Vegetation changes during a 36-year period in northern Chobe National Park, Botswana

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Abstract

Changes in vegetation cover in northern Chobe National Park (Botswana) were assessed using aerial photographs from 1962, 1985 and 1998, with subsequent ground proofing. In addition, cumulative browsing by elephants and the occurrence of fire scars were recorded on random vegetation sites within shrubland ($n = 20$) and mixed woodland ($n = 20$). Coverage of woodland vegetation decreased from 60% to 30% between 1962 and 1998, while shrubland vegetation increased from 5% to 33% during the same period. During the study period, woodland has gradually retreated away from the river front. While riparian forest covered a continuous area along the riverfront in 1962, only fragments were left in 1998. We found a significant decrease in browse use with increasing distance to the Chobe river for *Combretum apiculatum*, *Combretum elaeagnoides*, *Combretum mossambicense* and other woody plants combined (all $P < 0.0001$). The occurrence of fire ($P < 0.0001$) and basal area ($P < 0.0001$) were positively related to distance to the river. Elephant browsing occurred on >70% of available stems within 2 km from the river, while less than 20% of the trees had fire scars in the same zone. Beyond 7 km from the river, elephant browsing was reduced to >50% of available stems, while more than 50% of the trees had fire scars. The density of any of the shrubs was not related to distance to the river neither within shrubland (all $P > 0.05$) nor within mixed woodlands (all $P > 0.05$).

Key words: elephant browsing, fire, vegetation change

Résumé

On a évalué les changements du couvert végétal au nord du Parc National de Chobe (Botswana) au moyen de photographies aériennes prises en 1962, en 1985 et en 1998, avec une vérification ultérieure au sol. On a aussi relevé dans des sites pris au hasard l'usage alimentaire qu'en font les éléphants et les traces de feux, dans des zones arbustives ($n = 20$) et des zones arborées mixtes ($n = 20$). Le couvert végétal dans les zones arborées a diminué de 60% à 30% entre 1962 et 1998, alors qu'il augmentait de 5% à 33% dans les zones arbustives pendant la même période. Pendant la période que couvre l'étude, les zones arborées se sont progressivement éloignées de la rivière. Alors que la forêt riveraine couvrait une surface continue le long de la rivière en 1962, il n'en restait que des fragments en 1998. Nous avons relevé une diminution significative du broutage par les éléphants au fur et à mesure qu'on s'éloignait de la rivière Chobe pour les *Combretum apiculatum*, *Combretum elaeagnoides*, *Combretum mossambicense* et d'autres plantes ligneuses prises ensemble (toutes $P < 0.0001$). La survenue des feux ($P < 0.0001$) et la zone de base ($P < 0.0001$) étaient liées positivement à la distance jusqu'à la rivière. Le broutage des éléphants s'observait sur plus de 70% des pousses disponibles jusqu'à une distance de deux kilomètres de la rivière, alors que moins de 20% des arbres portaient des marques de feux dans la même zone. Au delà de 7 kilomètres de la rivière, le broutage des éléphants était réduit à moins de 50% des pousses disponibles alors que plus de 50% des arbres portaient des cicatrices dues aux feux.

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La densité d'aucun arbuste n'était liée à la distance jusqu'à la rivière, ni dans la zone arbustive (ensemble $P > 0.05$) ni dans la zone arborée mélangée (ensemble $P > 0.05$).

Introduction

Herbivory and fire have been implicated as the main influencing factors of plant community dynamics in many of the Sub-Saharan African ecosystems (Hobbs, 1996). Several studies have shown that increasing numbers and browsing by African elephants (*Loxodonta africana* (Blumenbach)) can have a marked local impact on mature woodland trees (Stewart & Talbot, 1962; Watson & Bell, 1969; Pellew, 1983; Dublin & Douglas-Hamilton, 1987). Caughley's (1976) hypothesis was applied to Chobe National Park (Botswana) by Cormack (1992), who concluded that the riparian forest, currently being under heavy impact by elephants, was allowed to mature at the end of the 19th century when elephant populations were reduced to their lowest by ivory hunters. A high fire frequency may trap the woodlands in the regeneration phase, which, with persistent burning, will slowly regress to a fire-climax grassland (Croze, 1974; Norton-Griffiths, 1979). In drier areas, characterized by low grass production, elephants alone may reduce woodlands as they tend to rely on browse from smaller trees (Dublin & Douglas-Hamilton, 1987). Caughley (1976), proposed in his stable limit cycle hypothesis that the woodland of the Luangwa Valley, Zambia was only allowed to regenerate at sufficiently low elephant densities. Dublin *et al.* (1990) proposed a multiple stable states hypothesis from their study in the Serengeti–Mara ecosystem in East Africa. They concluded that fire alone could be responsible for the perturbation which caused a change from woodland to grassland, after which elephants alone were capable of holding the vegetation in the grassland state (Dublin *et al.*, 1999). While fire and elephants have been focused in many studies on savanna woodland changes, a recent study from Taranquire in Tanzania attributed the decline of density of small trees over a 25-year period to a severe drought in 1993 (Vijver *et al.*, 1999). In this study, fire was not seen as a major cause for woodland changes and elephants affected the size distribution of the woody component rather than the density (Vijver *et al.*, 1999).

In semi-arid regions of developing countries like Botswana, the assessment of trends in land cover changes is important for the appropriate sustainable management of natural resources (Vanderpost, Ringrose & Matheson, 1998). Although many studies have been conducted within what is commonly referred to as the elephant range in Botswana (e.g. Child, 1968; Moroka, 1984; Ben-Shahar, 1993, 1996), knowledge of the extent of quantitative reductions in cover is still low, with the exception of a few studies (e.g. Nellis & Bussing, 1990; Gulinck, Andries & Serreneels, 1995). The objectives of this study were to quantify vegetation changes over a 36-year period in Northern Chobe National Park using aerial photos from 1962, 1985 and 1998. In addition, present elephant and fire impact were assessed in the two major vegetation types.

Materials and methods

The study area is located in the north-eastern tip of Botswana within the Chobe National Park. It covers a 15-km strip along the Chobe river from Kasane in the East to Serondela in the West and about 10 km southward. The annual rainfall of about 600–700 mm occurs from November to March and the mean annual temperature is 21.8 °C (Child, 1968; Sommerlatte, 1976). October is the hottest month, with mean maximum temperatures of 35 °C and June is the coldest month with mean minimum temperatures of 6–9 °C (Bhalotra, 1987). The vegetation of Chobe varies with physiography, parent material and soils (Gulinck *et al.*, 1995). Riparian woodland is found along the Chobe river. Main woody plants in this woodland include *Garcinia livingstonei* (T. Anders), *Capparis tomentosa* (Lam.), *Trichilia emetica* (Vahl), *Securinega virosa* ((Roxb. ex Willd) Baillon)), *Ficus sycomoras* (L.), *Kigelia africana* ((Lam.) Benth. Muell. Arg.)), *Acacia nigrescens* (Oliver), *and Croton megalobotrys* (Muell. Arg.). Southwards from the river on alluvial soil common tree species are *Combretum elaeagnoides* (Klotzsch), *Dichrostachys cinerea* ((L.) Wight & Arn.) *and Baphia massaiensis* (Taub.) (Simpson, 1975). From about 1–2 km from the Chobe river the vegetation changes gradually into a mixture of shrub and woodland dominated by *Baikiaea plurijuga* (Harms). These areas include *Baikiaea plurijuga*, *Burkea africana* (Hook.), *Ochna pulchra* (N.K.B. Robson), *Erythrophleum africanum* ((Welw. ex Benth) Harms), *Combretum elaeagnoides*, *Terminalia sericea* (Burch. ex DC.), *Bauhinia petersiana* (Bolle), *Croton gratissimus* (Burch.), *Pseudolachnostylis maprouneifolia* (Pax), *and Baphia massaiensis* (Taub.). More detailed descriptions of the vegetation are given by Simpson (1975), Moroka (1984) and Gulnick *et al.* (1995).

Large mammalian herbivores found in the area include elephant, giraffe (*Giraffa camelopardalis* (L.)), impala (*Aepyceros melampus* (Lichtenstein)), buffalo (*Syncerus caffer* (Sparrman)) and zebra (*Equus burchelli* (Gray)). Particularly high herbivore concentrations occur along the Chobe river front during the dry season, when seasonal pans are dry (Child, 1968; Melton, 1985; Calef, 1988). Elephant numbers have been reported to have dramatically increased and are still increasing at a rate of some 6% per annum since the ban on ivory hunting in the early 1980s (Gibson, Craig & Masogo, 1998). The prohibition of hunting between 1932 and 1945, followed later by the creation of the Chobe Game Reserve, resulted in the resurgence of the population with augmentation by immigration from neighbouring countries (Child, 1968; Melton, 1985). Hunting was completely banned between 1983 and 1996, and in 1995 the elephant population in northern Botswana was estimated to be around 80,000 (Gibson *et al.*, 1998).

Three sets of aerial photographs were used to assess vegetation changes. The first set was taken in July 1962 (1:40,000, black and white), the second in August 1985 (1:50,000, black and white) and the third in November 1998 (1:10,000, coloured). All photographs are available at the Department of Surveys and Mapping in Botswana, Gaborone. The registration and classification of vegetation cover types was carried out using stereo pairs of aerial photos. These were placed under a mirror stereoscope and different vegetation shades/hues were delineated. Finer details were identified on the photos with a pocket stereoscope. Classifications were made in accordance with Lillesand & Kiefer (1979) and Dickinson (1969). Eight land cover types was identified from aerial photos. The cover types were delineated and digitized using a stereo plotter into ESRI ArcView GIS. Hence, three digital maps (1962, 1985 and 1998, respectively) were produced in order to quantify and compare changes between the three periods.

Field work was carried out during October–November 1998 to check the cover types, which included river, floodplain, old floodplain, riparian forest, bare ground, shrubland, mixed woodland and woodland (Table 1). A general field assessment was made of all the vegetation cover types, comparing them with aerial photos in the field. A more detailed assessment of vegetation cover, browsing and fire impact was done in the dominating vegetation types, shrubland, mixed woodland and woodland. Within each of these vegetation types, twenty sites

Table 1 Descriptions of the land cover categories based on aerial photographs and ground proofing. The distinctions between the different vegetation types were based on the amount of cover (%), the canopy type (closed or open) and the hue on the photos. The hue description refers to the black and white photos only

Land cover type	General description
River	Areas covered by 100% open water mainly the Chobe river. Dark black hue.
Floodplain	Occurring on areas likely to be flooded during high tides of the Chobe river and including the Sidudu/Kasiskili island. Medium dark hue. With some noticeable isolated shrubs.
Old floodplain	Area occurring on clayey hydromorphic soils west of Kasane next to Serondela camp with some grassy (<60%) and bare patches (<20%). *Capparis tomentosa* (Lam.) bushes dominate this cover type. The hue alternating between whitish at some points (bare) and medium dark grey (grassy) to dark spots (shrubs).
Riparian forest	Vegetation along the main river channel. Mostly dense and appears as a continuous strip along the river valley. More than 80% tree cover and a closed canopy. Major species include *Trichilia emetica* (Vahl), *Gardenia livingstoni* (T. Anders), *Acacia nigrescens* (Oliver), *Kigelia africana* ((Lam.) Benth.), *Croton megalobotrys* (Muell. Arg.) and *Albizia harveyi* (Fourn). Darker than the neighbouring vegetation.
Bare ground	Open areas with no or <2% vegetation cover, very light greyish hue.
Shrubland	Areas covered by often patchy shrubs interspersed with some grassy areas and occasionally scattered mature trees (<10%). *Combretum apiculatum* (Sonder), *C. Mossambicense* ((Klotzsch) Engl.), *C. Elaeagnoides*, *Grewia pachycalyx* (K.Schum) and *Lonchocarpus nelsii* ((Schinz) Schinz ex Heering & Grimme) shrubs dominant. Medium to dark grey hue.
Mixed woodland	Areas dominated mostly by woody species with *Baikiaea* trees and shrubs (<50% cover). Noticeable areas with open canopy (<10%). Dark grey and almost continuous hue.
Woodland	Land covered by mature trees with a more or less closed canopy. Dominated by *Baikeae plurijuga* (Harms) (>10% canopy cover) and other trees including especially in the understory, *Pericopsis angolensis* ((Baker) van Meeuwen), *Croton gratissimus* (Burch.) and *Burkea africana* (Hook.). Darker grey hue than mixed *Baikiaea* woodland.

were randomly selected (each 50 × 50 m). Randomization was done using a randomised table on a 1 km × 1 km grid system divided into 100 × 100 cells. Existing fire breaks and main routes within the study area were used to access sites. No site was located closer than 50 m from any fire-break or road to avoid any possible effects these could have on the vegetation and on browsing patterns. From each site, the vegetation type, the shortest distance from the middle of the site to the Chobe river (derived from a 1:50,000 topographic map), the exact location of the site using a Geographical Positioning System (GPS Pathfinder Basic Receiver, Magellan 6000), the total number of standing mature trees (stem diameter > 10 cm at base) and the total number of trees with fire scars were recorded.

In order to characterize browse impact and stand density, three plots (5 m × 5 m) were randomly selected within each of the 60 sites, again, using a table of random numbers starting from the south-western corner of the site. The stand density or basal area ($m^2\ ha^{-1}$) was measured from the centre of each plot using a relascope. To assess browsing impact by elephant, the total number of stems of *Combretum apiculatum* (Sonder), *Combretum elaeagnoides*, *Combretum mossambicense* ((Klotzsch) Engl.), and other wooded plants (combined) was counted and compared with the number of browsed stems (cumulative browsing score, including both old and new elephant browse) for individual trees within the plots. Only stems positively identified as elephants were recorded (Ben-Shahar, 1998), thus excluding fine-browsing by other ungulates. The focus on *Combretum* species was done because they are common throughout the study area and they are all utilized by elephants (Stokke, 1999).

The area covered by each vegetation cover type was calculated using the ESRI GIS statistical package (ArcView, 1996). In order to identify vegetation changes at different distances from the Chobe river, analysis was carried out using distance intervals of 2 km from the river, up to 10 km (ArcView, 1996). The statistical data analysis was carried out using Minitab (1994). Simple linear regression models were used to predict any relationship between cumulative browsing score, basal area and fire scars and distance to the Chobe river. Only data from shrubland and mixed woodlands were used for these analyses, because these two vegetation types were found at regular intervals from the river, up to 9 km inland.

Results

From 1962 to 1998, the woodland coverage was reduced from 60 to 30% (Table 2 and Fig. 1), corresponding to an annual reduction in woodland cover of 1.47 $km^2\ year^{-1}$ during the 36 years study period. Mixed woodland increased from 19% coverage in 1962 to 34% in 1998, while shrubland increased from 5% coverage in 1962 to 33% in 1998 (Table 2 and Fig. 1). Vegetation changes have generally escalated from 1985 to 1998 compared with the period from 1962 to 1985. The area covered by shrubs doubled during the 23-year period from 1962 to 1985, while it more than doubled during the 13-year period between 1985 and 1998 (Table 2 and Fig. 1).

Table 2 Area cover (km^2) and total percentage covered by different vegetation types in the study area in Northern Chobe National Park in 1962, 1985 and 1998

	1962		1985		1998	
Cover type	km^2	%	km^2	%	km^2	%
River	5.6	4.1	9.5	7.1	8.9	6.8
Floodplain	11.7	8.5	10.8	8.1	10.1	7.7
Old floodplain	3.3	2.4	7.1	5.3	4.8	3.7
Riparian forest	0.8	0.6	0.7	0.5	0.09	0.07
Bare ground	0.05	0.04	0.08	0.04	0.08	0.06
Shrubland	7.3	5.3	13.6	10.2	32.6	25.0
Mixed Woodland	25.4	18.5	45.2	33.9	43.9	33.7
Woodland	82.8	60.4	46.3	34.7	29.9	22.9
Totals*	137.0	100	133.3	100	130.4	100

*The size of the study area is slightly different between years because of minor changes to the location of roads and other construction work used to identify the border on the aerial photos.

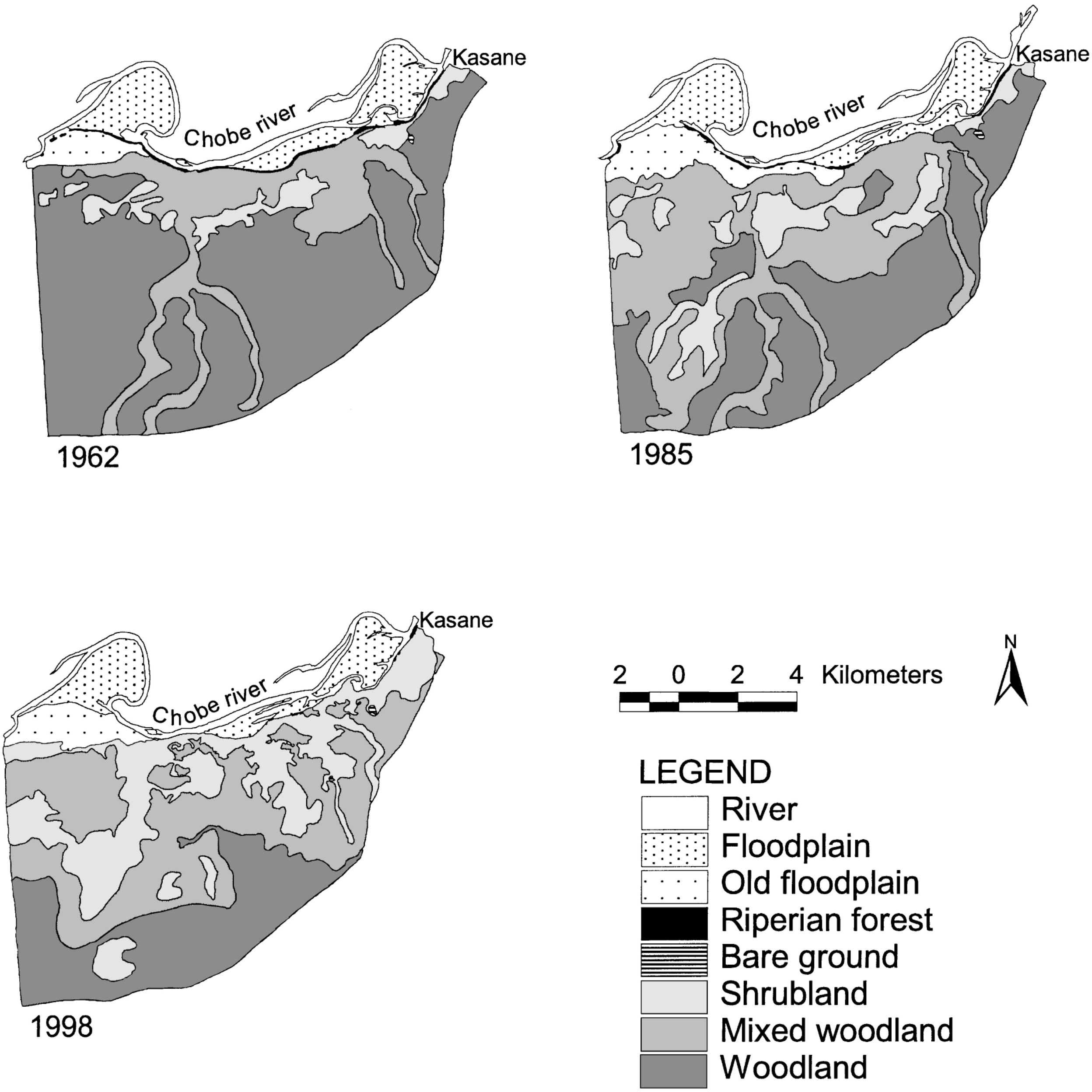

Fig 1 Vegetation cover types in the study area in northern Chobe National Park in Botswana in 1962, 1985 and 1998

In 1962, woodland was by far the dominant vegetation type within 2–4 km from the Chobe river (Fig. 2). During the study period woodland dominance has gradually retreated away from the river front. In 1998 woodland was not the dominant vegetation type before 6–8 km from the Chobe river. However, from 1985 to 1998, there has been some increase in woodlands at a distance of 6–8 km (Fig. 2). In 1962, shrubland cover extended to only 4 km but by 1998 it was found throughout the study area (Fig. 2). Close to the river (0–2 km), in 1998 shrubland was the dominating vegetation type, while woodland had been completely eliminated (Fig. 2). Combining shrubland and mixed woodland the cumulative browsing score on three *Combretum* shrubs and on other woody species combined was negatively related to distance to Chobe river (R^2 between 0.58 and 0.86, all $P < 0.0001$,

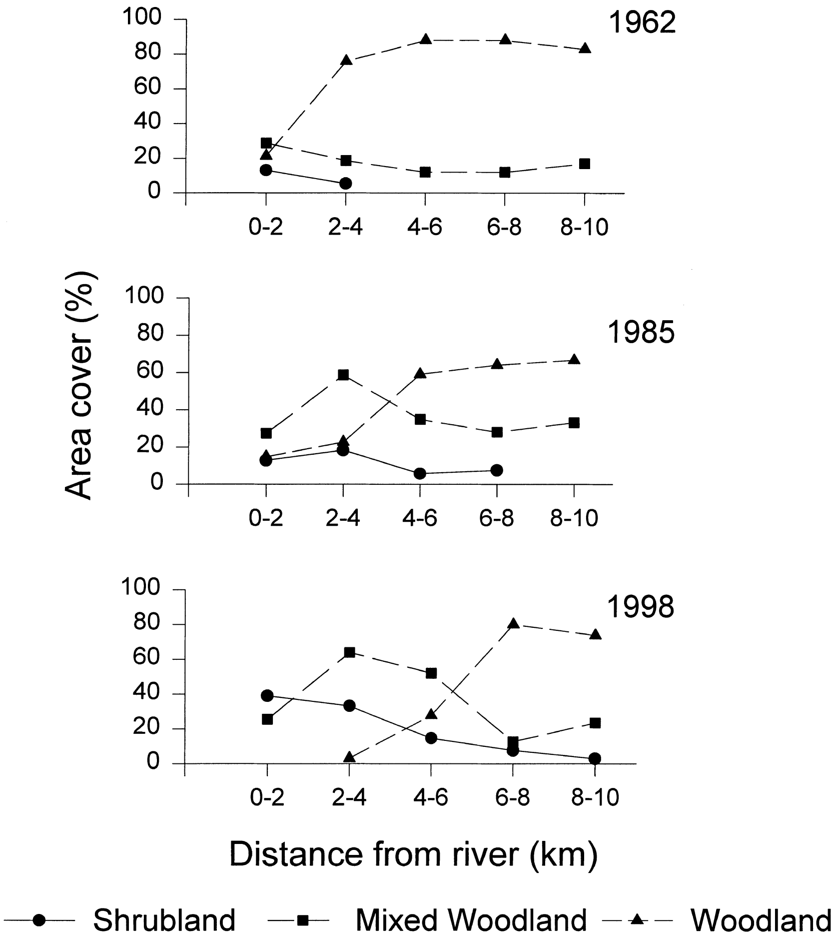

Fig 2 Percentage of land covered by shrubland, mixed woodland and woodland at different distances from the Chobe river in 1962, 1985 and 1998

and all $n = 40$, Fig. 3). Increasing distance from the river related positively to the basal area ($R^2 = 0.66$, $P < 0.0001$, $n = 40$) and to the occurrence of fire scars ($R^2 = 0.56$, $P < 0.0001$, $n = 40$) (Fig. 4). The density of any of the shrubs were not related to distance to the river, either within the shrublands ($P = 0.3$, $P = 0.7$ and $P = 0.1$, for *C. apiculatum*, *C. elaeagnoides* and *C. mossambicense*, respectively) nor within the mixed woodlands ($P = 0.7$, $P = 0.1$ and $P = 0.2$, for *C. apiculatum*, *C. elaeagnoides* and *C. mossambicense*, respectively).

Discussion

This study documents a considerable reduction in woodland in the northern portion of Chobe National Park between 1963 and 1998. While woodland has decreased, mixed woodland and particularly shrubland has increased in the same period. Several potential factors may be responsible for the woodland reduction. First the elephant population in northern Botswana has increased annually by 6% between and 1995 (Gibson *et al.*, 1998). Before 1987, only smaller areas were surveyed. However, in 1963 the elephant population was estimated to be only 500 within 450 km^2 area along the Chobe river (Melton, 1985). This census was done in the peak dry season, when elephants congregate along the Chobe riverfront (Melton, 1985). Our study also shows the heavy browsing impact by elephants in the study area, in particular close to the Chobe river. Thus the pronounced reduction in woodland cover seen closer to the river could be a result of heavy elephant browsing, particularly during the dry season. However, other studies have shown that smaller herbivores, such as impala, may hamper woodland regeneration during herbivore population peaks (Prins & Vanderjeugd, 1993; Barnes, 1996). At the present time there is a large impala population along

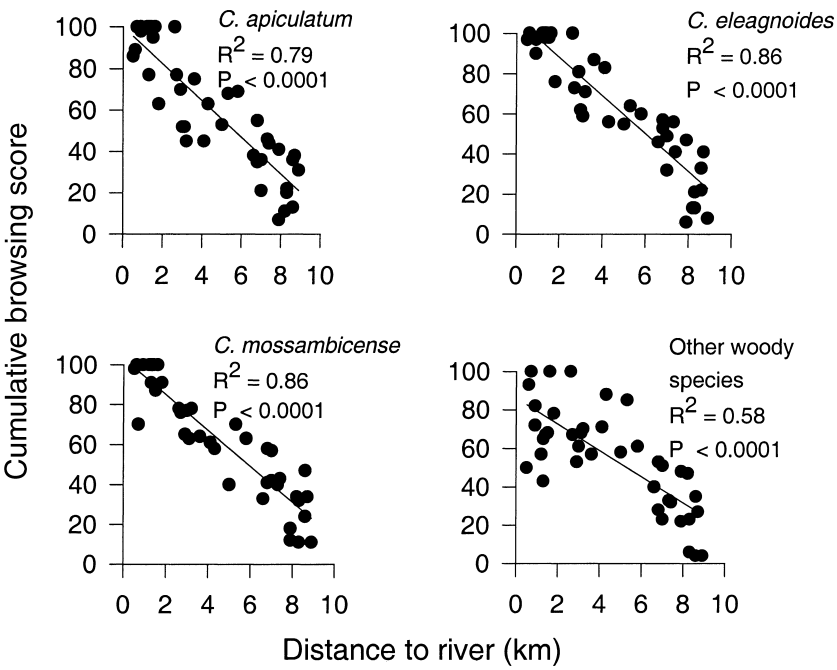

Fig 3 The relationship between cumulative browsing score and distance to Chobe river for *Combretum apiculatum*, *Combretum eleagnoides* and *Combretum mossambicense* and other woody plants combined within shrubland and mixed woodland vegetation types combined (all $n = 40$)

the Chobe riverfront which may also have contributed to the reduction seen in woody cover. In addition, the trampling of regenerating plants by high herbivore numbers during the dry season and seed removal by birds, rodents and primates could all contribute to the low cover closer to the river (Barnes, 1996). The fact that *Baikiea plurijuga*, the main tree species in the woodland, is not used heavily by elephants (Gulinck *et al.*, 1995; Ben-Shahar, 1996; Stokke, 1999) also indicates that elephant browsing alone cannot be responsible for all the observed vegetation changes. Elephants do, however, browse other species in the woodland. Increasing browsing pressure during the study period could potentially open the canopy cover, with an associated increase in grass growth and an increased fire frequency. We have shown that more than 50% of the trees have fire scars within a distance of 7 km from the river. Presently, fire is no longer a dominant factor closer to the river, while browsing is. We do not have temporal fire frequency data from the study period, and it is therefore impossible to assess the importance of fire over different time periods.

In addition to fire and increased herbivory, extended drought periods have occurred throughout Botswana during the 1980s (Ringrose & Matheson, 1987, 1990). A recent study from East Africa has shown that periodic drought may be more important than elephants or fire in determining the regeneration of trees (Vijver *et al.*, 1999). The drought periods in Northern Botswana caused the herbivores to concentrate around water points (Melton, 1985), with resulting heavy impacts on the neighbouring vegetation (Moroka, 1984). This study shows that vegetation changes have been particularly rapid during the period from 1985 to 1998 compared with the period from 1963 to 1985. Thus, it is likely that the drought periods in the 1980s also contributed to the general reduction of cover in the study area.

From 1985 to 1998 there has been a slight increase in woodland beyond 6–8 km from the Chobe river front. The regeneration of tropical trees is commonly episodic, related to factors such as rainfall (Gulinck *et al.*, 1995; Barnes, 1996) and browsing pressure (Caughley, 1976; Prins & Vanderjeugd, 1993). Studies in Zimbabwe have shown that the regeneration of *Baikiaea plurijuga* only occurs during years with above average rainfall (J. Gambiza, pers. comm.). Both 1988 and 1991 had more than 750 mm precipitation (data from Botswana Meteorological Services), which is well above average for the area. The re-establishment of woodland species in these years could possibly account for the increase in woodland further from the river front during later years.

The loss of riparian forest close to the riverfront is also documented in this study. In 1963 a continuous strip of

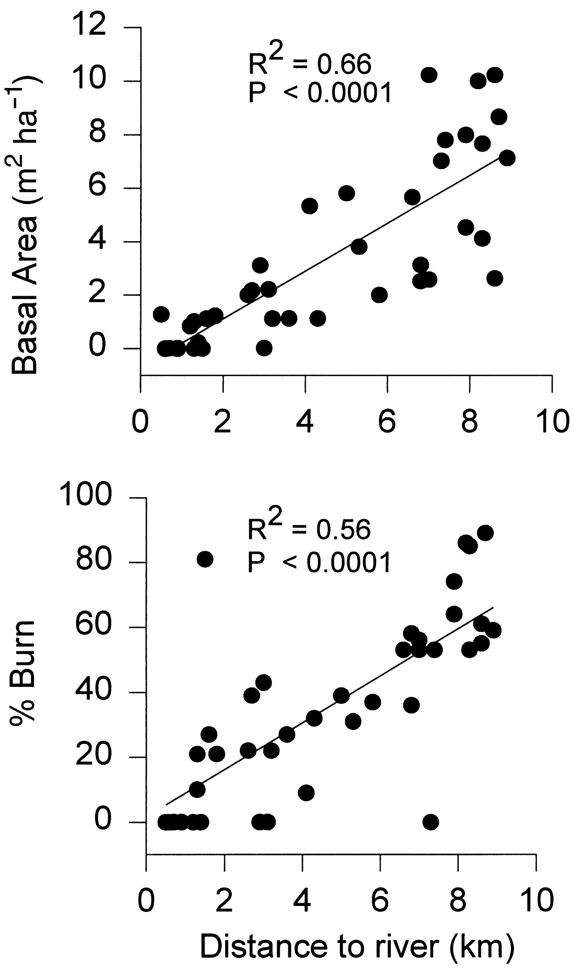

Fig 4 The relationship between basal area ($m^2 ha^{-1}$) and per cent fire scars and distance to Chobe river for shrubland and mixed woodland vegetation types combined (both $n = 40$)

riparian forest was found along the river front. At present only small fragments of this habitat type remain. Many of the larger trees in this vegetation type, such as *Acacia nigrescens* are now dying (pers. obs.). These trees were allowed to mature at the end of the last century, when elephant populations were at an historical low due to hunting (Cormack, 1992). Thus, the scenario seen today is probably more similar to the periods before extensive hunting during the 19th century, when elephant populations were high in Botswana (Campbell, 1990).

Several factors such as drought, fire, natural seeding processes and browsing, appear to be responsible for the dynamics of the vegetation ecology of this region. At the present time, elephant browsing is heavy close to the river, while the majority of trees have fire scars beyond 7–8 km from the river. Thus, our findings suggest a spatial variation in the relative importance and contribution of these factors with distance to water. Additional studies are needed to determine the effect of drought and particularly of smaller herbivores such as impala on the dynamics of the woody vegetation component in northern Botswana.

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