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Environmental impact assessment of commercial forestry in forest reserves in Chobe District, Northern Botswana

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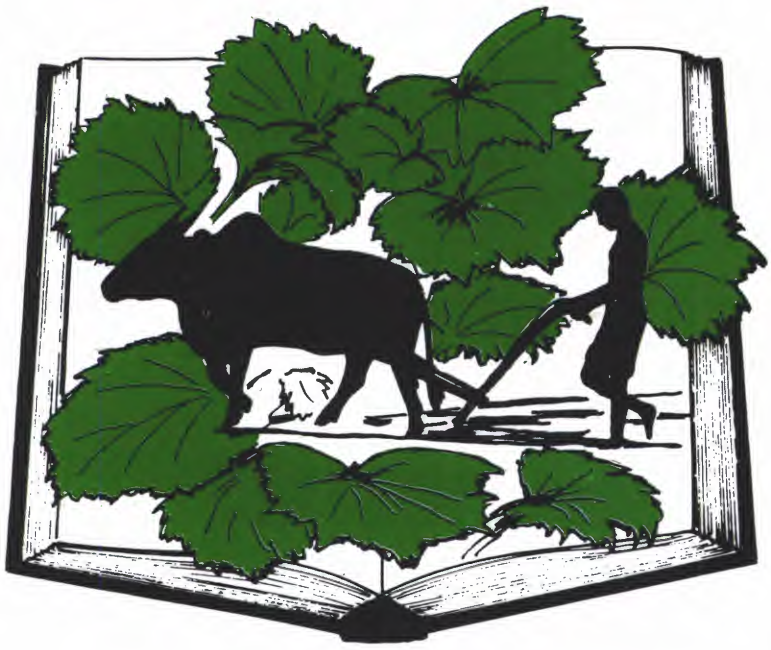

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Chobe Forest Inventory and Management Project

ENVIRONMENTAL IMPACT ASSESSMENT OF COMMERCIAL FORESTRY IN FOREST RESERVES IN CHOBE DISTRICT, NORTHERN BOTSWANA

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This report summarizes the conclusions of a four week consultancy undertaken to assess the ecological sustainability of forestry practices in five forest reserves in Chobe district in NE Botswana. The terms of reference (appendix I) included assisting an ongoing forestry project in formulating a management plan for these reserves, as well as outlining various scenarios under different management options.

The assessments and recommendations are based on short field surveys of the reserves and surroundings, consulting with relevant government and nongovernment authorities, literature reviews and analyses of preliminary data produced by an ongoing forest inventory project. Other reports from this project and the forthcoming management plan will contain more detailed descriptions of land use history, socio-economic conditions, and previous and current forestry operations. What follows are extracts of main features of this part of Chobe district that are considered particularly important when discussing management options for the forest reserves from an environmental point of view.

1. Natural Characteristics

1.1. Physiography and climate

Most of Chobe district of 22.500 km2 consists of flat woodlands on deep Kalahari sands. Excluding low-laying lacustrine deposits and alluvium along the Chobe-Linyanti drainage system and farm settlements here and along the eastern border which total less than 5 percent. The rest consists of an elevated plateau sand ridges interspersed with a system of smaller and larger pans. The flat topography and well-drained sands permit rapid percolation of the seasonal summer rains. There is a steep north-south gradient in rainfall, declining from nearly 700 mm/year in the north-east to less than 400 mm in the south over a span of about 130 km. The relative proportion of pans and shallower soils increase towards the south. Coupled with the decrease in precipitation, this leads to a gradual decrease in total tree cover and a 33more patchy distribution of continuous woodlands

in the southern part of the district.

Due to limited and seasonal rainfall, surface water in the interior pans dries out during the winter. Hence, most of the larger herbivores, including elephants, are seasonally migratory and move to and concentrate near the Chobe-Linyanti perennial drainage in the west during the early dry season. There is also a seasonal movement of mammals in the eastern part to artificial water sources provided in national parks and wildlife management areas across the Zimbabwean border. This movement and dilution of wildlife within most of the forest reserves and the northern part of Chobe national park takes place just prior to the start of the regular hunting season in April.

1.2 Vegetation

Chobe contains the only true forests and deciduous woodlands within Botswana. The forest vegetation and associated fauna is part of the Zambezian biogeographical region centered further north. Only in the Chobe section of the country is rainfall sufficient to support more or less closed canopy forest vegetation. The mukusi (Baikiaea plurijuga) forests represent the southernmost extension of the natural range of this species, which is geographically restricted to a narrow belt stretching from southern Angola eastwards through southern Zambia and northern Botswana to west-central parts of Zimbabwe. Mukusi is internationally recognized to be in need of conservation measures, as it has been severely exploited in neighbouring countries.

Unlike further north, mukusi in Chobe only locally develops climax-like, continuous canopies. Occurring at the periphery of its natural range, it is particularly sensitive to variations in climate (rainfall and soil moisture) and other exogenuous factors. Hence, with spatial variations in soil depth and the sharp north-south gradient in rainfall in NE Botswana, true mukusi climax-forests are restricted to the elevated longitudenal dunes of the deepest, well-drained soils of the Kalahari sand sheet (i.e. 'ferralic arenosol' soil type, FAO) in the northern part Chobe District. On shallower soils and southwards the mukusi becomes a subdominant associate of the miombo woodland. This vegetation type has a wide distribution throughout sub-Saharan Africa and contains a large number of deciduous tree species, all of which more or less adapted to periodic fires and a low and erratic rainfall pattern. Mukwa (Pterocarpus angolensis) is a co-dominant member of the miombo woodland association and is found scattered throughout the larger area covered by this broad vegetation type. Although commonly associated with mukusi on the deeper soil types, it becomes a more prominent member of the miombo on slightly shallower soils. However, rarely does it develop into a dominant woodland associate like mukusi; on average it makes up less than 5 percent of all canopy stems within the forest reserves.

Although proper vegetation mapping has not yet been conducted, the mixed miombo woodlands in Chobe, in addition to pockets of mukusi-dominated forests, appear to be composed of two, possibly three subtypes: a mixed deciduous woodland dominated by mukwa, mudumina (Kirkia acuminata), mogongo (Ricinodendron rautanenii), moako (Erythrophleum africanum), tsaudi (Guibourthia coleosperma) Combretum spp., and Brachystegia spp. , with mukusi as a subdominant; monalo (musheshe) (Burkea africana) - mogonono (Terminalia sericea) dominated type on shallower and drier soils frequented by fire; and a mophane (Colophospermum mopane) dominated type on harder, poorly drained soils, mainly near pans and in the south. Combretum spp. is a regular associate on the latter two types.

In areas disturbed by grazing, thickets consisting of Dichrostachys glomerata, Baphia obovata, and Combretum elaegnoides commonly develop in the understory. Similarly, dense thickets of mogongo may develop in areas where elephants concentrate to feed selectively on the fruits of this species. However, dense "mutemwe" thickets commonly found in mukusi forests in Zambia and which there seriously hamper natural regeneration of this species, do not occur in Chobe.

1.3 Woodland dynamics

The miombo woodland ecosystem has evolved certain ecological characteristics which need to be taken into account when making management prescriptions. Periodic fires and a low and seasonally irratic rainfall pattern have selected for eco-physiological adaptations which make this vegetation type particularly resistant to biotic pressures. Frequency and intensity of fires coupled with temporal variation in precipitation and spatial variation in soil characteristics (mainly depth and water holding capacity) to a large extent dictate floristic compositions and successional patterns. In the absence of fire, the miombo normally develops denser woody vegetation at the expense of perennial grasses and fire-resistant shrubs. Conversely, frequent and hot fires reduce tree regeneration and lead to a gradual opening-up of the canopy. In higher (>800 mm) rainfall areas late season hot fires normally stimulate regeneration of perennial grasses at the expense of shrubs and tree regrowth, whereas in low rainfall areas such fires may depress the perennial grasses as well as encroaching shrubs and lead to an invasion of fire-resistant scrubs intermixed with annual grasses. However, the direction of the understory succession varies markedly with local site conditions and species assemblages, making it quite difficult to predict accurately the outcome of any local fire regime.

Natural regeneration in miombo tree species are characterized by seeds which may retain viability for a long time before germinating, very rapid vertical root growth (to reach lower water level), and persistant annual shoot growth for many years until escaping from recurrent ground fires. Most species

develop thick subterrenean rootstocks which may survive for several decades (similar to grassland 'suffrutices') until favourable conditions enable the saplings to become established. These adaptations provide a "reservoir" of potential regeneration in the soil stratum which may be released when environmental stresses are relaxed. In an environment dominated by recurrent fires, regeneration is therefore not a continuous process. Rather, it gives rise to a wave-like recruitment of age-classes often spaced sveral years and even decades apart. The resilient nature of miombo woodlands acts as a safeguard against rapid deterioration from persistant natural or man-induced pressures. At the same time it provides management with a high degree of operational flexibility.

The mukusi climax forest type, on the other hand, does not possess these adaptations to the same extent. Quite susceptible to fire, this species (and similar associates like tsaudi) cannot withstand recurrent hot fires, neither during the regeneration phase nor after establishment.

1.4 Fauna

The fauna restricted to this portion of Botswana is characterized by its forest habitat affinity and has a wider distribution further north. Although not only restricted to Chobe, some 40-50 species of birds are mainly confined to this forested part of the country either as permanent residents or winter migrants. Forest-adapted wildlife species of particular importance for conservation and with potential value for sustainable utilization are sable antelope (Hippotragus niger), roan antelope (Hippotragus equinus) and Greater kudu (Taurotragus oryx). Because the area has not yet been adequately studied with respect to total faunal and biodiversity composition, it is not yet known if the forest reserves contain other endangered or rare species that require special conservation measures.

Chobe district now harbours the largest and densest population of elephants on the African continent. The international concern for the world-wide conservation of this species has put the government in a difficult position with respect to the management of this species. Following ban on hunting and efficient control of poaching, densities have increased to more than 1 animal/km2 throughout most of the district, with local concentrations of more than 4 animals/km2 during the dry season. Occurring in all forest reserves during the wet season and in concentrated numbers in western Chobe and Kasane forest reserves during the dry season, this species now exerts impacts on the vegetative composition of all the forest reserves in Chobe.

2. Human Population and Land Use History

On average, the human population density is quite low (appr. 0.6/km2) across the whole district of 22.500 km2. It is

concentrated to few localities along the periphery of the District. Thus, unlike most other rural areas where dense and expanding settlements tend to exert strong pressures on the natural environment, the forestry reserves have untill now not been much encroached upon by human activities. However, with the establishment of protected areas, where Chobe National Park covers 50 percent and the five Forest Reserves cover another 20 percent, the human population is now confined to small areas which puts restrictions on access to natural resources and expansion of settlements. This is particularly notable in the Enclave, where about 5500 people on 1.690 km2 of land are totally enclosed by the national park, the Chobe forest reserve and the Nabibian border.

The five Forest reserves are scattered across the whole district. Like the Enclave in the west, Kasane FR in the north abuts Kasane township (>3000 people) and Kazungula and Leshoma settlements (nearly 1000 people). Maikaelelo FR is remotely located along the eastern border of Chobe NP, distant from settlements and with no all-year access road. Kazuma and Sibuyu FRs are located further east along the Zimbabwean border, both adjacent to National Parks in Zimbabwe, and near the expanding agricultural settlement at Pandamatenga (about 2.500 people).

During the last decade the human population has been increasing at an estimated rate of 5-6 percent. Growth is predicted to increase to 8-9 percent in the next few years, mainly due to industrial and tourist development in the north (Kasane and Kazungula). This will put added pressure on the northern part of Kasane FR. The complicated land use situation in the Enclave is recognized by the government, and several planning excercises are currently under way for local community development. Inevitably, the local inhabitants in the Enclave will be involved in multiple use and management of the adjacent part of Chobe forest reserve. Similarly, the local village of Leshoma at the NE periphery of Kasane FR and the expanding population at Padumantenga adjacent to Sibuyu and Kazuma FRs will need to be considered in any management plan of these forest reserves. Only the Maikaelelo FR is distantly located from human habitation.

Cattle grazing has a long tradition in Chobe but is not a dominant land use like in many other districts of Botswana. Total stock is estimated at about 10.000 head. However, cattle are mainly concentrated to the Enclave and Leshoma where grazing land is severely restricted. In spite of low stock quality, the traditional linkage to cattle contributes to increasing the herds in spite of poor and restricted pastures. Some cattle encroachment now occurs at the periphery of most of the forest reserves, but impacts on the natural woodlands are insignificant.

Due to low human density and vast woodland resources, fuelwood and poles were never in short supply in the past. Collection was limited to areas near settlements which left most of the

"interior" woodlands little affected by subsistence use of such resources. Commercial logging has taken place in the past in Kasane FR in the 1930s and late 1980s, and in Chobe Game Reserve (now national park) in the 1940-50s. Currently, logging takes place in Sibuyu and Chobe FRs. Common to all operations is selective highgrading of mukusi and mukwa timbers. Concessions include eight other species, but few if any of these are harvested due to lack of markets. According to removed volumes, past logging intensity appears to have been moderatly low, in part due to enforced prescriptions as to diameter limits and retention of seed trees. A system of controlled early burning and prevention and suppression of wild fires operated during the 1960s and 1970s. This has now more or less been abandoned, and uncontrolled fires regularly burn large portions of the reserves each year.

In the past, the wildlife resources were utilized as a supplementary food source. Indigenuous Batawana and Basarwa tribes regularly killed small and larger hervivores with the aid of setting bush fires. Due to their low numbers, the impact on the wildlife stock was negligible. Today, local inhabitants may hunt inside the forest resereves provided they have a game licence. Quotas are set by the Department of Wildlife and National Parks and licences distributed by a raffle system. On average, about 6 percent of the licences issued for Chobe FR are allocated to the local people in the Enclave. The method used for assessing game abundance and setting quotas (aerial surveys) significantly underestimates the density of most species. Within the reserves, reliable quantitative estimates useful for management are probably only obtained for buffalo and zebra, aside for monitoring the local elephant populations. Poaching does occur and is claimed to be a main cause of a recent decline and spatial redistribution of some of the larger herbivores. Professional hunting has not been practiced within the reserves, but one company has recently started a combined hunting and non-consumptive safari operation in the eastern part of Sibuyu FR.

Use of other forest products like honey, tubers and fruits, medicinal plants a.o. has little tradition among the local inhabitants, and hence, these resources have yet received virtually no exploitation. The high populations of elephants and also lions represent a serious problem for the local communities, especially in the Enclave, due to crop and stock depredation. Although some compensation is offered and trouble animals may be shot, the procedure for dealing with these problems is laborious and not readily implemented.

Current land use policy in Chobe puts priority on further expansion of tourism and localized industrial development (Kasane and Kazungula), increased wildlife utilization and commercial agriculture (Pandumantenga scheme), besides improved subsistence farming and soci-economic development in the Enclave.

3. Results of Forest Inventory

The main results of the forest inventory can be summarized as follows (more detailed data are available in the report from the inventory project):

3.1 Logging removal

Current selective cutting of mukwa and mukusi removes approximately 10 percent of the overstory (>30 cm dbh) or less than 5 percent of the total number of trees >5 cm dbh in the woodlands. Due to its low relative abundance, past harvesting of mukwa has removed between 10 percent (Kasane FR) and 50 percent (Chobe block I) of the mature trees of this species. Current harvesting in Chobe Block II removes 70 percent or more of all mature mukwa larger than 35 cm dbh. For mukusi, the harvest intensity is about 35 percent of all mature trees (>30 cm dbh), or 8-10 percent of all mukusi trees >5 cm dbh.

3.2 Woodland damage

A large proportion of the trees are damaged by either fire or elephants or both. In addition, a large proportion of mature mukwa is diseased by "die-back" - a fungal disease caused by Fusarium spp.. The distribution of damage on trees larger than 5 cm dbh is estimated as follows (Chobe=C and Kasane=K Forest Reserves):

Percent damage	Fire		Elephant		Total damage	
	C	K	C	K	C	K
All Species	50	30	4	8	38	44
Mukusi*	55	28	0.5	0.4	30	43
Mukwa*	43	31	31	7	67	68

* Of all mukusi and mukwa, respectively

In this table, 'fire' denotes the percent number of trees with crown and extreme damage. 'Elephant' includes categories of moderate, severe and extreme damage, i.e. trees which have 2/3 or more of the stem girth debarked. 'Total damage' includes other causes than fire and elephant (although these agents may have predisposed the tree) and it only comprises the two worst categories, from which the tree is predicted to die.

In general, the situation in the other reserves is similar, with the possible exception of mukwa. Because the Kazuma and Maikaelelo reserves have not yet been logged, the proportion of undamaged and slightly damaged mukwa trees may prove to be somewhat higher in these woodlands. Nevertheless, the results present a very bleak picture of the general situation of the tree resources within the Chobe forest reserves. Fire and to

a lesser extent elephants, coupled with dieback and other agents, have significantly reduced the vigour and health of the woodlands. About 1/3 of the established stems are expected to die within the next decades, with highest losses predicted for mukwa.

3.3 Regeneration

Fire and browsing by elephants and other wild herbivores significantly depress tree regeneration. The following shows the density of potential regrowth (rootstocks) and the extent of damage caused by wildfires to annual shoots from these rootstocks. The data are extracted from the inventory results from Chobe (C) and Kasane (K) reserves (excluding sparsely timbered grasslands).

Species	Mukusi		Mukwa		All Species*	
	C	K	C	K	C	K
Rootstocks (stems/ha)	**968**	**60**	**4**	**42**	**1223**	**1103**
% damage	**40**	**74**	**29**	**44**	**42**	**75**

* 11 potential commercial species, including mukusi and mukwa

According to G.M. Calvert (pers. comm.) a minimum of 50 rootstocks/ha is needed for adequate regeneration. For mukwa the density is critically low in both reserves. However, the low density recorded may be an artifact of the sampling technique employed in the inventory: Because fires were occurring at the time when the field work was conducted, a disproportionate number of rootstocks may have been overlooked during the enumeration in Chobe FR. Furthermore, due to the irregular distribution and low density of mukwa throughout the reserves, the sampling procedure has probably been of insufficient intensity to assess the true regenerative capacity of mukwa.

The diameter distributions in the two reserves gave this general picture: small diameters (young age classes) of mukwa are virtually lacking in both reserves. Coupled with the low density of rootstocks (if correctly assessed), recruitment of this species is presently seriously reduced. Mukusi gave a more favourable picture: in Chobe FR, trees between 5 and 30 cm dbh were evenly distributed among all size classes at a combined density of roughly 25 stems/ha. In Kasane FR, mukusi was also evenly distributed on age, but at about half the average density found in Chobe. The low stocking density of trees above 5 cm dbh compared to the density of rootstocks, however, shows that also in this species is recruitment of saplings seriously curtailed, principally due to fire. Above 30 cm dbh, the frequency of larger size classes decreased markedly. Again, this depletion can largely be attributed to

cumulative effects of repeating fire damage to smaller diameters.

4. Assessment of Logging Practice

The proportion of trees removed by past and present logging operations is relatively low when considering the total stocking density of all species within the reserves. At present harvest intensity, temporal removal of less than 10 percent of the overstory or less than 5 percent of total stems will not adversely affect the total tree coverage within the reserves. However, harvests are selective on two species. The question is therefore whether such selective highgrading, even at widely spaced intervals, can contribute to a depletion of the relative abundance of these particular species. Provided recruitment is adequate and cutting cycles are properly spaced in time, selective harvests may be sustainable. However, due to the pronounced impacts of fire on seedling recruitment, logging may contribute to an ongoing depletion of these two species.

For mukusi, recruitment in the form of density of rootstocks and younger size (i.e. age) classes appears to be sufficient to offset the loss of mature stems due to logging. For mukwa, the situation is probably more critical. Density of rootstocks and young trees may be insufficient to assure replacement of mature trees lost to fire, die-back, elephants and logging. However, as mentioned earlier, the picture emerging from the inventory may be misleading due to the sampling method. Also, averaging the results over the total area within the reserves may have seriously underestimated the regenerative capacity of this species in localized mukwa-rich areas. Only more carefully designed sampling, properly stratified according to mukwa distribution, can give adequate information regarding this question.

Because current harvest intensity is quite high on mukwa and the residual stems are of inferior quality, logging probably contributes to any depletion of this species principally caused by fire, disease and elephants. Hence, strictly speaking, logging as currently practiced is not ecologically sustainable. The management plan may recommend continued harvest of mukwa through salvage cuttings. This may be justified from a socio-economic standpoint. However, it is questionable from an ecological point of view. It may be argued that the damaged trees are of genetically inferior stock and therefore should be removed. Because fire hits trees randomly and the genetic basis for insect and elephant attacks is likely to be minimal, such consideration is merely hypothetical. The degree of genetic inheritance of die-back is not known, but probably not strong. More important is the role these trees may serve as seed producers. Up to a point, lightly stressed trees tend to produce flowers and seeds more prolifically than unstressed trees. In general, mukwa does not produce much seeds compared to many other miombo species.

With the low density of mature stems in the woodlands, and the apparent lack of potential regeneration in the form of rootstocks, any further reduction of live trees will further reduce the regenerative capacity of this species. On the other hand, it is possible that cutting of overstory trees, including mukwa, will stimulate the recruitment of saplings through lower competition. Also, mukwa is considered a pioneer species which seems to regenerate best with some fire disturbance and soil scarification. Until these ecological factors have been properly investigated under the local site conditions in Chobe, it is recommended that any salvage cuttings should be carefully restricted to only removal of trees with advanced die-back and other damage. Priority should be given to retention of as many "healthy" seed producers as possible to safeguard against depletion of the growing stock.

Direct adverse effects on soil and nutrient cycling are insignificant. Due to the flat topography and sandy texture of the soils, water infiltration is rapid, and skid roads and landing sites are quickly revegetated. Only along the escarpment near the Enclave may an erosion hazard arise if this area is opened for local access and stock grazing. Due to the open structure of the woodlands, felling and log extraction can be performed with minimal damage to residual stems. However, due to carelessness, many trees are felled into the crowns of neighboring trees, thereby facilitating the spread of crown fires.

Current logging practice has other indirect effects. Most important are the effects of slash deposition. With less than 50 percent utilization of felled stems above 15 cm diameter, large volumes are left in the forest after cutting. This contributes significantly to the fuel load for late season hot fires. Much of the slash is left near remaining live trees which increases the subsequent fire impacts on these stems. Furthermore, the heavy fuel load leads to prolonged and intense spot burning. This completely kills all organic material and leaves patches of open, bare soil around the scattered slash sites. Besides negative effects on soil microfauna and loss of nutrients, particularly loss of nitrogen to the atmosphere from more widespread hot burns, localized intense fires and subsequent bare spots may contribute to frost pockets and mycorrhizal damage which may hamper tree seedling establishment. Any salvage cuttings should therefore stipulate maximum reduction of logging slash, preferably removal of woody stems down to a top diameter of 10 cm and deposition away from neigbouring trees.

Wildfires, mukwa die-back and increasing elephant damage are the principal causes of the high mortality of trees in the woodlands. The large volume of logging slash adds fuel for more intense burns. The high incidence of fires is the principal cause of the successional change or "savannization" process now taking place throughout the forest reserves: a gradual opening-up of the canopy and reduction of total tree cover (at least in the short term), accompanied by a an

increase in fire and elephant resistant shrubs (Dichrostachys glomerata, Baphia obovata, Combretum spp., Bauhinia macrantha a.o.) . According to the inventory results, the fire regime does not seem to favour an increase in the relative coverage of grasses at the expense of shrubs. Except for local areas on shallower soils (?) regeneration of shrubs and trees is prevalent over most of the reserves. This is probably due to a large proportion of rootstocks accumulated over many years which is typical of miombo woodlands.

The successional set-back now occurring will have little if any negative effects on total biodiversity. Rather it will lead to a shift in relative species compositions. Density of fire and elephant resistant plant species will increase at the expense of species sensitive to these agents. Production of dead material will provide better habitats for invertebrates and fungi. This may benefit certain insectivorous and hole nesting birds. Conversely, loss of overstory trees will reduce the habitat quality for canopy species, particularly frugivorous birds (viz. Ricinodendron fruits) and forest-adapted mammals. There are signs that a characteristic and attractive species like sable antelope is now decreasing due to ongoing habitat changes. Time did not permit more specific assessment of likely impacts on different taxonomic groups, partly because most of the biota is not yet described.

Biodiversity can be measured on different spatial scales. Within a small and ecologically distinct area, a reduction of forest cover may lead to loss of climax-adapted species. Normally this also leads to a loss in local biological diversity, so-called "alpha-diversity". On a larger scale, a patchy reduction of tree cover and successional set-back may lead to larger diversity, so-called "beta-diversity". Because fire and elephant impacts are unevenly distributed throughout the reserves and they are superimposed on ecological units which are also unevenly distributed, the overall effect on total biodiversity is probably neutral rather than negative at the current impact level.

Widespread fires and opening-up of the canopy may also affect the regional and, eventually, the global climate. Emmission of CO2 and other gases adds to the general greenhouse effect. As reported by the international Panel of Climate Change, bush fires in Africa is an important factor and probably contributes more than burning and deforestation of tropical rainforests in this repect. Reduction of tree cover and exposure of bare ground probably also lead to increased albedo and higher fluctuations in temperature which may alter the local and regional precipitation pattern.

5. Scenarios under Different Management Alternatives

5.1 No intervention

If all logging ceased and fire and elephant are not controlled, the woodlands are expected to be further modified

by the escalating pressures of fire and elephants. The ongoing process of "savannization" will continue, with increasing decline of tree cover replaced first of all by fire and elephant-resistant shrub and bush encroachment. Depending on site conditions and timing and severity of fires, grass cover may also increase. As the fuel load is reduced by a gradual reduction of total combustible biomass, tree and shrub regeneration may again increase, provided sufficient number of rootstocks are still intact for sprouting. However, a growing elephant population will keep any tree regrowth in check and maintain an open, savanna-like vegetation structure. Eventually, because dispersal routes are limited, the expanding elephant population will reduce its own food supply to the point where food shortage coupled with unfavourable climatic events will lead to major die-offs. There is no reason to expect that the subpopulations of elephants in Chobe will regulate their own densities through density-dependent adjustments in fertility or natural mortality quickly enough to reach any equilibrium level with the biological "carrying capacity" of the available elephant range. Admittedly highly speculative, a major crash in the elephant population may occur within the next two-three decades, considering its present density and growth rate. Following death of a large proportion of elephants, the former woodlands will slowly recover through a series of successions, eventually to a mixed miombo woodland in dynamic equilibrium with the predominant fire regime.

During the course of this scenario, the woodlands will progressively lose more and more of their timber trees, precluding any sustainable utilization of this resource.

5.2 Only salvage cutting of mukwa (and mukusi)

With strict adherence to cutting prescriptions, seed tree retention and slash removal but with no control of elephants or other fire control than practiced at present, the same scenario is predicted as above, with a more rapid loss of mukwa.

5.3 Fire control with or without salvage cutting

With an efficient fire prevention and suppression programme, the successional change towards more open woodlands will be slowed down but not completely arrested. The expanding elephant population will exert increasing impacts on the woodlands, in the early phase directed primarily towards palatable species like mukwa, Brachystegia boehmii, Ricinodendron rautanenii, Colophospermum mopane, Kirkia acuminata and Terminalia sericea. If instigated in the early phase of the current population build-up, an effecient fire programme will significantly improve the stocking density and general vitality of the mukusi-dominated parts of the reserves. Other associated species which will benefit are fire-sensitive or less palatable elephant-species like Guibourthia coleosperma and Erythrophleum africanum .

With time, a completely unregulated elephant population will exert pressure also on the less palatable species, mainly by uprooting and breakage of larger stems and browsing on saplings and smaller trees. This will reduce tree coverage also in the mukusi-dominated stands of the reserves, thus curtailing sustainable utilzation of the more elephant resistant parts of the woodlands. Unless further expansion of the elephant population is prevented within the next decade or two, mukusi may also be damaged to the extent which precludes economically sustainable timber utilization, even if an effective fire prevention programme is installed.

5.4 Fire and elephant control

If wildfires are effectively controlled and the current elephant population is kept at present levels through hunting and culling of annual increments, the ongoing successional set-back will be arrested. The vegetative composition of the woodlands are expected to change gradually into a higher relative coverage of fire-sensitive species. Improved recruitment of mukusi will lead to re-establishment of climax-like communities of this species, thus enabling sustainable utilization of this timber tree to take place. The increasing incidence of elephant damage to mukwa at current density level of elephants makes it difficult to predict if stabilization of elephants coupled with fire control can provide adequate conditions for sustained harvesting of mukwa. This will also to a large extent depend on any future spread of die-back. Because both soil scarification and a light fire regime is advantaguous for regeneration of mukwa and several other miombo species, complete fire control in all vegetation types is not advisable.

5.5 Fire and elephant control plus provision of water

If water is provided in the interior through boreholes, dry season movement of elephants and other migratory hebivores will be reduced, thus relaxing the impact of elephants on the woodlands near the Chobe-Linyanti drainage system. However, effects are only expected to be moderate. In order to revert the rapid deterioration of the riverain woodlands along Chobe/Linyanti, the elephant population would need to be reduced drastically, which is an unlikely management option at present.

However, provision of water in the interior will improve the habitat quality of several wildlife species and act to keep parts of the local populations from moving out during the dry season. Thus, not only may this improve productivity of game for wildlife utilization, but it will also "keep them there" and therefore make them more available for harvesting during the regular hunting season.

Because large tracts in the southern and eastern parts of the forest reserves consist of open wooded grasslands not naturally suited for commercial forestry, wildlife management

appears to be an ecologically viable priority-use option for these areas. Such is also consistent with the recently adopted national conservation strategy. Recent government policy decision calls for culling of the annual increments of elephants. Hence, certain quotas may be allocated to the Forest Reserves, both for harvesting trophy bulls and cow/calf groups. This may generate significant revenues to the local and regional economies. It is implicit that any wildlife utilization scheme be designed so as to maximize local community participation and sharing of revenues.

However, any water development in the interiore must be carefully designed to prevent localized habitat degradation. An ecologically "safe" approach may be to use some of the already existing pans, properly spaced, but to rotate water provision among them. Also, it should not be undertaken unless a stabilization of elephant numbers is achieved simultanuously. If not, water provision in the interior will only prolong and increase the total area of habitat degradation now caused by elephants along the Chobe/Linyanti waterways.

6. Management Implications and Recommendations

The dry miombo woodlands in Chobe are adapted to periodic droughts, fire and grazing by herbivores. They are not in static equilibrium, but floristic and faunal compositions change with climatic and man-induced factors. Episodic tree regeneration gives rise to uneven, wave-like age distributions. They are robust and resilient ecosystems, which will, if not degraded too far, respond and revert back if present unsustainable factors are arrested. The dynamic nature of such woodlands makes it difficult, if not inappropriate, to attempt to define what constitutes a "natural" climax state of the different sub-types in terms of floristic and faunal compositions. Rather, one must try to identify the ungoing development process and ask if present trends are compatible with management objectives.

In Chobe district, and within the the Forest Reserves, two main factors - wildfire and elephants - are now exerting mounting pressures which modify the woodlands. Both act in concert, together with past and current logging, to reduce canopy cover and set back the natural successions to more open wooded and scrub savanna with more fire and elephant resistant species. If desired, this trend can be changed by appropriate management intervention.

Assuming that conservation of the woodlands for sustainable utilization of both timber, wildlife and other veld products are a main objective of management, the rising impacts of fire and elephants need to be reduced and controlled. Depending on area-specific management objectives, the reserves may be subdivided according to their natural properties for multiple use management. Three main priority-uses, each demanding different management techniques, may be considered: timber

production, wildlife utilization, and non-consumptive tourism. These are not necessarily mutually exclusive. However, their viability to a large extent depend on site characteristics and location. Fortunately, the spatial distribution of areas suitable for these different uses are quite compatible with such a multiple use approach.

Timber production should be pursued in the most accessible and productive woodlands which contain an adequate potential growing stock of mukusi, mukwa and other species of commercial potential. Such areas are largely confined to the southern part of Kasane FR and northernmost part of Kasane Extension and the western part of Chobe FR. Mukusi-dominated stands will require more or less complete prevention of fires, and highest attention to fire control should be directed to these areas. Mukwa requires some light burning to reduce competing shrubs. Field experience and information gathered from permanent sample plots will aid in developing an appropriate fire regime for this and other commercial species. Closely controlled livestock grazing may be compatible with timber production, and may be tried out on an experimental basis.

Conservation for non-consumptive tourism should be pursued in high quality miombo woodlands and mukusi forests located within easy reach of visiting tourists. Such may be in the vicinity of Kasane and the Enclave, and in the Kazuma FR. Like sites for timber production, they also require close control of fires. Low intensity timber extraction and controlled livestock grazing to reduce fuel loads are compatible with this priority-use, but some parts should be left totally undisturbed.

Wildlife utilization should be pursued in the more open woodlands and grasslands on the poorer soils, mainly confined to the southern and eastern parts of the reserves, which are also more inaccessible. The eastern part of Chobe FR, the southern 2/3 of Kasane Extension, Maikaelelo FR, and Sibuyu FR all appear to be more suitable for wildlife utilization than for priority timber production, especially under the assumption that a full fire prevention programme can not be readily implemented in all the reserves. However, to a large extent the economic viability will depend on whether trophy elephant hunting will be granted and on the provision of water. Because adequate information on the wildlife resource (species densities and productivity) is lacking, and allocation of quotas is currently based on an inappropriate census technique, a quantitative assessment of the resource and practical census techniques must be conducted and designed before implementation.

7. Summary

1. The forest resource in NE Chobe consists of a mixture of miombo woodlands and a southern extension of mukusi forests, with mopane woodlands scattered on shallower soils.

Except for the mukusi-dominated parts, these woodlands are drought and fire-adapted ecosystems with a high degree of resilience, i.e. they have a "built-in" capacity to withstand periodic stresses induced by water shortages and wildfires. Because these major environmental factors tend to vary temporally, these woodlands are also highly dynamic entitites which over time change their relative species compositions. The mukusi forests, on the other hand, represent a more true climax vegetation type, where the dominating mukusi species may reach very old age (1000 years) with optimum regeneration taking place with some soil scarification but in the absence of fire.

2. Although formerly not much affected by human activities, and still sparsely populated, all five forest reserves are now subjected to increasingly strong man-induced (excessive fire and logging) and natural (elephant) pressures which change the floristic and faunal compositions in the direction of a more open-grown, earlier successional ecosystem. Commercial forestry contributes to this successional set-back, but its relative role is insignificant compared to the impacts of fire and elephants.

3. Only two species, mukwa and mukusi, are harvested selectively. On average, current cutting intensity removes only a small proportion of the total tree coverage (less than 10 percent of all trees larger than 5 cm dbh) which has little direct effect on overall woodland density.

4. Provided potential regeneration of mukwa (density of rootstocks) is not higher than indicated by the forest inventory (see 3.3) a management option to continue salvage cutting of mukwa (and mukusi) from the reserves is questionable from an ecological point of view. Existing mature trees, even though of reduced vitality due to fire, die-back and elephants, provide seeds for regeneration, thereby safeguarding against further depletion of the mukwa growing stock. Any genetic "benefit" from salvaging dieback-infected trees is probably marginal and unjustifyable, considering the loss of seed producers which such an operation will entail. If to be conducted for socio-economic reasons, it should be restricted to removal of stems in the highest disease/damage categories only. If re-sampling of mukwa regeneration in Chobe FR - and the inventory results in Sibuyu, Maikaelelo and Kazuma reserves - show adequate density of rootstocks, salvage cutting may also include lesser damaged stems.

5. Direct adverse effects of the logging operations on residual vegetation or soil substrate were insignificant, mainly due to 1) flat topography with deep and sandy soils which minimizes erosion and facilitates quick revegetating of skid roads and landing sites, and 2) open-grown nature of the woodlands which - in general - permits selective felling with little or no damaging to adjacent live trees.

6. Due to low extraction efficiency (less than 50 percent of

estimated volume > 15 cm diameter), a large proportion of the felled trees are left in the forest. This assures adequate recycling of nutrients, but wastes potential resources for fuelwood and significantly adds fuel load for late season hot fires. Careless felling of trees and leaving cut-offs and slash near residual live stems contributes to increased bole and crown damage to neighbouring trees.

7. Intensity and frequency of wildfires, mainly man-induced, have increased in recent years. Species that are sensitive to fires, like mukusi, suffer high mortality both during the regeneration phase and as mature trees. Mukwa, once established beyond the sapling stage, is normally quite resistant to fires. However, because this species is often damaged by elephant through debarking, established mukwa is also negatively affected by fires. In addition, a large proportion of mature mukwa is attacked by die-back disease, which is currently spreading and causing significant losses to this species in Zambia and Zimbabwe.

8. The elephant population in Chobe has increased remarkably during the last two decades. Densities within most of the forest reserves now exceed 1.0 animal/100 ha; during the dry season increasing to 2-3 animals/100 ha in NW Kasane and W Chobe FRs. Such densities are considered 5-10 times larger than the lower treshold for impacting woodlands. Hence, elephants are now significantly modifying the vegetative composition and structure of the Chobe riverain forests, with increasing impacts also on the forest reserves. Their effects are relatively low on mukusi (low palatability) but more pronounced on mukwa and other palatable species.

9. If not adequately controlled, the growing elephant population will alter the vegetative structure and composition of the reserves by reducing the density of trees. Species like mukusi will not be much affected due to its low palatability, but mukwa and other species of potential economic value will be reduced. Although seasonally migratory to areas outside the reserves (including Namibia and Zimbabwe), eventually the local subpopulations are expected suffer major die-offs, because dispersal areas are limited or physically not readily available.

10. Because woody species have different tolerance levels to fire and elephants (browsing, debarking and breakage) the cumulative effect of fire and elephants, and to a lesser extent commercial forestry, is to change the natural, semi-closed forests to more open woodlands, consisting of a relatively higher proportion of fire and elephant resistant species. In the short term, and if not allowed to accelerate, this change may not reduce total biodiversity, but only lead to a shift in relative species composition. There are now signs that forest-adapted herbivores like sable and roan antelopes are declining within the forest reserves, which can partly be attributed to the "opening up" or "savannization" process now taking place.

11. If not arrested by human intervention, the ongoing modification by fire and elephants will eventually, on a longer time perspective, lead to a loss in total biotic diversity and lower overall land productivity. Certain species of birds belonging to the "northern" zoogeographical distribution range may be lost as will probably forest-adapted mammals like Greater kudu and sable antelope and an economically valuable tree species like mukwa. Also, the high incidence of wild fires and gradual loss of tree cover may have adverse effects on the regional and global climate by adding CO2 and other greenhouse gases and accentuating local temperature and water fluctuations.

12. In order to arrest the degradation process now taking place and restore the woodlands to a condition where sustainable multiple-use forest management is ecologically feasable, fire and elephant impacts must be reduced. The natural woodlands have evolved a high degree of environmental resilience and will recover readily if released from these impacts. Mukusi-dominated forests of still high quality cover relatively small areas within the reserves and these may therefore be given highest priority with respect to fire control. Mukwa and other fire-adapted species of the more typical miombo association occur on shallower soils and are more prominent in the drier, southern parts of the reserves. Regeneration of these species is not adversely affected by light and low-frequency fires. Indeed, a light fire regime may stimulate both directly and indirectly to germination and subsequent establishment. Hence, total prevention of fire may not be needed mukwa-rich areas to be managed for timber production.

13. The forest reserves are parts of a larger elephant range in NE Botswana. Throughout most of the reserves, management for mukwa timber (and other secondary commercial species) is not compatible with a very dense elephant population, even if fire is reduced to an ecologically adapted level. In order to bring the elephant population down to a tolerable impact level, a large proportion of the present population needs to be culled, and then stabilized through sustainable harvesting of the annual increment. It is highly doubtful if the GOB will initiate such a large-scale culling programme. Instead, present policy calls for stabilization of the population at present levels through controlled, annual harvests. Because large parts of the forest reserves appear to be better suited for wildlife utilization than for timber production, multiple-use management is both ecologically and economically more appropriate than single commercial forestry use.

14. A multiple-use programme, directed towards a combination of timber production, wildlife utilization (and other veld products), and non-consumptive tourism may be achieved through subdividing the reserves into different priority-use areas, based on accessibility and natural properties of woodlands with respect to timber trees and wildlife. Timber production: mukusi and mukwa-rich portions of Kasane and western part of

Chobe Forest Reserves. Requires efficient fire prevention programme which may be combined with low intensity, controlled livestock grazing and non-consumptive tourism. Wildlife utilization: Kasane Extension, eastern part of Chobe FR, and Maikelelo and Sibuyu Forest Reserves. Requires better control of wild fires, but not complete prevention. Provision of permanent water through boreholes in existing pans (on rotational basis to avoid localized habitat deterioration) is expected to improve habitat quality and productivity for wildlife, as well as "to hold back" some of the migratory elephants and other large herbivores during the dry season. Hunting of elephants should be included, both for trophy-fee revenues and for subsistence use of meat and other products. Conservation and non-consumptive tourism: Selected areas of high quality woodlands of different types (mukusi forest and mixed diciduous woodlands) near Kasane and the Enclave and possibly Kazuma Forest Reserve. Requires adequate restoration of sites through fire control, but may be combined with low intensity forest utilization and livestock grazing.

15. The Chobe elephants in Botswana are increasing at a near maximal rate of 5-6 percent/year. One subpopulation appears to migrate from Zimbabwe in the dry season to Chobe, including the three eastern Forest Reserves, in the wet season. Apart from the agricultural development scheme in Pandamatenga, this land area is presently more or less uninhabited and not under pressure for settlement by local people. The "northern plain" (a large area of natural grassland recently being considered for agricultural development) falls within this migration corridor. Due to the importance of this area for maintaining unimpaired movement of elephants and other large herbivores between NE Chobe and Zimbabwe, it is recommended that this area not be changed for commercial agriculture production or other development purposes. Most likely, such fragmentation of habitat will have negative effects on the quality of the local wildlife populations, including elephants. Instead, maintenance of a continuous wildlife habitat corridor will ensure maintenance of a viable population of elephants and other migratory herbivores in this area, from which an annual surplus may be harvested and generate revenues for the regional and national economy. The Chobe national park and the three Forest reserves Maikalelo, Kasane Extension and Kazuma may all form parts of such a larger, regional wildlife conservation and management area.

16. The forest inventory now being completed provides much-needed baseline information on the forest tree resources. However, because the ecological characteristics and dynamic processes of the mukusi forests and miombo woodlands are poorly known, and because the reserves may be managed for a wider range of products and services besides timber, it is recommended that the following monitoring programme and field investigations be initiated:

a) Vegetation type mapping: the distribution and relative abundance of commercial tree species (current and potential)

and associated fauna appear to follow the spatial variation pattern in soil types and precipitation gradient. The forest inventory was stratified according to two broad categories of tree density, which cuts across underlying subdivisions of soil types, fire history and rainfall. For future multiple-use management the forest reserves should be delineated according to basic ecological units for which vegetation maps are most useful.

b) Wildlife inventory: Presently, annual quotas for harvesting wildlife are based on aerial surveys which grossly underestimate all but a few of the larger herbivores. In order to develop proper management techniques and optimize the utilization of this resource, a thorough inventory needs to be undertaken. This will require developing proper census techniques to monitor the movement and productivity of the main species to be included in a multi-species management programme.

c) Biodiversity: For managing the reserves on an ecologically sustainable basis, biodiversity needs to be monitored within the different subdivisions of the reserves. This will require description and mapping of other key floral and faunal elements than yet available and development of practical field techniques for routine monitoring purposes.

d) Re-inventory of regeneration capacity of mukwa: The result of the present inventory may have seriously underestimated the potential reproduction of this important timber species. Re-assessment should be based on a stratification according to the relative density distribution of this species (already available from the first inventory) and be undertaken during the late wet season when regrowth is more easily detected.

e) Monitoring of woodlands: a system of permanent sample plots has been established during the inventory. Also, the cutting blocks in Chobe FR Block II are well suited for monitoring purposes. Appropriate plots and coupes should be selected and monitored for the effects of wild and controlled fires, large mammal impacts and domestic stock grazing on woodland development. Such are needed in order to refine any management schemes now to be initiated in the reserves.

Acknowledgement

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27/11/91

CHOBE FOREST INVENTORY AND MANAGEMENT PLAN

CONSULTANT PERSONNEL TERMS OF REFERENCE

Job title: ENVIRONMENTAL IMPACT STUDY SPECIALIST

Expected duration of work: Four weeks

Expected date of commencement: February 1992

FORESTRY

Purpose of the job

To undertake an environmental impact study of past logging activities, the effect of the changing elephant population, the increased incidence of wild-fires, and their attendant effects on the vegetation, particularly the quality of standing timber and its regeneration.

ECOSYSTEM

Specific duties

To assess the impact of past land-use practices in the area, and to provide an array of likely outcomes for the same areas according to various management and land-use options.

Such a composite study is of major significance with regard to providing an indication to the likely impact of possible land-use practices in the future.

Expected output

To assist the Project Coordinator, and his team, draft the Management Plan for the Chobe Forest Reserve. To provide the Government of Botswana with a clear set of guidelines on the likely impact of options for possible future management and land-use practices.

Minimum qualifications and experience preferred

M.Sc. in Forest Ecology, or a related ~~disciple~~ discipline.
Ten years related work experience in developing economies within the tropics. Experience within Miombo woodlands would be an advantage.

21/11/91

CHOBE FOREST INVENTORY AND MANAGEMENT PLAN

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