include all nations and support the development of global cooperation in the field of fire. The whole set of conclusions and recommendations is given in Appendix I.

Among other, the UN conference recommended the establishment of a global vegetation fire inventory on the base of agreed standardized parameters and criteria; the development of a Global Vegetation Fire Information System; the collaboration with the scientific fire programmes under the International Geosphere-Biosphere Programme (IGBP); the development of a satellite dedicated to quantifying the geographical extent and environmental impact of vegetation fires; the development of a Global Fire Information Network; and that a group be formally established under the auspices of the United Nations to facilitate addressing global wildland fire needs.

The last of these recommendations was explicitly repeated by the Wildland Fire '97 Conference (Vancouver, British Columbia, Canada, 25-30 May 1997) in which Namibia was represented by the Director of Forestry.

2.7 Regional Cooperation within the Southern African Development Community (SADC)

All member countries of the Southern African Development Community (SADC) have one unifying problem, among other, the problems of changing fire regimes associated with population growth, land-use changes, and land degradation (Moyo et al. 1993). It is consequent that SADC came up with proposals on a regional Southern African wildfire management project (SADC 1996).

Although the SADC Regional Forest Fire Management Systems Review Report did

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Namibia is also urged to follow the activities of the IDNDR Early Warning Programme. Basic principles are laid down in the Early Warning Programme Working Group Paper on "Wildfire and Related Environmental Hazards" (IDNDR 1997). The IDNDR Early Warning Conference will be held in Potsdam, Germany, September 1998.

FAO: Food and Agricultural Organization of the United Nations. ECE: Economic Commission for Europe. ECE Member States: all countries of Europe, including East Europe, the former Soviet Union (CIS), the U.S.A. and Canada. The FAO/ECE Team of Specialists operates out of the UN Trade Division, Timber Section, ECE, Geneva.

not refer to the state of and the work accomplished by other national, regional Southern African and international initiatives in fire science and management, it points into the right direction when recognizing the need for regional cooperation in fire management.

However, the recommendations of SADC are build on a centralized regional approach and leave restricted space for specific national development in fire management. The importance of social (community-based) fire management is disproportionately under-represented in the proposal. This fact underscores the importance of developing a national Namibian fire management strategy which builds on the specific cultural roots of the country. Only then Namibia will be able to contribute and take advantage of a regional SADC fire management system. Both developments, however, should be promoted simultaneously.

The SADC programme is important for Namibia insofar that in North Namibia a large part of wildfires are originating in the SADC member countries Angola, Zambia and Botswana. Border-crossing fires require transnational response strategies!

2.8 Recommendations by the International Tropical Timber Organization (ITTO) through the "Guidelines on Fire Management in Tropical Forests"

Between 1993 and 1997 the International Tropical Timber Organization (ITTO) developed "Guidelines on Fire Management in Tropical Forests" (ITTO 1997). These fire management guidelines are designed to provide a base for policy makers and managers at various levels to develop programs and projects in which the specific national, socio-economic, and natural problems related to fire in tropical natural and planted forests will be addressed. The scope of the guidelines is to assist the ITTO member countries (producer and consumer countries) to develop programs for reducing damage caused by fire; and to help tropical forest managers and rural residents to safely use and take advantage of the beneficial effects of fire in land-use systems. The guidelines recognize that many forest fires originate in the agricultural and pastoral systems; and in degraded vegetation which is outside of forests. Therefore, fire management on former and degraded forest lands may help to re-establish productive forests and to safeguard the success of reforestation programs.

At present, Indonesia is the first country in which the general ITTO guidelines are "fine-tuned" to the national level. However, the ITTO guidelines are not exclusively developed for the ITTO Member Countries or the tropical countries *sensu strictu*.[7] The guidelines address principles which are also valid outside the

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Namibia does not belong to the group of 26 tropical Producer Countries or the Consumer Countries which are members of ITTO. Some member countries from Africa, however, may soon follow the process of fine-tuning the general international guidelines to national policies. African ITTO Member

ITTO region, especially in the less developed world of the subtropical and temperate zones. Namibia could certainly take advantage of ITTO's precursor work when formulating a national fire policy and fire management strategy. A brief synoptic review of the ITTO Guidelines are given in Appendix II.

3. The Ecological and Environmental Basis of Fire in Namibia

3.1 Fire Ecology

It is not the aim of this report to go into details of the state-of-the-art knowledge on the ecological and atmospheric role of fire in Southern African savannas, woodlands, and forests.[8] However, some basic information on the historical and ecological role of fire are given in brief.

3.1.1 Fire Sources

Lightning storms are rare during the dry season. As pointed out by van Wilgen and Scholes (1997) it has generally been inferred that the pre-human fire season was therefore concentrated in the late dry or early wet season when fuels are still dry enough to ignite.

However, it must be noted that the use of fire by early humans is documented for the last ca. 1 million years (Brain and Sillen 1988, Kershaw et al. 1997). This implies that in addition to lightning-caused fires during the late dry and early wet season, anthropogenic fires - preferably set during the dry season - must have contributed to shape vegetation and habitats of humans and wildlife of the subcontinent. Regardless of long- and short term variability of climate, land occupancy by humans and fire regimes (see Weiss et al. 1996) it is assumed that savanna and forest ecosystems have been in equilibrium with fire disturbances over evolutionary time scales.

Countries include: Cameroon, Congo, Cote d'Ivoire, Gabon, Ghana, Liberia, and Zaire.

The reader is kindly referred to a number of monographs and synoptic reviews on savanna and fire ecology which contain numerous original publications and references. In chronological sequence these books are notably the publications of Tall Timbers Research Station (1972), Huntley and Walker (1982), Bourlière (1983), Booysen and Tainton (1984), Frost (1985), Tothill and Mott 1985, Cole (1986), Goldammer (1990), van Wilgen et al. (1997)

3.2.2 Vegetation Types, Fuel Properties and Fire Regimes

Vegetation types and fuel properties have been described in depth by van Wilgen and Scholes (1997) and reveal the presence of a variety of fire regimes on the Southern African subcontinent. In Namibia fire is a common phenomenon on the two major vegetation types and their transition forms, the savannas (covering ca. 64% of Namibia's territory) and the forests and woodlands (ca. 20%).

Some selected examples of the main fire problems are highlighted under the two categories given below. First, the effects of wildfires in forests, woodlands and the agro-pastoral environment of the East Caprivi Zipfel will be described, based on own observations and other surveys, e.g. by Breitenbach (1968). Second, the effects of fire exclusion on wildlife conservancies and farms in the arid savanna zones will be summarized.

3.2.2.1 Problems arising from Wildfires in Northern Namibian Forest Ecosystems Intermixed with Agricultural and Pastoral Areas

Baikiaea Forests In this originally dense upland forest with dominating Zambezi Teak (*Baikiaea plurijuga*) the amount of grass growth and other understorey plants is restricted. Low-intensity surface fires do not have a destructive impact on the forest species composition. Opening of the forest canopy by logging allows the invasion of grasses and formation of understorey vegetation. The forests become highly flammable, and high-intensity surface fires damage the remaining trees up to the crown level. Most damage is caused by repeated burning of the regeneration. The post-fire succession leads to the formation of dense and tall thickets of *Terminalia sericea* and *Combretum* spp. Under undisturbed conditions the *Terminalia-Combretum* thicket leads the way towards reconstruction of the Baikiaea forest. However, under present conditions of frequent burning the fire-prone Terminalia-Combretum thickets, the restoration of Zambezi Teak forests is not possible.

Severe abrasion and erosion of humus-enriched topsoil after high-intensity stand replacement fires expose immature subsands which are colonized by the *Burkea-Pterocarpus* woodland. Fire and shifting cultivation further lead to deep soil erosion and formation of troughs and channels. Under present land-use and fire pressure the rehabilitation of these disturbed sites towards a Baikiaea forest is not possible.

Baikiaea-Erythrophleum/Erythrophleum-Combretum Woodlands Uncontrolled fire and excessive grazing severely disturb these woodlands, lead to severe erosion and formation of *Acacia-Burkea* woodlands or to *Terminalia-Acacia* savannas.

Combretum-Acacia Savanna This formation occurs on sand soils which are seasonally waterlogged and slightly inundated. Overgrazing and uncontrolled fires lead to temporary soil compaction at the end of the fire season. Rapid run-off of the first precipitation leads to severe erosion.

Burkea-Pterocarpus Woodland and Pterocarpus-Baikiaea Forest These two formations occur intermixed. *Pterocarpus angolensis* growing on the fire-disturbed Burkea-Pterocarpus subclimax woodland offers conditions suitable for the regeneration of Zambezi Teak. *P.angolensis* has a good coppicing capacity. Various authors indicated that fire promote the establishment and development of Pterocarpus regeneration (Trapnell 1959, Calvert 1973, Geldenhuys 1977). With further development to the *Pterocarpus-Baikiaea* forest the grass growth increases, and late fires become destructive and lead to the degradation to *Acacia-Burkea* woodlands.

Acacia-Burkea Woodland This woodland formation is a devastation stage which occupies vast areas in the upland (Baikiaea) region.

Colophospermum Forest This important forest type dominated by *Colosphermum mopane* covers large lowland areas. It is also considered as a arid/fertile savanna formation. In undisturbed forests the grass cover is sparse, and low-intensity surface fires predominantly burn the resinous live and dead leaves, especially in the low-growing scrub form of this vegetation type. Once the forest is opened, the heavy grass cover increases the fire intensity which in turn often carries the surface fire into the crowns of the Mopane trees. Most damage is caused by repeated burning of the buttresses and penetration of fires into the root system. The resprouting capability of Mopane allows the restoration of crowns and explains the multi-stem habit of most trees.

3.2.2.2 Effects of Fire in Maintaining the Arid and Moist Savanna Ecosystems of Etosha National Park

After a large fire in October 1997 the Etosha National Park at present is in the focus of national discussion on fire management strategies.[9] The burning strategy of Etosha National Park was developed around 1980 and has been updated by a decision-support system (du Plessis 1997; see also para. 4.1 of this report). the fire management strategy recognizes the role of natural fire in vegetation regeneration and wildlife habitat dynamics and includes the use of prescribed management fires where natural fires do not accomplish the goals of sustainable wildlife habitat management.[10]

Etosha region receives a higher share of ignitions by lightning as compared to human causes: In the 1970s between 50 and 75% of all fires were caused by lightning (Siegfried 1980). It must be clearly stated, however, that fragmentation of the vegetation of the national park (establishment of fuelbreaks between blocks, tourist access roads) and climate variability (onset of the dry period

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The fire which burned between 6 and 10 October 1997 started as a prescribed burn on a Block which had not received any fire since the last 20 years. The prescribed burning decision was based on criteria given by Du Plessis (1997). The fire eventually escaped due to unexpected weather conditions and finally covered ca. 300,000 ha.

For vegetation classification of Etosha National Park see le Roux (1980) and le Roux et al. (1988).

around 1980 until today) will not allow at present the re-establishment of fire regimes exclusively based on lightning.

Despite the problems arising from the current dry period there is no doubt that natural fires as well as prescribed management fires will continue to play an important role in maintaining the dynamic equilibrium between succession of vegetation and its utilization by wildlife. However, at present a debate of wildlife scientists, botanists and park managers both in Etosha National Park and in Kruger National Park (South Africa) controversially disputes the exclusive integration of lightning fires into the management scheme and to ban prescribed management fires. This debate reveals that questions arising from the definition of the "natural" role of fire and other disturbances in national parks or conservancies are cannot yet be answered definitely.

3.3 Impact of Recent Land-use and Environmental Changes on Fire

While the concepts of national parks aim to provide refugia for endangered species and natural (or close-to natural) fire regimes in an environment undisturbed by other changes, the vast majority of Namibia's territory is subjected changes that are either related to climate variability or to human occupation pressure.

3.3.1 Drying of Liambezi Lake

The drying of Liambezi Lake is a prominent example of recurrent changes of environmental conditions in Namibia. The lake is located in the East Caprivi Zipfel and was periodically filled with water flowing in from various directions (Mendelsohn and Roberts 1997). In 1982 the lake fell dry, probably due to the onset of the dry period affecting Namibia. The soils of the lake basin are dominated by organic layers of up to more than 1 m. Among various colonizing grass species *Imperata cylindrica* is a typical pyrophytic invader on freshly exposed sites. These grasslands are burning annually at large scale. Besides threatening the agricultural lands and grazing resources of the basin, fires burn deep into the organic layers and persist there during the whole dry season. Underground fire represent a threat to domestic animals and wildlife, e.g. the reported loss of more than 170 buffaloes in 1996.

Other grasslands in the Zambezi floodplains and on former forested sites are subject to annual fires. Local communities are often depleted of valuable grazing resources at critical times during the dry season. Mass slaughtering of livestock often is the consequence of large-scale wildfire damage in grasslands. These fires may be considered as a natural phenomenon but are incompatible with the demands of land for rapidly growing human and livestock populations.

3.3.2 Bush Encroachment in Farmlands

Large tracts of Namibia's farmlands are subjected to heavy bush encroachment, tentatively on more than 30 million hectares in Central-North Namibia. The reason for bush encroachment is primarily attributed to overgrazing by livestock over decades. Along with the exclusion of wildlife by fencing, fire was also systematically suppressed. While domestic animals graze selectively, natural wildland conditions would have provided manifold disturbances, including regular fires, which would have kept open these landscapes.

Bush encroachment represents a serious challenge to proper land-use planning. The use of fire, without any other treatment, for re-converting the inaccessible bushlands into open domestic livestock and wildlife habitats in most areas is not feasible any longer. The lack of surface fuels (grass-herb layer) will not allow to carry a fire which potentially could open the bushland.

However, under the light of new strategies towards a more efficient and environmentally compatible utilization of vegetative biomass, alternative concepts and methods should be identified anyway. While Namibia has already ca. 500 wildlife/hunting farms on former cattle farm lands, it is highly unrealistic that this concept could be realized on a major fraction of the bush-encroached land. Free-burning fires, on the other hand (if possible at all), are not desirable from the point of view that biomass energy should be utilized and not wasted.

Instead, a multiple-use system could be developed which would involve charcoal production and grazing systems combined with a tree cover improvement programme. Charcoal production (including the use of fine charcoal for briquette production) is currently conducted by various land owners.[11] After bush clearing the grass cover re-establishes within at least two years, and the site is ready for a new grazing cycle. Instead of returning to the old practices, however, a silvicultural component could be developed that would support the restoration of a desirable tree component. Jointly with the bush clearing selected tree species could be marked and promoted by pruning and selecting single stems. These trees could grow during several cycles of charcoal production and grazing. During the grazing phase they will provide shelter for cattle. The final utilization of the tree cover could either envisage large-sized charcoal and/or fuelwood production or timber production - if site conditions allow.

The reason why biofuel energy production is mentioned in this report: If Namibia intends to develop a national fire policy the approach must be inter-sectoral and include all lands on which fire currently or potentially plays a role. A national fire policy must also include alternatives to maintaining natural fire regimes or traditional land-use concepts. The use of plant biomass as a resource of renewable energy will become more important in the years to come.

At present a total of ca. 5000 tons of charcoal is produced on the base of bush clearing. Most of the products are exported to South Africa and Europe.

3.4 Impact of Fires in Southern African Ecosystems on Atmospheric Chemistry and Climate

Since the early 1990s a series of large research campaigns and individual projects were initiated to explore the role of vegetation fires on ecosystems and biogeochemical cycles. In order to explore environmental impacts of free-burning fires, the magnitude, characteristics and impacts of fire emissions needed to be investigated at regional and global scales. Most important is the clarification of the contribution of vegetation fires in various time scales (prehistoric, pre-industrial, contemporary) on the dynamic composition of the atmosphere and the possible contribution of excessive human-caused fires to anthropogenic climate change.[12]

In the 1980s the phenomenon of seasonally enhanced tropospheric ozone in the South Atlantic region had been observed (Fishman et al. 1986). The working hypothesis was that high atmospheric ozone concentrations as observed by satellites (tropospheric ozone residual) are caused by emissions from savanna and forest fires on both sides of the Atlantic. The clarification of this hypothesis required an experimental setup which included the investigation of:

* ecology and land-use relationships of savanna fires and other vegetation fires;
* spatial and temporal distribution of burning;
* emission factors and ratios from fires in the most important vegetation types;
* environmental conditions influencing fire occurrence, fire behaviour, and transport patterns and fate of emissions; and
* modelling the contribution of pyrogenic emissions from the southern African subcontinent on global emission budgets.

The Southern African Fire-Atmosphere Research Initiative (SAFARI) was designed in 1990, jointly with the project Transport and Atmospheric Chemistry Near the Equator - Atlantic (TRACE-A), to investigate the contribution of vegetation fires in Southern Africa on this large-scale atmospheric phenomenon. SAFARI was conducted under the International Geosphere-Biosphere Programme (IGBP) (Lindesay et al. 1996).

This large fire-atmosphere research program was implemented in its field phase in 1992 and evaluated in the following 4 years. SAFARI's Southern African component was based on ground, air- and spaceborne investigations in/over South Africa, Namibia, Zimbabwe, Zambia, and Botswana. The research components in Namibia embraced precursor fire ecology and fuel assessment research in Etosha National Park in 1991 (Kannenberg 1994; see also du Plessis 1997), and meteorological and ozonesonde measurements in Etosha National Park (Okaukuejo) during the field campaign in 1982 (van Wilgen et al. 1997).

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[12] Major syntheses of the global atmospheric and climatic role of vegetation fires are published by Goldammer (1990), Crutzen and Goldammer (1993), Clark et al. (1997), Goldammer and Furyaev (1996).

The results of the SAFARI research campaign are published in a special issue of the Journal of Geophysical Research (1996) and in a synthesis book by van Wilgen et al. (1997). The research reveals that south of the Equator about one third of the total area of infertile savannas and grasslands burns every year, and one twelfth of the fertile savannas. This adds up 1.3 million square kilometres of 9.6 million square kilometres south of the Equator (Scholes 1995). The amount of plant biomass burned in Southern Africa is ca. 177 million tons per year (van Wilgen and Scholes 1997). The amount of combusted biomass in the various ecosystems of Namibia is ca. ..... tons per year (Scholes 1995, 1998 [pers. comm.]).

It is clear that the emissions from vegetation fires in Namibia have a considerable impact on atmospheric chemistry. Concerning the assessments of fire emissions in the frame of the Climate Change Report the following must be stressed:

Any assessment of the release of radiatively active gases and aerosol should take into account

* the known mechanisms of carbon fluxes
* the life time of "greenhouse gases"
* the environmental fire history (baseline year)

Thus, the emissions from various fire types and fire regimes must be valued differently. This following statement is somewhat in accordance with recent recommendations of the Intergovernmental Panel on Climate Change (IPCC):

- Trace gases and aerosol originating from those fire ecosystems which are characterized by recurring (short-term interval) fires (e.g., savannas, woodlands and forests which are not subjected to degradation by fire effects and other human disturbances), are being emitted since evolutionary time scales. Thus, they are not a phenomenon of the present anthropogenic global change process. For instance, the carbon released by savanna fires will be sequestered during the next growing season (annual fires) or at the end of the fire cycle. Consequently, there is no "additional net release" of carbon as compared with historic conditions. The validity of this statement, however, can only be confirmed for a fire regime of a particular ecosystem or cultural landscape for which information on the history of recurrent natural and human-made fires is available.

- Emissions from those fire which lead to the reduction of carbon storage due to vegetation and site degradation will contribute to the additional anthropogenic greenhouse effect.

Distinction between these fire types (fire regimes) and their emissions respectively must be made. Thus, a careful assessment is required to come up with numbers which address the requirements of the UN Convention on Climate Change.

Vegetation types in Namibia act as sources and sinks of greenhouse gases:

* Net source of greenhouse gases: Fires which lead to degradation of vegetation cover, e.g. in the Caprivi forest ecosystems and other infertile and fertile savannas and woodlands. This includes fires in organic terrain of the Liambezi basin which has been accumulated in historic time scales.

* Net sink of greenhouse gases: Formerly logged and overgrazed farmlands in which bush encroachment takes place.

The Climate Change Report requires quantitative data on land-use changes and vegetation fires for the years 1993-95. The author of this report will contribute to this report by providing data on the total amount of vegetation burning (see above), emission factors for charcoal production, charcoal burning and fuelwood burning (follow-up to this report, to be sent to the Desert Research Foundation).

4. Fire Management

4.1 Fire Management Options

Archival information from the German colonial period reveals the first attempts by concession companies and the colonial government to stop deliberate burning which was considered to destroy forests and other vegetation. The *Deutsche Kolonialgesellschaft für Südwestafrika* gave an order to ban all fires in 1888 (Leutwein 1906). It was soon followed by a fire ban issued by the colonial administration in 1894 which considered burning of vegetation criminal offence (Deutsches Kolonialblatt 1894; see also Erkkilä and Siiskonen [1992]).

In the arid and moist savannas of Etosha National Park controlled burning, as practised country-wide by many land users, until 1980 was officially not permitted (van Wilgen et al. 1990). All human-caused and lightning fires were either extinguished or contained with the smallest possible area. It was only in 1981 that fire was recognized by management and research as playing a fundamental role in the development and maintenance of the current vegetation communities (du Plessis 1997). Fire was then finally acknowledged to be an efficient means for the removal of moribund grass material, controlling bush encroachment, recycling nutrients and manipulating game movements. Park management has now developed an objective approach to intentional veld burning in which lightning fire incidents are simulated, and the subjectivity in choosing areas to burn is reduced. The selection of areas to be burned depends on the mean seasonal rainfall in each "burning block", the time since the last burn and the accumulation of herbaceous fuels. Additional factors considered are the moribundness in grasses, the game pressure and the cover of green vegetation derived from satellite data (du Plessis 1997). The decision support-system in the form of an algorithm enables Park Management to select blocks for prescribed burns. Lightning fires form an integral part of the strategy. Fires caused by lightning are allowed to spread throughout

a burning block. In exceptional drought years lightning fires will be limited to the smallest possible area.

In the forest regions of Northeast Namibia it is generally agreed that there are on the one hand fire adaptations of the vegetation, on the other hand logging activities and associated disturbances of the canopy and soil the fire regimes are changing and lead to the degradation and impede the regeneration of some desirable forest tree species. Geldenhuys (1997) suggests a strong silviculture and fire management program for the valuable species *Baikiaea plurijuga* and *Pterocarpus angolensis*. He recommends:

"Historical facts as well as research results require that fire be considered as a natural feature and therefore an integral part of the woodland vegetation. As such fire could be used as a useful instrument in the management of the woodland to reduce and manipulate the woody vegetation. Apart from the fact that total protection against fire is undesirable for the natural development of the vegetation, with the exception of certain species and vegetation types, it remains unpractical and almost impossible. By considering the ecological requirements of the different species, can the conditions under which fire can be used as a management tool be prescribed and controlled. When fires do start under unfavourable conditions, such as during accidental fires (due to lightning or human activities) or deliberate unauthorized fires, then protection measures must be applied to reduce damage to the minimum. To use fire as a management tool requires that the preventive measures must be used when favourable conditions become unfavourable to make protection necessary. It is known that uncontrolled fires cause severe damage to woody vegetation because such fires usually occur during the late dry season when a large biomass of dead material exist. Measures to control such fires, both passive preventive measures and active suppression measures are provided in the management plan of Nakabunze Reserve (Tab.1.)."

Tab.1. General prescriptions for fire management and fire protection in the Nakabunze Reserve (Geldenhuys 1997)

Management Group	Fire Management	Protection Priority
Baikiaea improvement Regeneration of shrub form	Total protection Burn every 5 years in early dry season	Extinguish fires as soon as possible
Baikiaea improvement Regeneration of mainly small trees	Burn every 3 years in early dry season	Limit burning area; allow fire to burn out
Pterocarpus-Baikiaea-Guibourtia improvement	Burn every 3 years in early dry season	Try to contain fire. Limit burning area; allow fire to burn out
Pterocarpus improvement	Burn every 2 years in early dry season	Limit burning area; allow fire to burn out
Grassland	Burn annually in early dry season	Limit burning area; allow fire to burn out
Open Woodland	Burn annually in early dry season	Limit burning area; allow fire to burn out

In Namibia there is a broad range of factors influencing the role of fire in different ecosystems:

- climate and site conditions
- historic and present characteristics of vegetation, human occupation, land use systems and fire regimes
- future land-use in following long term national goals in land use plans in accordance with the overall targets of sustainable development policies

Socio-economic and political developments require a critical review of fire policies which may lead to formulation of new strategies or possibly reconsideration of established procedures.

It is clear that certain ecosystems require tolerance of natural and human-caused wild fires, e.g. in certain savanna and wild life refuge areas. Other ecosystems require a strong fire exclusion, e.g. in those forests where wild fires and other modern stress factors lead to severe forest destruction. Finally, some ecosystems require the use of prescribed management fires (e.g. early burns and burns in the later stage of the dry season) in order to maintain or restore ecosystem functions that are dependent on recurrent disturbance by fire.

The development of such fire management options require the inputs from various sectors of science and society. Since new knowledge has been gained on the environmental role of fire in Southern Africa in the last decade and Namibian scientists and administrators have not always been involved in fire research and

6. References

Booysen, P.de V. and N.M. Tainton (eds.) 1984. Ecological effects of fire in South African ecosystems. Ecological Studies 48, Springer-Verlag, Berlin 426 p.

Bourlière, F. (ed.) 1983. Tropical savannas. Ecosystems of the world 13. Elsevier Scientific Publ. Co., Amsterdam, 730p.

Brain, C.K. and A. Sillen 1988. Evidence from the Swartkrans cave for the earliest use of fire. Nature 336, 464-466.

Breitenbach, F. von 1968. Long-term plan of forestry development in the Eastern Caprivi Zipfel. Department of Forestry, Indigenous Forest Office, Saasveld, South Africa, 164 p.

Calvert, G.M. 1973. Progress report on ecology and planning. Rhodesia Forestry Commission, Western region, Bulawayo (unpubl. report).

Cole, M.M. 1986. The savannas. Biogeography and geobotany. Academic Press, London, 438p.

Clark, J.S., H. Cachier, J.G. Goldammer, and B.J. Stocks (eds.). 1997. Sediment records of biomass burning and global change. Springer-Verlag, Berlin-Heidelberg-New York, 489 pp.

Crutzen, P.J, and J.G. Goldammer (eds.) 1993. Fire in the environment: The ecological, atmospheric, and climatic importance of vegetation fires. Dahlem Workshop Reports. Environmental Sciences Research Report 13. John Wiley & Sons, Chichester, 400 p.

Deutsches Kolonialblatt 1894. Verordnung des Kaiserlichen Landeshauptmannes für das Südwestafrikanische Schutzgebiet, betreffend Wald- and Feldbrände. Deutsches Kolonialblatt. Amtsblatt für die Schutzgebiete des Deutschen Reiches vom 15.11.1894. Mittler and Sohn, Berlin

Erkkilä, A., and H. Siiskonen. 1992. Forestry in Namibia 1850-1990. Silva Carelica 20. University of Joensuu, Faculty of Forestry, 244 p.

Fishman, J., P. Minnis, and H.G. Reichle. 1986. Use of satellite data to study tropospheric ozone in the tropics. J. Geophys. Res. 91, 14,451-65.

Geldenhuys, C.J. 1977. The effect of different regimes of annual burning on two woodland communities in Kavango. South African Forestry J. 102, 32-42.

Geldenhuys, C.J. 1997. Past, present and future forest management in the Southern African Region with special emphasis on the Northern Regions of Namibia. Directorate of Forestry, Ministry of Environment and Tourism, Republic of Namibia, Windhoek, Forestry Publ. No. 5, 44 p.

Goldammer, J.G. (ed.) 1990. Fire in the tropical biota. Ecosystem processes and global challenges. Ecological Studies 84, Springer-Verlag, Berlin-Heidelberg-New York, 497 p.

Goldammer, J.G. 1993. Fire management. In: The tropical forestry handbook (L. Pancel, ed.), 1221-1268. Springer-Verlag, Berlin-Heidelberg.

Goldammer, J.G., and V.V.Furyaev (eds.) 1996. Fire in ecosystems of boreal Eurasia. Kluwer Acad. Publ., The Hague. 528 p.

Heikkilä, T.V., R.Grönqvist, and M.Jurvélius 1993. Handbook on forest fire control. A guide for trainers. Forestry Training Programme (FTP) Publication 21, Helsinki, Finland, 239 p.

Hilbert, R., and T. Dankemeyer. 1994. The current situation in Bushmanland according to fire and forest. Mimeo, incl. Minutes of the Workshop on Problems of Fires in Bushmanland: Bushmanland Forest Station, 22 September 1994 (minutes compiled by T. Dankemeyer) (mimeo on file, Directorate of Forestry, Namibia, 5 + 4 pages).

Huntley, B.J., and B.H. Walker (eds.) 1982. Ecology of tropical savannas. Ecol. Studies 42, Springer-Verlag, Berlin, 669 p.

International Decade for Natural Disaster Reduction (IDNDR). 1997. Wildfire and Related Environmental Hazards. Early Warning Programme Working Group 6 Report. IDNDR Geneva (in press.)

International Tropical Timber Organization (ITTO). 1997. ITTO Guidelines on Fire Management in Tropical Forests. ITTO Policy Development Series No.6. ITTO, Yokohama, 40 p.

Journal of Geophysical Research Special Issue. 1996. Southern Tropical Atlantic Regional Experiment (STARE): TRACE-A and SAFARI. J. Geophys. Res. 101, No. D19, 23,519-24,330.

Kannenberg, N. 1994. Gras-Biomasse in Savannenbiomen des Etosha National Park: Anwendung des Disc Pasture Meter (DPM). In: Feuer in der Umwelt. Ursachen und ökologische Auswirkungen von Vegetationsbränden. Konsequenzen für Atmosphäre und Klima (K.F.Weiss and J.G.Goldammer, red.), 76-91. Arbeitsgruppe Feuerökologie und Biomasseverbrennung, Max-Planck-Institut für Chemie, Abteilung Biogeochemie, c/o Universität Freiburg. Arbeitsbericht 1992-94. Selbstverlag, 136 p.

Kershaw, P., M.B. Bush, G.S. Hope, K.-F. Weiss, J.G. Goldammer, and R. Sanford. 1997. The contribution of humans to past biomass burning in the tropics. In: Sediment records of biomass burning and global change (J.S.Clark, H.Cachier, J.G.Goldammer and B.J.Stocks, eds.), 413-442. Springer-Verlag, Berlin-Heidelberg-New York, 489 p.

le Roux, C.J.G., J.O. Grunow, J.W. Morris, G.J. Bredenkamp, and J.C. Scheepers. 1988. A classification of the vegetation of the Etosha National Park. S. Afr. J. Bot. 54 (1), 1-10.

Leutwein, T. 1906. Elf Jahre Gouverneur in Deutsch-Südwestafrika. Mittler and Sohn, Berlin, 589 p.

Lindesay, J.A., M.O. Andreae, J.G. Goldammer, G. Harris, H.J. Annegarn, M. Garstang, R.J. Scholes, and B.W. van Wilgen. 1996. International Geosphere-Biosphere Programme/International Global Atmospheric Chemistry SAFARI-92 field experiment: Background and overview. Special Issue TRACE-A and SAFARI, J. Geophys. Res. 101, No. D19, 23,521-23,530.

Mack, F., J. Hoffstadt, G. Esser, and J.G. Goldammer. 1996. Modeling the influence of vegetation fires on the global carbon cycle. In: Biomass burning and global change. Vol. I (J.S.Levine, ed.), 149-159. The MIT Press, Cambridge, MA.

Mendelsohn, J., and C. Roberts. 1997. An environmental profile and atlas of Caprivi. (With vegetation description by C.Hines). Directorate of Environmental Affairs, Namibia. Windhoek, 45 p. + App.

Ministry of Environment and Tourism 1996. Namibia Forestry Strategic Plan. Directorate of Forestry, Windhoek, 55 p.

Moyo, S., P. O'Keefe, and M. Still. 1993. The Southern African environment. Profiles of the SADC countries. Earthscan Publ., London, 354 p.

du Plessis, W.P. 1997. Refinements of the burning strategy in the Etosha National Park, Namibia. Koedoe 40 (1), 63-77.

le Roux, C.J.G. 1980. Vegetation classification and related studies in the Etosha National Park. D.Sc. (Agr.) thesis, Univ. Pretoria.

Scholes, R.J. 1995. Greenhouse gas emissions from vegetation fires in southern Africa. In: African greenhouse gas emission inventories and mitigation options: Forestry, land use and agriculture (F.F.Fitzgerald et al., eds.), 63-73. Kluwer, Netherlands. <book form of a special issue of Environmental Monitoring and Assessment 38, 169-179>.

Siegfried, W.R. 1980.The incidence of veld-fires in Etosha National Park. Madoqua 12, 225-230.