Journal of Environmental Management (1997) **49**, 355–366

Tree loss in the Gonarezhou National Park (Zimbabwe) between 1970 and 1983

C. Tafangenyasha

Gonarezhou National Park, P. Bag 7003, Chiredzi, Zimbabwe

Received 14 *October* 1995; *accepted* 2 *January* 1996

Photopanoramas were used to study tree loss in the Gonarezhou National Park, Zimbabwe, between 1970 and 1983. The tree population declined, because of low recruitment and the loss of trees at 30·1% in 13 years with nearly 2·3% per annum at panorama points not close to water. There is an obvious but not simple relationship between tree mortality rate and temporal changes in elephant density. The association between elephant density and tree mortality is more evident in the 1977–1983 period when, by coincidence, excessive woodland destruction and elephant densities increased, and, in the same period, loss rates were probably exacerbated by dry spells. The main factors influencing tree loss are probably elephant density, fire and droughts. Because fire is probably a secondary factor in the consumption of woody vegetation, elephant density and drought are probably the main factors that influence tree mortality. Other environmental factors that can influence conditions in the Park are highlighted.

Keywords: tree loss, photopanoramas, Gonarezhou National Park, Zimbabwe, elephants.

1. Introduction

The vegetation of the Gonarezhou National Park, which is representative of the semi-arid *Colophospermum mopane* zone (Rattray and Wild, 1955), is protected from over-utilization by large animals especially elephant (*Loxodonta africana* Blumenbach) and is well preserved. However, over-utilized patches do occur at some watering points in the Gonarezhou. Barnes (1983) suggests that high rates of woodland decline in Ruaha National Park are largely caused by high elephant densities and O'Connor (1985) recommends a time span far in excess of 20 years for monitoring woody vegetation. Over the period 1970–1983, a number of photopanoramas were taken around watering points, and some panorama points were established in woodlands not close to water. From these photopanoramas, it became evident that trees were being broken, uprooted and were disappearing. A lack of knowledge about rates of losses and patterns of woodland destruction was identified. A research project was initiated with the aim of

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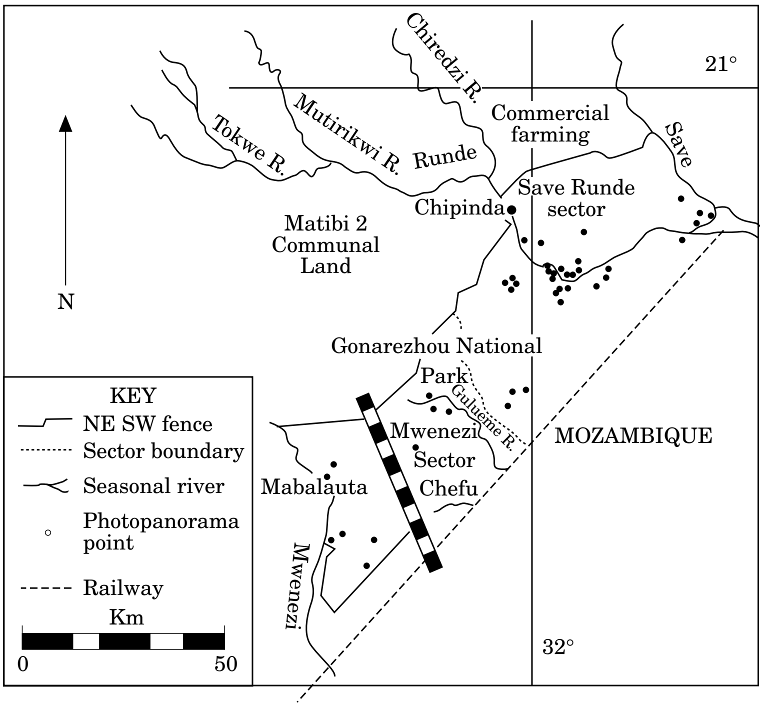

Figure 1. The geographical location of the Gonarezhou National Park showing the positions of the photopanorama points in the Save Runde area.

documenting tree losses on available photopanoramas taken in the Gonarezhou. Using photographs taken by previous research workers, it was possible to establish to what extent the trees around panorama points were disappearing.

In the Gonarezhou, elephants are the predominant large herbivores and aerial surveys were initiated in 1967 to monitor their abundance and distribution. This paper reports on tree loss between 1970 and 1983 and an attempt is made to show its relationship with elephant densities in the Park. The results highlight problems associated with the methodology and provide insight into the extent of woodland decline in the Park. They have guided subsequent management oriented research and provided the basis on which elephants in the Park are managed.

2. Study area

The Gonarezhou National Park covers 5000 km^2 and is situated in the south east of Zimbabwe between latitudes 21° 00′ to 22° 15′ S and longitudes 33° 15′ to 32° 30′ E. Altitude varies between 165 and 575 m a.s.l. The entire Gonarezhou consitutes the catchments of the Guluene, Chefu, Save, Runde and Mwenezi Rivers (Figure 1). The river courses constitute special habitats in their riverine vegetation, surface waters and floodplain. Other natural water resources in the Park are the seasonal pans and dams which hold water to varying durations into the dry season. Broadly, the geology of the Park and the soils derived from it are three major types: (a) the granophyre complex in the north of the Park, (b) basaltic intrusions located in the extreme north west with a smaller intrusion found in the south west corner, and (c) Cretaceous sedimentary series of the cave sand-stone type.

The sand-stone gives rise to deep, highly permeable soils. About five categories of this soil type, based mainly on colour, depth and amount of calcareous material incorporated in the soil (Purves and Fullstone, 1975) are recognizable, and these occupy a large part of the Park on undulating ground. The granophyre, basalt and rhyolite geological types all give rise to shallow lithosolic soils, particularly on upland terrain. They are variable in coloration from dark to reddish brown soils. Soils derived from basalt tend to be heavy textured, their coloration depending on drainage. The granophyre give rise to shallow finely textured sandy loams. Because of relatively high amounts of exchangeable sodium, these soils in depressions tend to be sodic (Purves and Fullstone, 1975). A significant soil type in the Park, on account of its associated vegetation, is the alluvial type; very variable in composition, but generally deep, forming vertisols in places (Purves and Fullstone, 1975). Alluvial soils occur in riverine areas and are most extensively developed on the Save Runde confluence, and along the Mwenezi river flood plains.

The following vegetation types have been recognized in the surveys conducted in the Gonarezhou National Park (Sherry, 1977):

(1) *Colophospermum mopane* woodland
(2) *C. mopane* scrub
(3) *C. mopane*: sandveld ecotone complex
(4) Dry deciduous sandveld woodland and scrub
(5) *Brachystegia glaucescens* woodland
(6) *Julbernadia globiflora* woodland
(7) *Androstachys johnsonni* thicket
(8) *Guibourtia conjugata* woodland
(9) *Guibourtia conjugata* and *Baphia obovata* thicket
(10) *Combretum* bush savanna
(11) *Acacia nigrescens* tree savanna
(12) Riverine and alluvial woodland
(13) *Spirostachys* woodland and *Terminalia prunoides* woodland
(14) *Milletia stuhlmannii* woodland
(15) Rivers with phragmites reed beds and *Ficus capreifolia*
(16) Streams and pans with *Spirostachys africana* characteristic

Low-lying riparian woodland is dominated by *Xanthocercis zambesiaca*, *Spirostachys africana*, *Lonchocarpus capassa*, *Combretum imberbe* and *Cordylia africana* trees. Higher parts of the area north of the Runde river in the broken granophyre terrain, are covered by mixed woodland, often with *Brachystegia glaucescens* as the dominant species, but *Acacia nigrescens*, *A. welwitschii* and *Colophospermum mopane* are common species. On the Cretaceous sands south of the Runde River, dominant species include a variety of tree species and an extensive shrub layer. *Androstachys johnsonnii* occurs on the higher parts of small hills in the neighbourhood of the plateau rim. *Kirkia acuminata* and *Adansonia digitata* are frequent in *Colophospermum mopane* woodland on gravelly basalt. Annual grasses and, in years of high rainfall, forbs dominate the herbaceous layer. The vegetation has largely been modified by large mammals, fire, droughts and human activities. The key large mammals responsible for vegetation change include elephants, hippopotamus (*Hippopotamus amphibus* L.) and impala (*Aepyceros melampus* Lichtenstein). Cultivation has entailed the destruction of large areas of vegetation on

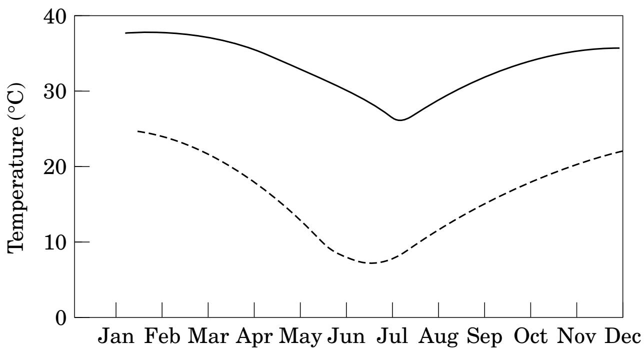

Figure 2. Mean maximum (|—|) and minimum (|- - -|) temperatures at Chipinda, 1976–1983) ($n=12$).

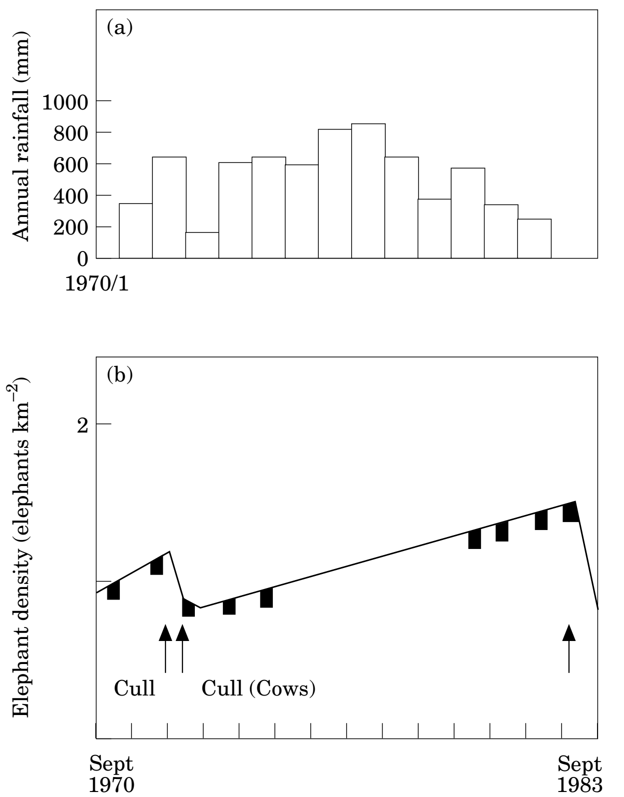

Figure 3. Annual variation in: (a) rainfall (1970–1983 data from Chipinda): and (b) elephant density in the dry season. The elephant density model assumes that population increased at 7% per annum (Hall-Martin, 1980; Barnes, 1983), except when there were culls or droughts (Kerr, 1978). ■ indicates mean elephant density from aerial surveys.

the Save and Runde alluvium. A recent development, bush clearing in anti-tetse fly operations, has modified the vegetation in some areas.

The low lying areas of the Park generally have high temperatures and low rainfall (Figures 2, 3). The high summer temperatures with peaks in the January–February

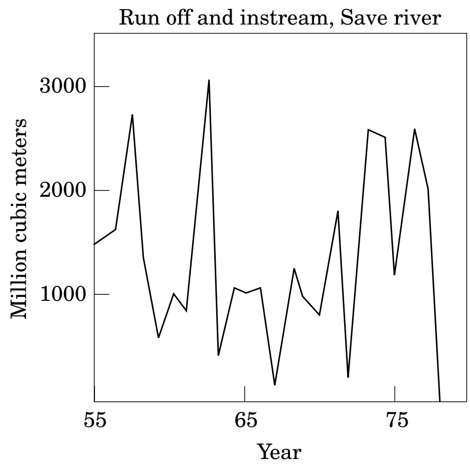

Figure 4. Annual flow of the Save river at the Save Gorge Station (after Magadza *et al*., 1993).

period and the clear skies also induce high evaporation rates, so that effective rainfall is generally lower than the recorded values. On average, in the lowveld, precipitation exceeds evaporation for only about two to two and half months. For most of the year, the area is moisture deficient, except in the deeper horizons of the soil profile. The high summer temperatures (Figure 2) approach the physiological limits of enzyme systems, which are generally set at 42°C to 43°C, and, as a result, thermal refugia become very important at such temperatures: canopy shade for large mammals, pools for aquatic vertebrates such as hippoppotamus (Magadza *et al*., unpublished data). Figure 4 shows records of annual flow of the Save River at the Gorge station and indicates that the river could dry up in some years.

3. Methods

Photopanoramas were established in parts of the Gonarezhou National Park as early as 1966 by A. A. Ferrar. B. Y. Sherry photographed 49 panoroma points in 1970, and, by 1977, more than 50 panoramas had been established. The pre-1977 panoromas were essentially partial panoromas, while attempts were made to convert partial panoramas into full panoramas in the post 1977 period. More panorama points were established during the period between 1977 and 1983 by R. Peek and I. Coulson, although the majority of the panoroma points were not relocated in subsequent years. In 1983, G. Sharp re-photographed 49 points with some new panorama points included, and catalogued all panoramas in two photo-albums. Criteria used in panoroma selection are unknown: although the points are not randomly distributed, they are spread over the distribution of water points, with few points photographed some distance from water points. All 15 points photographed in the Mwenezi sector were close to water. Monitoring the changes in the vegetation at watering points was prompted by the perceived damage by elephants which was occurring at an alarming rate to all major vegetation types but, in particular, in the riverine and alluvial communities.

Usually, black and white photographs were taken at the end of the dry season, using a 35 mm camera with a 50 mm lens, and with the camera mounted on a tripod stand. Full panoramas consisted of eight overlapping photographs, each photograph facing at an angle 30° from the previous one. Positions of photopanorama points were established by realignment with the earlier photographs. For ease of analysis, photographs taken at one point, on one date, were glued together to produce one long photograph. The catalogue of photopanoramas for the Save Runde sector include panorama points photographed in 1970, 1971, 1974, 1975 and 1983. All panorama points located in the Mwenezi sector were photographed in 1970, 1971, 1972, 1975, 1977, 1982 and 1984.

When each photopanorama was compared with the previous photographs of the same point, it was recorded whether each large tree in the earlier photograph was still standing or had fallen over, and, if possible, the species was identified. Wet season photopanoroamas were not used in the analysis of tree loss. The rate of tree loss in the period between successive photographs of a panoroma point was calculated using the log model annual mortality rate formula of Swaine and Lieberman (1987) as used by Dunham (1989). Not all photographs reflected change, and, in these instances, the previous tree count was taken as constant.

The number of large trees of known fate in the earliest photographs of a point was assumed to be equivalent to a Tree Index of 100. In years when a point was re-photographed, the Tree Index was calculated as:

$$I_x = I_{(x-1)} \cdot \frac{N_{(x)}}{N_{(x-1)}}$$

where: I_x = Tree Index when point was photographed for $(x-1)$th time; $N_{(x)}$ = Number of trees still standing when point was photographed for xth time. The index was constant or declined, and, for any point, it was directly related to tree density. To allow comparisons between points, percentage aerial cover around each point was estimated using a grid template superimposed on 1:25 000 aerial photographs taken in 1974 and 1982. The radius of the plot represented by the grid varied from 250 to 500 m, for most points, the radius was 250 m. The pattern of aerial cover of the woody vegetation on aerial photographs when observed under a 3 × magnification stereoscope was simply compared with the grids of various densities and seen which it clearly resembles.

Information on whether or not a panorama point was ravaged by fire was obtained from the fire history records of the Park.

Between September 1970 and October 1983, a total of 11 aerial surveys were made. For the years 1970 to 1972, a Piper Super Cub with a pilot and one observer was used to obtain minimum total counts and distribution data. This method enables a navigator and a minimum of two observers to participate. The surveys were conducted using a randomized systematic sampling method (Norton-Griffiths, 1978). The stratified areas of the Park were flown 100–250 m above ground level and at approximately 185 km/h. All elephants seen were counted and their location was recorded. Species nomenclature follows Drummond (1975) and those names currently in use at the National Herbarium, Harare.

4. Results

In the Mwenezi sector, tree loss near watering points was very variable over the 14-year period. Severe tree loss occurred between 1970 and 1982, during which period losses of 10% to 16% were invariably suffered. However, tree loss which had amounted to 16% in 1970 was reduced 10% between 1971 and 1972. Over the period between

1982 and 1984, tree loss had been reduced to 7%, a marked decline over a 14-year period. Overall tree loss amounted to 62% over a 14-year period, indicating a loss rate of 9% per annum.

Sharp (1985) classified 15 panorama points in the Mwenezi sector into different habitat types and determined trends in tree loss within each habitat type. The following habitat types were recognized:

(1) riparian and alluvial woodland on the Mwenezi floodplain;
(2) artificial pan sites within the mopane woodland and mopane sandveld ecotone;
(3) natural pan sites within the dry deciduous woodland and scrub community; and
(4) *Androstachys johnsonnii* community on granophyre.

Mean tree loss in the four habitat types over the 14-year period was invariably different, 16% (*Androstachys johnsonnii*), 48% (floodplain), 67% (*Colophospermum mopane*) and 13% (sandveld). Annual rates of tree loss were also variable, 1·4% (*Androstachys johnsonnii*), 3·5% (floodplain), 4·7% (mopane) and 1·5% (sandveld).

Sharp (1985) postulated extinction dates for constituent species in each habitat type: 2050 (*Androstachys johnsonnii*), 1998 (floodplain), 1998 (*C. mopane*) and 2050 (sandveld).

Tree loss for all panorama points in the Save Runde sector was 4·7% in the period 1970–1971 and this decreased to 0% in the period 1971–1972. Between 1971 and 1975, tree loss was maintained at between 0 and 2·9%. Tree loss increased from 5·3% to 11.2% during the period 1975–1983. Mean tree loss for all 34 panoroma points studied for 13 years was 16%, with a mean loss rate of 4% per annum. For 13 years, it is estimated that there was a reduction of 30·1% of large trees, with nearly 2·3% per annum in the panorama points not close to water.

Around waterholes in the Save Runde sector, tree mortality is invariably high, and, in the 13 years of study, a reduction of 26% of large trees, with nearly 2% per annum was recorded. This level of woodland destruction is not surprising considering that animal pressure is greatest in the dry weather at watering points. Bromwich (1972) noted a similar reduction at an artificial water point in the Mwenezi sector. At one panorama point, tree loss due to river-bank erosion amounted to 0·2% and this loss was recorded along the southern bank of the Runde river.

In the Save Runde sector, *Colophospermum mopane* contributed disproportionately to the losses, and its loss rate of 2·4% per annum was highest in comparison to other tree species in the study. Tree loss in mopane woodland constituted 61% of the overall losses in panoroma points not close to water. *Brachystegia glaucescens* with loss rates of 1·7% per annum has invariably suffered high losses of large trees. *Acacia tortilis*, *A. sieberana* and *Hyphaene natalensis* are heavily damaged and few trees have disappeared on some photopanoramas. The Runde river with both banks in the Park is a complex mosaic of upper canopy trees, and near the river trees, which include *Adansonia digitata* and mopane, have disappeared in places. *Combretum imberbe*, *Lonchocarpus capassa* and *Xanthocercis zambesiacum* which occur in upper canopy of rivers and pans have suffered a loss rate of 1·2% per annum. There is an apparent lack of recruitment into the tree layer in all tree populations observed in the study and thus tree density declined; constant percentage tree-loss rate implies that absolute tree-loss rate (in trees ha^{-1} yr^{-1}) declined. At four points (photopanoramas 3, 18, 20 and 24) the tree-loss rate was low early in the study and later increased, but generally evidence of changes in tree-loss rates are difficult to attribute to time or elephant density (Figure 5). Mean percentage

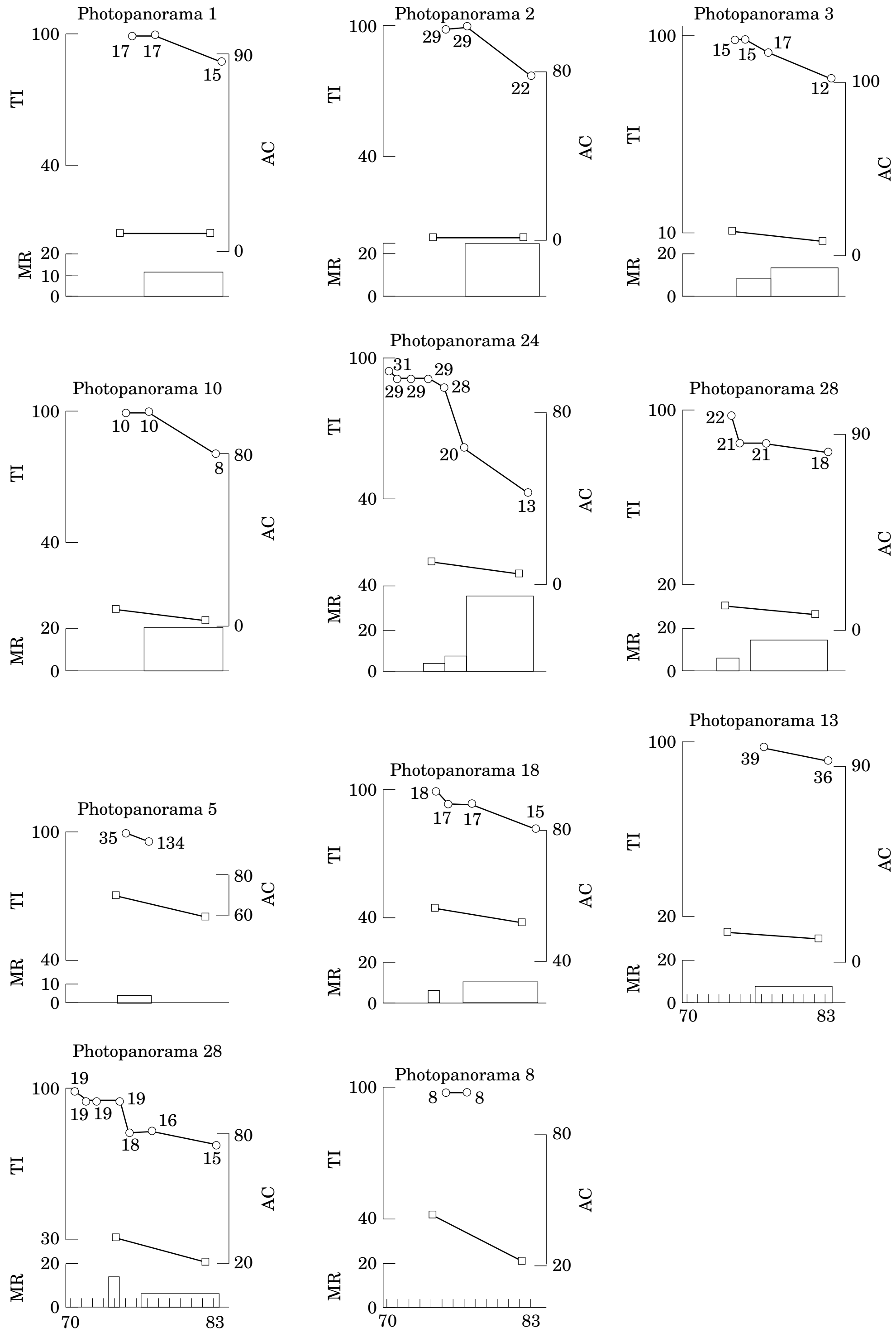

Figure 5. Variation in the Tree Index (○, TI) aerial cover of trees (□, AC in %) and mortality rate (histogram, MR in % year^{-1}) at each photopanorama point.

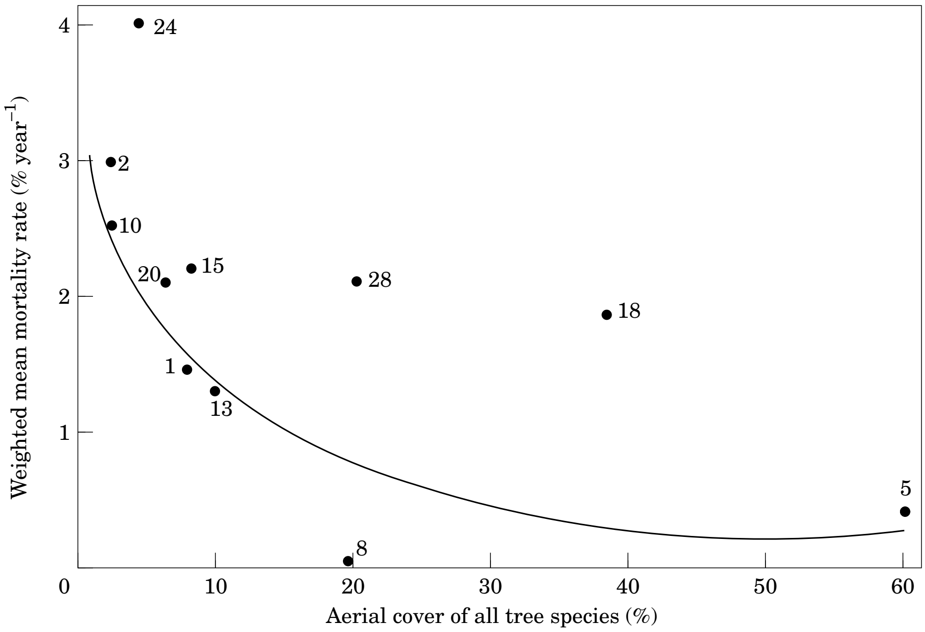

Figure 6. Percentage tree mortality over the entire period for which each photopanorama was monitored was inversely related to the aerial cover of all tree species (a measure of tree density). Mean mortality rate was calculated by weighing percentage mortality rates for each point by the number of years which estimate was calculated. For all points not close to water ($r = -0{\cdot}59$, $P<0{\cdot}1$: percentage mortality rate $= 2{\cdot}51$ (% cover)$^{-0{\cdot}037}$; this curve shown.

tree-loss rate was inversely correlated with tree density (Figure 6); this implies that absolute tree-loss rate was positively correlated with tree density.

5. Discussion

The bulk of the photopanoramas used in this study comprise photographs taken at panorama points near watering points. Martin and Connybeare (1992) felt that photopanoramas were located too close to water in the Gonarezhou to be useful and suggested monitoring in open woodlands, and, if possible, in each vegetation type. However, existing photopanoramas in the Save Runde sector had not been used in the analysis of vegetation change by 1985 (Sharp, 1985), and close examination of these photographs showed they could be useful in monitoring tree-loss. Because some panorama points were established without permanent markers, the numbers of useful panoramas was drastically reduced with a consequent loss of potentially useful information. The establishment of photopanoramas at water points in the Gonarezhou represents the first attempt at the quantification of vegetation change.

The study suggests that tree disappearance is common through most of the wooded areas, but varies in intensity at some localities (Figure 5). Figure 5 also shows that both absolute amount and percentage of the tree loss change as the total amount of vegetation is reduced. For 13 years, it is estimated that there was a reduction of 30·1% of large trees with nearly 2·3% per annum in the panorama points not close to water in the Save Runde sector. This loss compares with a 96% reduction of large trees over a period of 14 years, amounting to nearly 7% per annum in the Serengeti (Lamprey *et al.*, 1967) and 0·9% per annum in the riparian fringe woodland of the Mana Pools National Park (Dunham, 1989). The presence of large numbers of broken and uprooted mopane woodland trees suggests that mopane woodland is mainly selected in preference to other species. Anderson and Walker (1974) have noted a strong selection for mopane in the damage pattern in Sengwa Wildlife Research Area and the Gonarezhou respectively.

Although river-bank erosion is a limited geomorphological phenomenon, it probably accounts for a negligible tree mortality in the Park. Herbivory and droughts are presumably two key factors that can reduce the protective cover of the river-banks that has a stabilizing effect.

There has certainly been fire damage to trees in the past because charred remains are obvious and fires have been recorded as recently as 1983. Fire damage accounts for an immediate death of trees which have been pushed over. Because the perceived effects of fire on broken, ringbarked, bark-stripped or uprooted trees are probably greater than on live standing trees, fire is likely to play a secondary role in vegetation destruction (Laws *et al.*, 1975). Information on whether a panorama point was ravaged by fire was obtained for the Save Runde sector only.

Over the period 1970–1971, six panorama points were burnt. In the same period (1970–1971), three panorama points were repeatedly burnt, and five panorama points were burnt in the period 1972–1974. The worst fire season was in the period 1974–1975, when nearly the whole of the Save Runde area was burnt and only three panorama points were not burnt. Seven panorama points were burnt in the period 1975–1977, and, in a severe burn in the period 1977–1983 that was characterized by a number of separate fires, 16 panorama points were affected by fire damage. From examination of the fire records, it is immediately apparent that no panorama point has escaped fire damage over the 13-year period, and some points have been burnt repeatedly within each photographic period.

The fire management policy for the Park outlines key fire susceptible vegetation communities. Key vegetation communities with low fire tolerance and which represent degraded habitats include the *Brachystegia glaucescens* stand on sands, *Androstachys johnsonnii* stands on slopes of extensive escarpment and granophyre terrain, and *Spirostachys africana* communities on the lowlands of the dissected escarpment. The pattern of change in the Park has been recorded elsewhere, as the elephants over-browse the woodlands, laying waste the mature trees, there is an increase in the woody vegetation and grass cover allowing fires to become progressively more intense with the resultant lowering of species diversity (Laws *et al.*, 1975). The vegetation in the Park is predominantly shrubland, although the process of woodland conversion to grassland is slow.

The majority of degraded sites were formerly cultivated, and cover of woody plants has increased since abandonment. Bush clearing in anti-tsetse fly operations has modified the vegetation in some places. Only two vegetation types (*Colophospermum mopane-Spirostachys africana* and *Androstachys johnsonnii*) have become degraded since the proclamation of the Gonarezhou as a protected area in 1968 (O'Connor and Campbell, 1986 a,b). Since 1968, the Park has been protected from fire, although some fires are difficult to control.

It is unclear to what extent termite *Hodotermes mossambicus* Hagen activity has influenced loss of trees, although, at Mana, they are known to be competitive consumers of vegetation (Dunham, 1989). No significant termite mound construction was evident in the panorama points throughout the study period.

There is an obvious, but not simple, relationship between tree-loss mortality rate and temporal changes in elephant density. The association between elephant density and tree-loss mortality rate is more evident in the 1975–1983 period because elephant density reached a peak during this time and widespread tree destruction is recorded in this period. Mean percentage tree loss in the period 1970–1971 was 4·7% and this was reduced to 0–2·9% in the period 1971–1975 while in the period 1975–1983 the loss increased from 5·3 to 11·2% suggesting a coincidence in elephant density and excessive woodland destruction which reached a peak during this period, the time when elephant density was greatest. Loss rates of trees were probably exacerbated by dry spells between 1977 and 1983 during which a severe drought was experienced in 1983 (Figure 2). Wing and Buss (1970) and Field (1971) suggest that there is a decrease in browsing with an increase in rainfall, and an increase in tree mortality is likely during drought years. Only by observation over a long period could some of the possible effects of elephant density be proved or disproved, and this observation requires increasing photo-coverage of panorama points not close to water.

Dry season elephant densities in the Gonarezhou increased from 0·95 elephants per square kilometre in 1970 to 1·2 per square kilometre in 1972. Since a major cull in 1972, aerial surveys have shown dry season densities which varied from 0·85 elephant per square kilometre in 1972 to 0·9 square kilometre in 1974. From 1980, elephant increased from 0·9 square kilometre to 1·46 per square kilometre, and, following a major population reduction in the whole Park of 1010 elephant in 1983, densities dropped markedly to 0·99 elephant per square kilometre. The recorded densities are high for a semi-arid environment such as the Gonarezhou (Eltringham, 1977; Cumming, 1981). However, these densities have been partially accommodated by the seasonal shifts in distribution: during the wet season, the population is distributed throughout the Park, but water supplies in the Central Guluene-Chefu area dry up in the dry season and food supplies diminish drastically. Elephants are therefore forced to move towards permanent water, largely along the Save, Runde Mwenezi rivers, resulting in marked concentration in these areas.

Several studies (e.g. Bromwich, 1972; Anderson and Walker, 1974; Cumming, 1981; Barnes, 1983) have reported elephant damage on woody species, and that, in combination with other factors such as insect and fungal activity, a tree's life is shortened. Elephants in the Gonarezhou are more important as direct and indirect agents of tree mortality, so that tree mortality may decline as a result of drastic reductions in the elephant population. Thus, relative abundance and distribution of elephants have provided a basis for management decisions in the Park. Elephant densities elsewhere in Africa average 1·5 km^{-2}, ranging from 0·1 to 5·0 km^{-2} (Eltringham, 1977).

The inherent feature in the river systems of the Park demonstrated for the Save River the variability in flood peaks, and therefore extent of flooded areas at the Save Runde confluence. These are illustrated in Figure 3, where it is apparent that flow records indicate that flooding failure would have occurred at least three times between 1959 and 1977, and the impact on riparian communities has been difficult to quantify, although this impact is likely to lead to an ecological succession process of a more arid environment.

I am greatly indebted to previous research workers in the Gonarezhou for taking the photo-panoramas used in this study.

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