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Full Length Research Paper

Elephant damage to *Sclerocarya birrea* on different landscapes

M. Q. Seloana[1]*, J. W. Kruger[2], M. J. Potgieter[1] and J. J. Jordaan[1]

[1]Department of Biodiversity, University of Limpopo, P. O. Box 1106, Sovenga, 0727, South Africa.
[2]Department of Economic Development, Environment and Tourism, Private Bag X 9484, Polokwane, 0700, Pretoria, South Africa.

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The African elephant (*Loxodonta africana* Blumenbach) is a keystone species and ecosystem engineer. Elephants can cause serious damage to important trees, with only certain species being targeted such as Marula (*Sclerocarya birrea* A. Rich. Hoscht). High levels of elephant utilization may to some extent, compromise the viability of some woody plant populations leading to vegetation changes coupled with a possible loss of species diversity and/or structural diversity. In order to quantify their effect a study was initiated in 2014 to investigate their effect on tree height, degree of branch damage, the extent of debarking, and degree of stem damage. This was done within elephant's frequently and non–frequently used sites, and a neighbouring enclosure (control site). One hundred and fifty (50 per site) mature *S. birrea* trees were randomly selected within each site. Tree height was recorded using clinometers, degree of branch damage, extent of debarking (circumference debarked using different percentages of intensity) and degree of stem damage were assessed using different categories. Results indicated that the type elephant damage in both the frequently and non–frequently used sites was different, varied in intensity. A high proportion of Marula trees had been damaged. The size distributions of the trees showed that there was no regeneration. Furthermore, this study also demonstrated that elephants are able to damage Marula trees in several ways, the most destructive being bark stripping and pushing over trees. It is concluded that elephant impact is a powerful mechanism in shaping the structure and composition of Marula woodlands in the Atherstone Collaborative Nature Reserve. The findings of this study provide valuable baseline data and acts as a starting point for the introduction of adaptive management principles in small savanna reserves. This can be achieved by an intensive management programme responding to slight changes in the vegetation and would necessarily involve controlling elephant numbers.

Key words: Crown diameter, damage, elephant, herbivory, marula.

INTRODUCTION

A home range of an animal can be defined as the total area occupied by an individual or group (Schindler, 2005). Habitat diversity in the landscape will influence the location and size of an elephant home range (Okello et al., 2015). Home ranges of elephants in the Atherstone Collaborative Nature Reserve have diversity of habitats, dominated by bushland, woodland and grassland. Elephants roam the landscapes utilizing different habitats and its resources that meet their needs and enhance their survival (Harris et al., 2008). Okello et al. (2015) further indicated that within these broad habitats, different vegetation structures occur, which differ in woody plant density and composition. These different habitats provide diverse resource types needed for elephant survival. Such areas become their core use home range and elephants seem to show preference for such landscapes. Elephants expand their home range in the wet season to find suitable forage, and concentrate near water points in the dry season in regions where water availability is highly seasonal (Okello et al., 2015).

Habitat characteristics and resources within them can determine level of preference and use of different habitats. The level of impact of elephant densities is governed by elephant feeding behavior co–occurring with other ecological and environmental factors (Ferguson, 2014). The effect of herbivory on woody plants depend on the intensity and frequency of damage, plant phenological, resource relationships at the time of herbivory, plant tissue(s) removed (Clegg, 2010), the availability of resources in the environment to support regrowth, and the browsing history of the plant (Gadd et al., 2001). The outcome of herbivore impact on a particular woody species depends on the nature of the damage, the ability of the plant to recover, its demography and role that it plays in a plant community (De Boer, 2015).

Sclerocarya birrea subspecies *caffra* (Sond.) Kokwaro, also known as Marula is highly selected by the African elephant (*Loxodonta africana* Blumenbach) (Shannon et al., 2008), and hence heavily utilized (Jacobs and Biggs, 2001). The repeated browsing by elephants causes serious damage through breaking and removing of branches, and by preventing or reducing recruitment and regeneration (Balfour et al., 2007). However, *S. birrea* trees are resilient to most types of damage (Vogel et al., 2014). They can resprout from the base or epicormically if toppled (i.e. pushed over; the roots can either remain in the soil or the tree can be uprooted to varying degrees), or if the canopy is broken (Jacobs and Biggs, 2002). Hence, it is expected that *S. birrea* trees are able to sustain relatively high levels of damage before adults die (Vogel et al., 2014). Debarking depends on the ease with which bark can be separated from the underlying wood (Landman et al., 2007). Species with single stems and whose bark has to be chiselled off rather than stripped (e.g. *S. birrea*) can eventually be ring barked, while species with more than one main stem, but whose bark otherwise strips easily, can usually not be debarked (e.g. *A. erubescens*) (Loarie et al., 2009). The ease with which Marula trees can be debarked by elephants could ultimatey lead to the mortality of the Marula tree population at the ACNR. It is thus recommended that measures be implemented to protect Marula trees from being debarked. These could be in the form of laying stones around the stem to restrict elephants from coming in contact with the trees. This method has been successfully used to prevent debarking by elephants in the Addo Elephant National Park (Lombard et al., 2001). During 1994, 20 elephants were introduced to the ACNR. According to aerial and ground surveys conducted during 2015, all indications are that elephant numbers are in the vicinity of 106 animals. The total stocking rate equates to 10.35 ha/LSU, with the stocking rate for the grazing component 14.14 ha/LSU, and the number of browser units at 6.19 BU/100 ha. This suggests that the carrying capacity for elephants at the ACNR has been exceeded by far. Reserve management is furthermore of the opinion that the large elephant number has had a significant ecological impact on the vegetation composition of the reserve. This has led to large–scale changes in the demographic structure of Marula, mainly characterized by a reduction in the number of larger trees (Kerley et al., 2008). For the ACNR a much lower portion ranging between 6 and 8% of the total biomass is recommended by LEDET (Kruger, 2013).

The aim of this study was to investigate and compare the damage by elephants to Marula trees occurring in different landscapes in the ACNR, in order to obtain a detailed assessment of the current Marula population status in the reserve. The damage was investigated in terms of: (a) height of damage, (b) branch herbivory, (c) debarking damage, (d) stem damage and uprooting by elephants. The population structure of Marula on the reserve proved to be unstable. Due to the fact that no regeneration of Marula trees is evident, the current generation of Marula trees is under severe pressure from a too large population of elephants. Such degradation could lead to a loss in ecosystem function, which not only implies a loss in ecosystem productivity and resilience, but also the need for ecosystem restoration.

MATERIALS AND METHODS

Study area

The Atherstone Collaborative Nature Reserve (24˚34.491'S

*Corresponding author. E-mail: queenseloane@gmail.com. Tel: 078 073 2745.

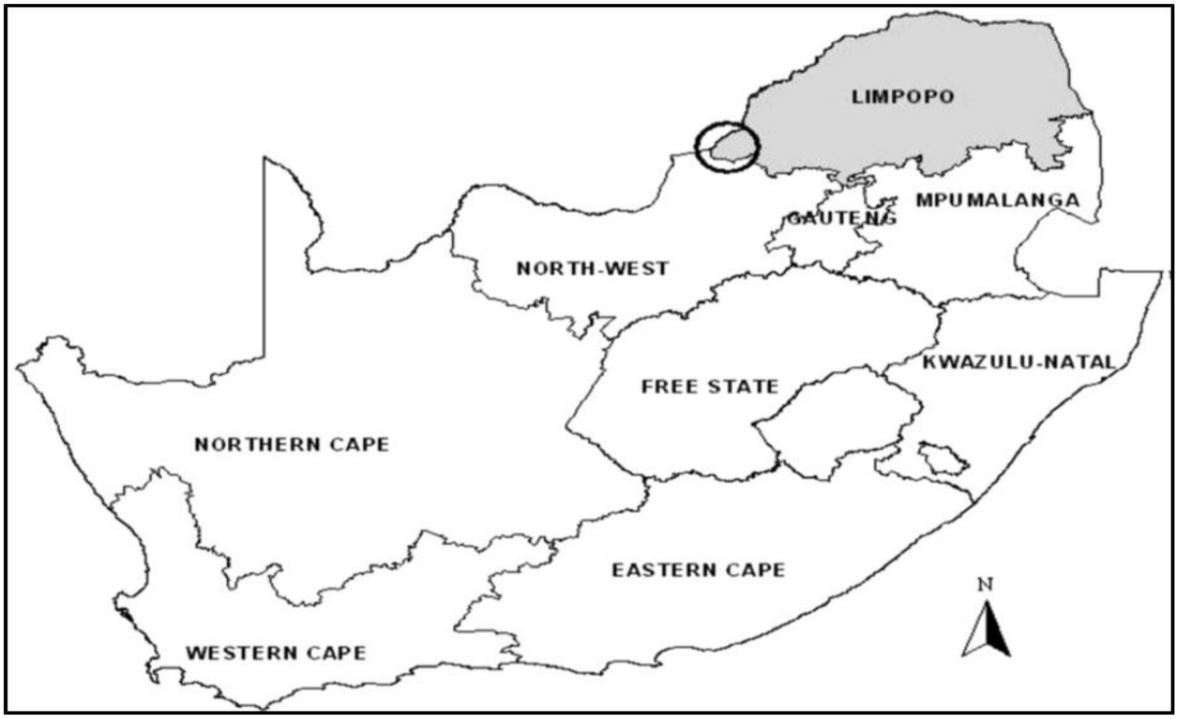

Figure 1. Location (circled) of the Thabazimbi District in the Limpopo Province of South Africa (Marnewick et al., 2008).

and 26˚47.11'E) is situated in the Thabazimbi District of the Limpopo Province's Bushveld Region in South Africa (Figure 1). The reserve covers an area of approximately 22688,163 ha (Pretorius, 2011). Vegetation and landscape features vary from tall open woodland to low woodland. The study commenced in May to December. The study was conducted within three areas (Figure 2): the Mixed Bushveld and Turf Thornveld veld types, which dominates the reserve, and the Marula camp and Goedgewag area (an enclosure).

Western Sandy Bushveld (Figure 3) varies from tall open woodland to low woodland with broad–leaved and microphyllous tree species being prominent (Mucina and Rutherford, 2006). The Vegetation Unit was further devided into Mixed Bushveld and Turf Thornveld (Acocks, 1954), in an area that was classified by Pauw (1988) as *Grewia bicolor – Combretum apiculatum* Short Open Tree Veld. This veld type was again was reclassified in 2004 by De Klerk (2004) as Red Bushwillow–veld. Dominant tree species include *A. erubescens* on flat areas, *Combretum apiculatum* on shallow soils of gravelly upland sites and *Terminalia sericea* on deep sands. Other tree and shrub species include; *Acacia erioloba* (E. Mey.), *A. nigrescens* and *Sclerocarya birrea* (tall trees); *A. mellifera* subsp. *detinens, A. nilotica* and *Combretum zeyheri* (small trees); *C. hereroense, Euclea undulata* and *Coptosperma supra–axillare* (tall shrubs); and *Clerodendrum ternatum, Indigofera filipes* and *Justicia flava* (low shrubs). The field layer comprises grass species such as *Anthephora pubescens, Digitaria eriantha* subsp. *eriantha*, *Eragrostis pallens, E. rigidior* and *Schmidtia pappophoroides*. Herbs that occur in the vegetation include; *Blepharis integrifolia, Chamaecrista absus, Evolvulus alsinoides* and *Geigeria burkei* (Mucina and Rutherford, 2006). *Sclerocarya birrea* stand out in this veld type, with a number of large trees towering above other trees.

They give a special character to this veld type, but are poorly represented (Mucina and Rutherford, 2006).

The Marula camp and Goedgewagt enclosure is Western Sandy Bushveld (Mucina and Rutherford, 2006). The Goedgewagt is an area outside the reserve which mainly caters for livestock, the Marula trees found in the area are not damaged, and it was selected together with Marula camp as a way of comparison measure between the different landscapes. The enclosure is part of the bigger *Combretum apiculatum*/*S. birrea* veld type. The only animals that can get access to the Marula Camp are Vervet monkeys (*Cercopithecus aethiops* Linnaeus) and warthogs (*Phacochoerus aethiopicus* Pallas). Frequently used sites can be defined as areas that become elephant's core use as seem to show preference for such landscapes. So, habitat characteristics and resources within them can determine level of preference. Non–frequently used sites are defined as those areas that are not used more frequently as other areas.

Data collection

One hundred and fifty mature Marula trees were randomly selected, with 50 each in the three study areas. The following data was collected under damage classification:

i) Tree height was recorded, determined by measuring it with a 2 m survey clinometer, using the following height classes: 8–10, 10–12, 12–14, 14–16, and 16–18 m. Height was then totalled and expressed in percentage.
ii) Degree of branch damage (Figure 4A) was assessed, using five categories: 1 = no utilization, 2 = minor utilization (a few minor branches broken), 3 = moderate utilization (many minor branches broken), 4 = high utilization (main branches broken), and 5 = main

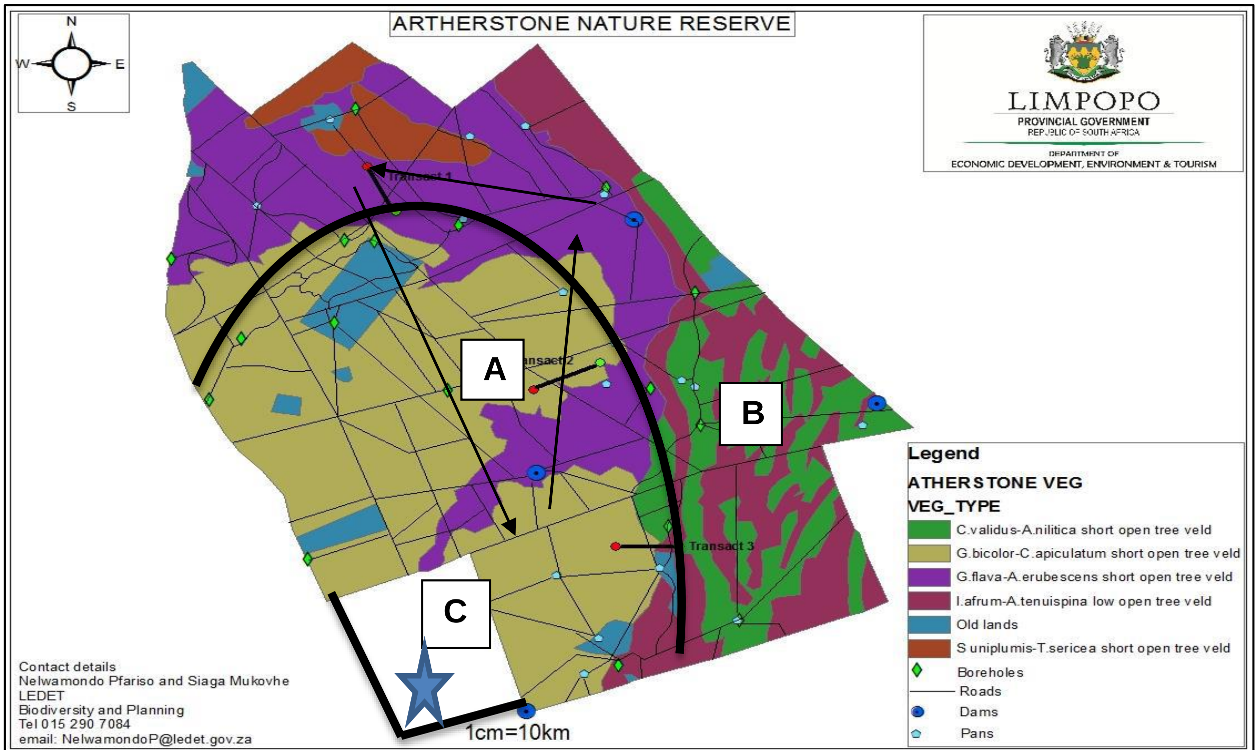

Figure 2. Vegetation map indicating: (A) the frequently used site, (B) non–frequently used site, and (C) the enclosure (Marula camp and Goedgewagt (blue star)) at the Atherstone Collaborative Nature Reserve (Nelwamondo, 2016).

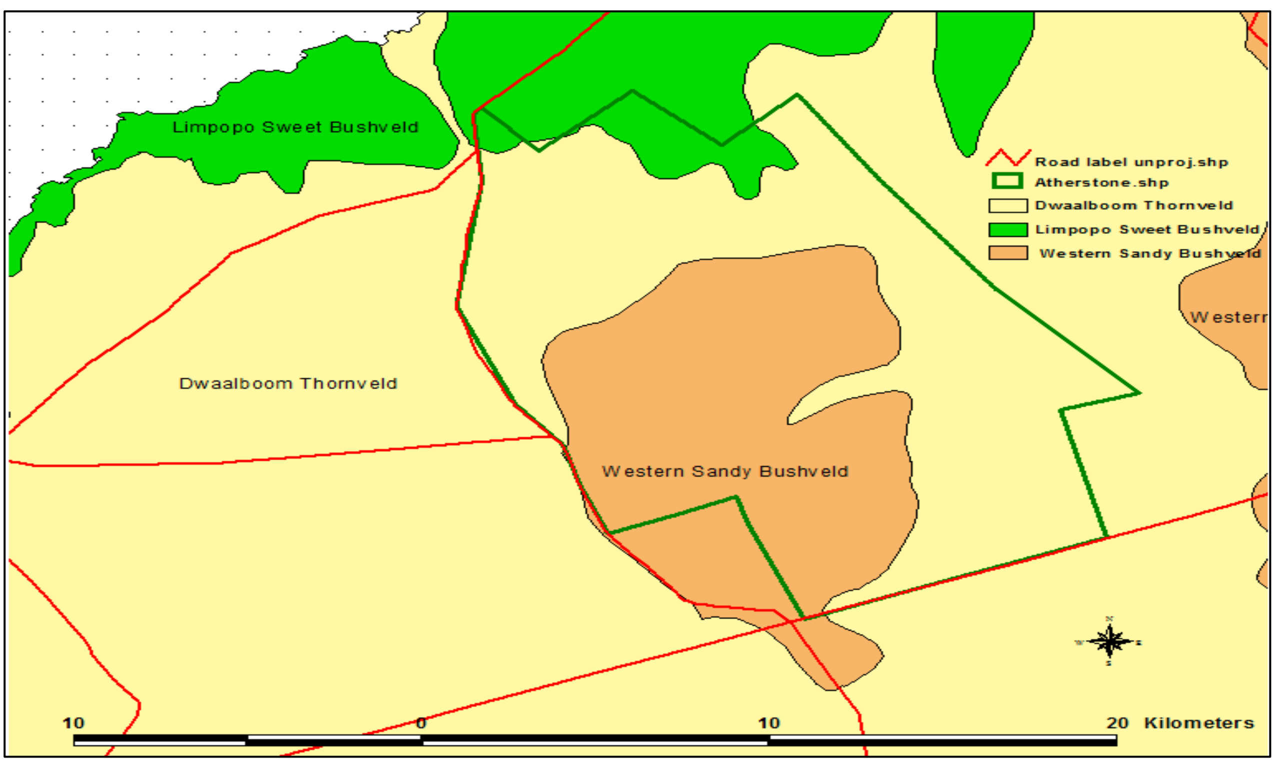

Figure 3. Vegetation of Atherstone Collaborative Nature Reserve (Kruger, 2013).

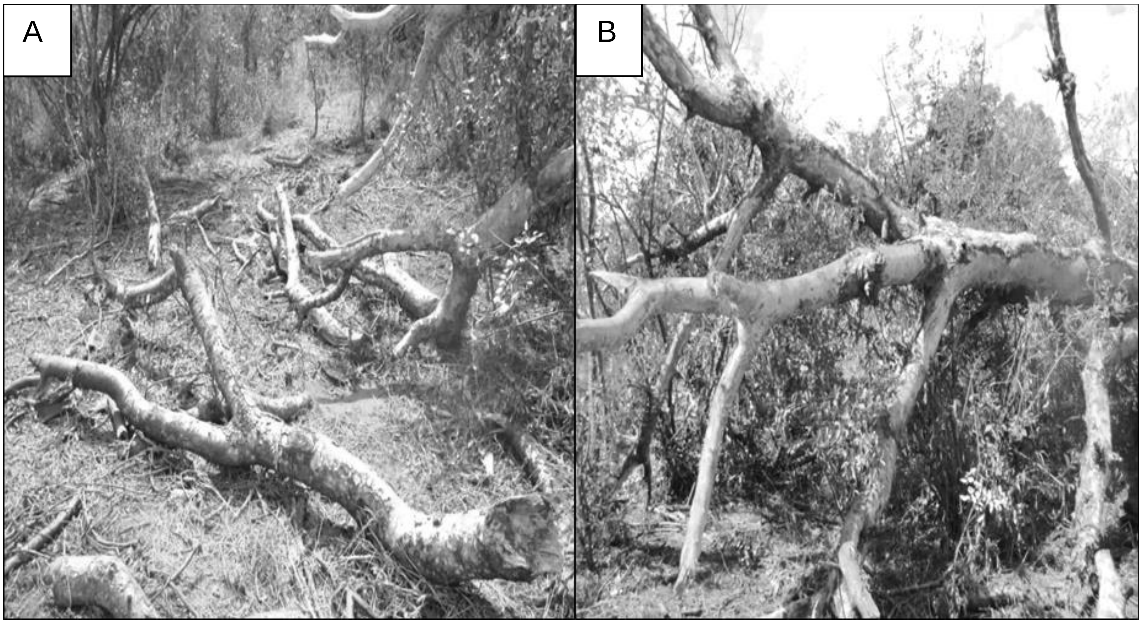

Figure 4. Marula tree damage as a result of elephant feeding in the Atherstone Collaborative Nature Reserve (A) branch damage and (B) debarking damage.

stem utilization (main meristem broken off).

iii) The extent of debarking (Figure 4B) focused on debarking only (focusing on the main stem) and was evaluated using five categories: 1 = no bark removal, 2 = 1–25% of circumference debarked, 3 = 25–50% debarked, 4 = 50–75% debarked and 5 = 75–100% debarked.

iv) Degree of stem damage was assessed (the degree of the stem damage mainly focused on the intensity of the damage), using six categories: 1 = no damage, 2 = main stem completely ring-barked, 3 = whole tree pushed over, main stem broken but still partly attached, 4 = whole tree uprooted, 5 = whole tree pushed over, main stem still intact and 6 = canopy and one of main stems removed.

v) Feeding modes whereby the main stem was pushed over or broken was considered to represent 100% damage. Uprooting events in which all the stems were removed or flattened were also classified as 100% damage. Damage by factors other than elephant (other large mammalian browsers such as giraffe or old age, disease or lightning) was classified as unknown damage in accordance with Ben–Shahar (1993).

Data analysis

Data were analysed via a two–tailed t–test for independent samples, using SPSS software (SPSS, 2013). The total numbers of counts per category were compared.

RESULTS

Height

The results show no significant difference in tree height between frequently and non–frequently used sites and the enclosure. Only mature trees occurred at all three sites. The average tree height in the non–frequently used site was 12.50 m, compared to 11.58 m in the frequently used site, while in the enclosure, it was 12.38 m. According to Figure 5, 45% of the frequently used site trees occurred in the 8 to 10 m height class, 32% in the 10 to 12 m and 23% in the 14 to 16 m height class in the frequently used site. In the non–frequently used site, 25% of the trees occurred in the 8 to 10 m height class, whereas 31% in the 10 to 12 m and 44% in the 14 to 16 m height class. In the enclosure, 25% of the trees occurred in the 8 to 10 m height class, whereas 36% occurred in the 10 to 12 m, and 34% in the 14 to 16 m height class. No trees lower than 8 m and between 12 to 14 m were encountered.

Branch damage

In terms of branch damage, a significant difference ($p<0.05$, t–value = -4.748, df=88.215) was found between frequently used sites (56%, n= 50) and non–frequently used sites (37.2%, n= 50) (Table 1). Elephant impact on branches seemed to decrease with increases in tree height. In the frequently used site, only 6% of Marula trees were not damaged, whereas 24% of Marula trees were not damaged in the non–frequently used site. No damage occurred in the enclosure. In the frequently used site, 42% of Marula trees were classified as those that

Table 1. Data analysis (SPSS: 2–tailed t–test); frequently and non–frequently used sites and in the enclosure.

Type of damage	Sites compared	Mean difference	Interval		n	T-value	2-tailed significance (P-value)
			Upper	Lower			
Tree height	Frequently used site vs non frequently used sites	-0.92000	-0.16272	-1.67728	100	-2.411	0.018
	Frequently used site vs enclosure	0.80000	1.55864	0.04136	100	2.093	0.039
	Non–frequently used site vs enclosure	-0.12000	0.67609	-0.91609	100	-0.299	0.765
Branch damage	Frequently used site vs non–frequently used sites	-0.94000	-0.54659	-1.33341	100	-4.748	0.000*
	Frequently used site vs enclosure	2.80000	3.12480	2.47520	100	17.324	0.000*
	Non–frequently used site vs enclosure	1.86000	2.08974	1.63026	100	16.270	0.000*
Debarking damage	Frequently used site vs non–frequently used sites	-.04000	0.45169	-0.53169	100	-0.161	0.872
	Frequently used site vs enclosure	3.68000	4.02660	3.33340	100	21.337	0.000*
	Non–frequently used site vs enclosure	3.64000	3.99746	3.28254	100	20.463	0.000*
Stem damage and uprooting	Frequently used site vs non–frequently used sites	-.80000	-0.29647	-1.30353	100	-3.176	0.002
	Frequently used site vs enclosure	2.24000	2.71541	1.76459	100	9.468	0.000*
	Non–frequently used site vs enclosure	1.44000	1.61377	1.26623	100	16.653	0.000*

* = Significant at P≤ 0.05.

had minor branch utilization, 79% as moderate branch utilization and 75% as high branch utilization, respectively, compared to 58% of Marula trees within minor branch utilization , 21% moderate branch utilization, and 25% high branch utilization classes in the non–frequently used site (Figure 6).

Debarking damage

In terms of debarking damage, a significant difference ($p<0.05$, t–value = -.161, df=97.907) was found between frequently used sites (73.6%, n= 50) and non–frequently used sites (72.8%, n= 50) (Table 1). In total, including frequently and non–frequently used sites, 96% of all the surveyed Marula trees had debarking damage (Figure 7), while no damage occurred in the enclosure. Of these, more than 50% had undergone major damage in the form of ringbarking. Only 4% of Marula trees had no bark removal in the frequently used site, in the non–frequently used site all recorded trees were debarked. In the minor debarking damage by elephants, while major frequently used site, 33% of surveyed trees experienced damage was encountered on 52% of the surveyed trees. In the non–frequently used site, 67% of surveyed trees had minor debarking damage, while major debarking damage was observed on 52% of trees.

Stem damage

In terms of stem damage, a significant difference ($p<0.05$, t–value = -3.176, df=61.864) was found between frequently used sites (37.7%, n= 50) and non–frequently used sites (28.8%, n= 50) (Table 1). In the frequently used site, 23% of Marula trees were recorded with no stem damage, 43% of trees were dead but the main stem was still intact, 11% of trees were pushed over, while all trees were pushed over but main stem was still intact, 50% of trees had their canopy or one of the main stem removed and all trees were uprooted. In the non–frequently used site, Marula trees were all damaged, 57% of trees were dead but the main stem was still intact, 89% of trees were pushed over, while none of the trees were

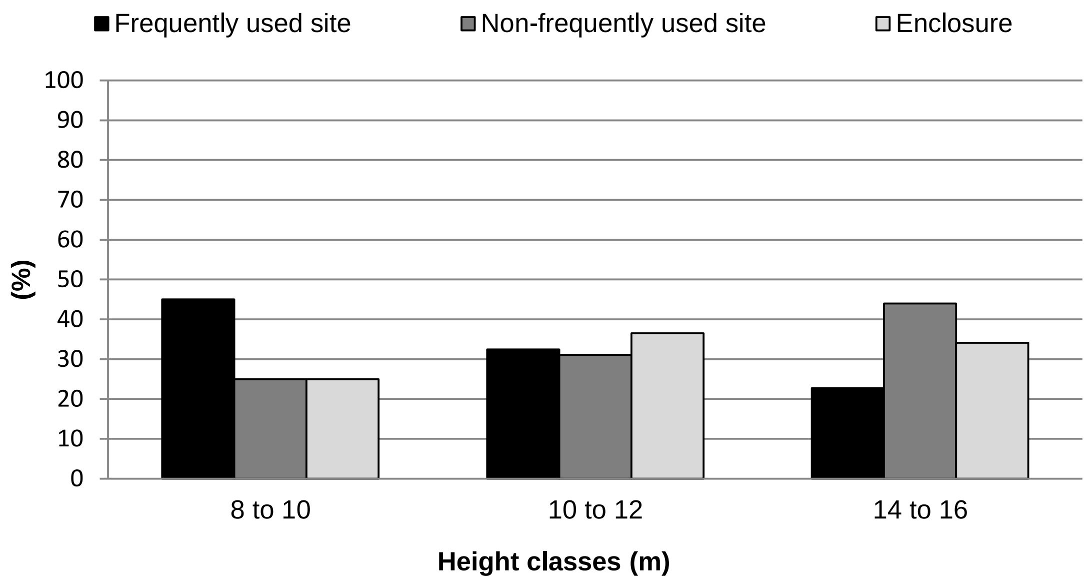

Figure 5. The proportional distribution of Marula tree heights across the three sampling sites.

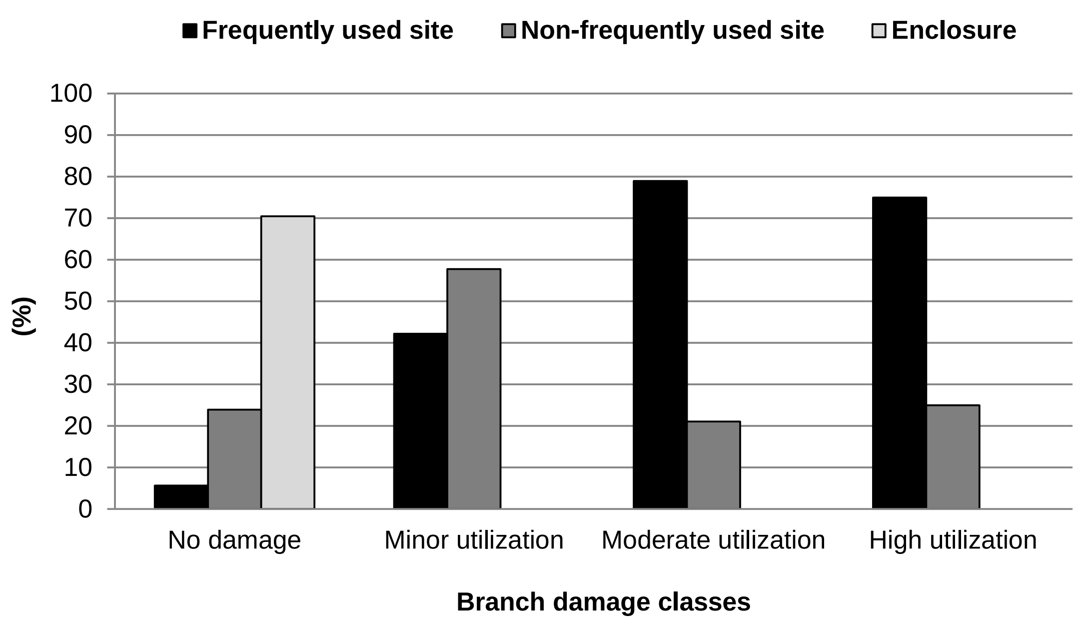

Figure 6. The proportional distribution of Marula tree branch damage across the three sampling sites.

pushed over but main stem was still intact, 50% of trees had their canopy or one of the main stem removed and none of the trees were uprooted. In the enclosure, the trees were not affected by elephants (Figure 8).

DISCUSSION

The study aimed at investigating the interactions between elephants and vegetation; assess the long–term impact of elephant damage on selected vegetation types, and extent of damage on certain species for browse, such as *S. birrea*. The results revealed that sites with high elephant density had been detrimentally impacted with regard to the height of Marula trees. Thus it came as no surprise that distributional differences existed on tree height on both the frequently and non–frequently used sites, and as expected in the enclosure. Teren and

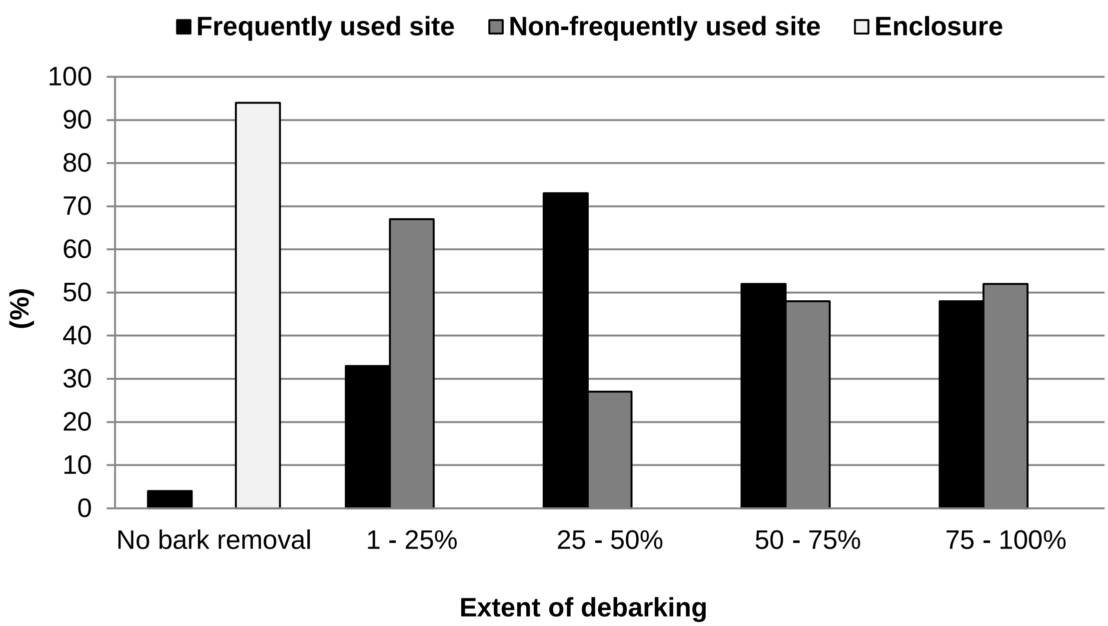

Figure 7. The proportional distribution of Marula tree extent of debarking across the three sampling sites.

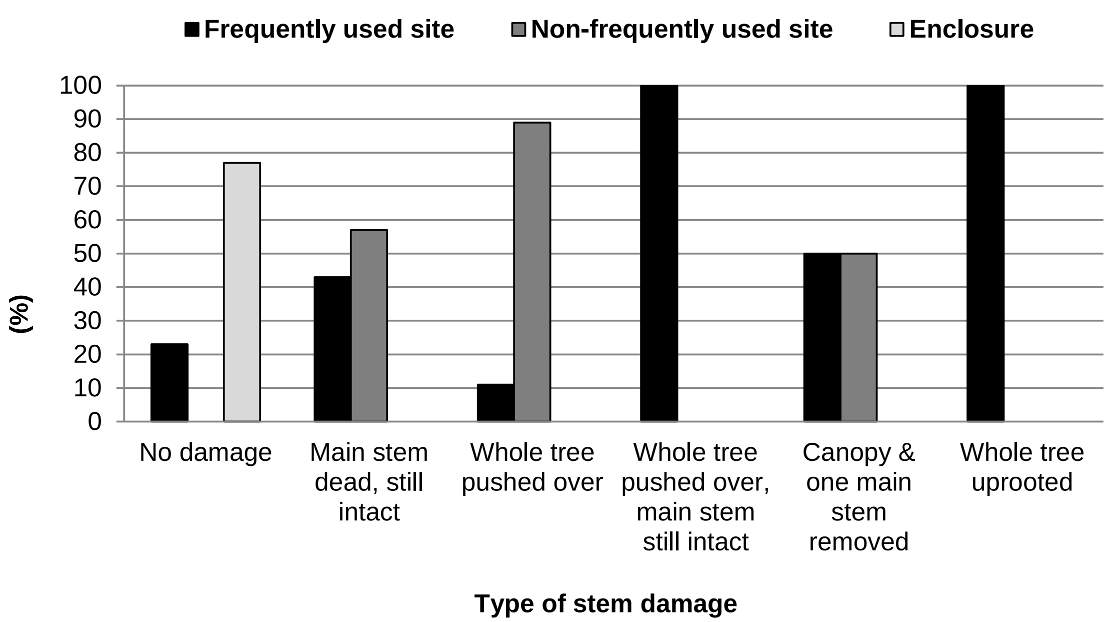

Figure 8. The proportional distribution of Marula tree stem damage across the three sampling sites.

Owen–Smith (2010) speculated that this could be because these Marula trees have outgrown the size threshold for pollarding by elephants. The absence of Marula trees in lower tree strata (8 m and lower) indicated that either little or no regeneration of the Marula population occurred during the last decade or that these strata of Marula trees are being targeted by elephants. This needs further investigation. It is therefore predicted that further loss of individuals in the 8 to 10 m height classes is to increase significantly.

Branch damage appeared to be lesser on taller trees, where elephants could not reach, which explains the low percentage recorded in all the branch damage class which showed a decreasing trend. Where trees were shorter, more branches appeared to be broken, as elephants attempted to reach utilizable plant parts, which explains a higher percentage recorded on minor utilization class within the non–frequently used site. Overall, elephants did not target Marula tree branches *per se*, but that the upper parts of trees were mostly targeted when fruits were available or where leaves were out of reach, which explains the high percentage recorded (on high utilization class). An important aspect is the time during which browsing occurs. This is important because it determines the plant responses to browsing (Gadd et al., 2001). None of the Marula trees were observed to have died as a result of branches being broken. Breaking of branches or harvesting of leaves is considered much less damaging to a plant.

Debarking damage

The study has indicated that almost all trees that were surveyed were ringbarked (70%+) irrespective of where they occurred (frequently and non–frequently used site). Elephants did not restrict ringbarking to any specific area in the reserve (excluding enclosure). The zero percent recorded in the non–frequently used site (for the no bark removal) was because the trees were exposed and available to the mega–herbivores. However, the higher intensity of debarking (50 to 75% and 75 to 100%) was commonly observed. Tree species vary considerably in the degree to which they are debarked. Although elephants do feed on trees by debarking, trees show an ability to recover by scar ridges formation, although the process is slow and scar tissue seldom covers the entire exposed area. However, the bark regenerates infrequently and usually a small number of trees regenerated. Hence it is expected that Marulas are able to sustain relatively high levels of damage before adults die.

Stem damage occurred, irrespective of whether it was in the frequently or non–frequently used site. There was a decreasing trend on the graph on the non–frequently used site. The highest trend noted within the dead but still intact main stem within the non–frequently used site, was due to the debarking that was followed by wood borer infestation. It has been suggested by Van Aarde et al. (2005) that some of the tree felling insidents may be a social display unrelated to feeding (especially by the male groups). Furthermore, Fritz et al. (2002) indicated that elephants are so much larger than most co–existing herbivores, which lend them to have greater impacts, such as tree, felling on vegetation.

Immune–contraception is regarded as the most effective means of controlling elephant populations using reproductive control measures as it is safe, reliable, effective, easily administered and reversible (Bertschinger et al., 2008). The primary objective for a contraceptive program will be to manage the growth rate of the population by simulating natural disturbance cycles; thus it will promote an indefinite period of zero growth. Only if translocation is unsuccessful could selective culling of individual bulls, and specific herds to reduce the overall population to within the recommended guidelines, be followed (Delsink, 2009). However, an important point is that culling programme will not prevent the disappearance of mature Marula trees from the ACNR. Elephants will still have an impact on their favoured plant species, even at low densities. Culling can therefore not be seen as a way of prevention measure for elephants in selecting for favoured species, but merely an attempt to slow the process down.

The demography of *S. birrea* at the ACNR could also be increased by re–stocking the population with plants from other populations (augmentation) (e.g. 100 individual seedlings of *S. birrea* that can be grown in a greenhouse). Adult Marula trees can be secured for the time being by surrounding them with stones, so that they cannot be affected and consumed by elephants. With introduced saplings, the saplings can be secured by restricting the presence of elephant bulls where Marula trees are prevalent. This will assist in reducing damage to Marula trees especially during the dry season. Vegetation plots can also be monitored. These sites should be photographed and examined at the end of the dry season and during the peak flowering/seeding period. A series of photographs must be taken from the same point at the same time every year. This will provide a visual reference point of the impact of various external influences on the vegetation, such as excessive grazing and fire practices (Bothma and Van Rooyen, 2002).

Conclusions

Elephants, like any herbivore, do not forage randomly but usually exhibit a hierarchy of selection from landscape, through vegetation type, to species and plant part. As such, the elephants will exhibit hierarchy of foraging in that palatable landscape. This explains the reason behind the damage difference on both the frequently and non–frequently used site. Elephants may be avoiding certain vegetation types and therefore not much damage found on Marula trees in those areas. Management practices such as increased elephant population have contributed to the decline of Marula trees in the reserve, though other contributing factors such as biotic or abiotic factors should never be discounted when considering vegetation change. To prevent the extinction of Marula trees in the reserve, it is imperative that the reduction of the elephant population needs to be addressed. Security measures should be adopted to protect the threatened tree species from developing even age population structures. A necessary measure would be to monitor the structural diversity of the Marula population.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Challenges of human settlement on wildlife in Bale Mountains National Park, Southeast Ethiopia

Demeke Datiko Hansilo* and Lemma Tiki

School of Biodiversity Conservation and Natural Resource, Madawalabu University, P. O. Box 247, Ethiopia.

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An investigation on challenges of human settlement on wildlife was carried out in 2014/2015 in and around Bale Mountains National Park. Among 25 villages bordering the National Park, 10 villages were purposefully selected for data collection. During the study period, semi-structured interviews and direct observations were conducted within the selected communities. A total of 365 households (35 households per villages, except 50 households for Rira) were randomly selected. Many parts of the protected area were found to be under cultivation. The main socio-economic activities of the respondents were mixed farming (58.0%) and livestock keeping (28.9%). The major reasons for off settlement near/inside the National Park were forage (52%), farming (25.6%) and both forage and farming (21.5%). Human settlement, agricultural expansions, and livestock grazing are the major problems of wildlife management inprotected area. Most of the cropland and human settlement expansions have been increasing from time to time and resulting in excessive losses of natural habitats for wildlife. This phenomenon was also attributed to migration of people from other places for farming and livestock grazing which has led to deforestation and intense decline in vegetation of protected area. Therefore, provision of appropriate conservation education should be emphasized for the local communities at different levels in the study area. Active measures have to be implemented to control the human settlement and livestock impact and safeguard the future of wildlife management in the park.

Key words: Bale Mountains, conservation, human settlement, park, wildlife.

INTRODUCTION

Today, protected areas are aimed to conserve biodiversity and large scale natural ecosystems. However, these protected areas are increasingly facing a number of challenges (Wearing and Neil, 1999; Suich, 2008). The tendency of establishing human settlements in previously wildlife areas is becoming common and endangering the future life of wildlife species (Ogutu et al., 2012). Such activities increase hand in hand with the increase in population growth and poverty (Galanti et al., 2006). Increased human population pressure and its negative impact on habitat loss in African countries is a common phenomenon (Newmark, 1996, Kideghesho et al., 2006). Some of the wildlife species in the Tarangire-Manyara ecosystem are reported locally extinct due to habitat destruction and overexploitation indicating high pressure of human impacts on wildlife (Shemweta and

*Corresponding author. E-mail: datikodeme@yahoo.com.

and Kideghesho, 2000). The growing population pressure should be handled with care as the land is constant, while the human population is growing rapidly especially around protected areas (Kideghesho et al., 2006).

Human population growth bordering protected areas is high and has become a serious threat to the management of wildlife species all over Africa (Newmark et al., 1994). Many protected areas in Ethiopia are becoming isolated and the reasons for the isolation include growing human population in areas adjacent to protected areas and land use change towards agriculture, infrastructure, and settlement in areas that were previously unpopulated. Bale Mountains National Park (BMNP) is one of the most threatened National Parks (Mamo and Bekele, 2011; Vial et al., 2011). Most of Ethiopia's endemic wildlife is found in BMNP. However, the human population of Ethiopia reached about 85 million in 2013. If the current growth rate (2.3%) continues that means Ethiopia will reach 100 million. Increased population growth in Ethiopia goes hand in hand with the high demand on food requirement. Thus, in order to meet the requirement of the increased population, more cropland is needed at the expense of wildlife habitats, because an increasing food production is a priority. The expansion of cropland reduces natural ranges of many wild animals due to the loss of habitats and fragmentation which ultimately result into local extinctions of wildlife (Goldman, 2009). Several factors are responsible for local extinctions of these wildlife species, but the most pronounced are loss of habitat as a result of human settlement and expansion of cropland which are primarily pressured by increased human populations (Stephens et al., 2001; Woodroffe and Donnelly, 2011; Pittiglio et al., 2012). High human settlement in BMNP might pose challenges on the survival of wildlife there (Vial et al., 2011).

For many years, the natural habitats of Ethiopia have been altered by human settlement/pressures including overgrazing, which affect the wildlife. Majority of livestock production in Ethiopia takes place in afro-alpine grasslands (Laverenchenko et al., 1998; Vial et al., 2011). There is no published work on Bale National Park. Human settlement and livestock grazing is high in the BMNP (Vial et al., 2011). Moreover, the overall land coverage has been changing from time to time due to human activities within the park. The exact trend is not described by previous works. Therefore, the aim of the present study is to reveal the negative impacts of human settlements (livestock grazing, agricultural expansion) on wildlife in the study area.

MATERIALS AND METHODS

The study area

BMNP is situated in the southeastern highlands of Ethiopia, in the Oromia National Regional State of Bale Zone (Figure 1). The park encompasses 2,200 km^2 of mountains and forest. Geographically, BMNP is located between 06°41' - 07°18'N and 39°03' - 40°00'E, about 400 km from Addis Ababa, the capital city of Ethiopia, BMNP contains the largest continuous area (over 1,000 km^2) of afro-alpine habitat in Africa (Vial et al., 2011). It covers an altitudinal range from 1,500 to 4,377 m asl (Fishpoll and Evans, 2001). Tullu Deemtu (at 4,377 m asl) in the Bale Mountains is the highest peak in Southern Ethiopia.

BMNP possesses one of the highest incidences of animal and plant endemicity among terrestrial habitats in Africa. In BMNP, there are at least 1321 species of flowering plants, of which 163 are endemic (23 to Bale alone) to Ethiopia. In BMNP afro-alpine areas of altitude >3400 m asl have a vegetation composition of *Erica arborea*, *Helichrysum* species, *Alchemilla* species, and giant *Lobelia* (*Lobelia rhyncopetalum*). The mountains are one of the centres of faunal diversity and endemicity, which generate numerous natural processes vital to human existence and support an important reservoir of genetic resources (EWNHS, 1996). BMNP is the home of diversity and endemism of fauna (EWNHS, 1996). The park supports 68 mammal species (Fishpool and Evans, 2001). The park is home to the largest populations of both the endemic and endangered Ethiopian wolf (*Canis simensis*) and Mountain Nyala (*Tragelaphus buxtoni*), as well as the endemic Bale monkey (*Chlorocebus djamdjamensis*) and the giant mole rat (*Tachyoryctes macrocephalus*). Over 170 bird species have been recorded in BMNP to date, about 20% of the species recorded for Ethiopia. Among the endemic birds of Ethiopia, 57% are found in Bale Mountains (IBC, 2007).

Before the establishment of BMNP, human population density and its impacts on the biodiversity of the area was not that much significant. In 1998, there was an estimated human population of 2,500. However, in 2003, the number of inhabitants was estimated over 40,000, representing a 16-fold increase in 20 years time (Stephens et al., 2001; BMNP, 2007). Many people live within the park's boundaries, increasing pressure on the natural resources of the area and diminishing natural habitats of wild animals.

Temperature of the area is variable, particularly in areas of the highest altitudes during the dry season and more or less the same pattern of temperature during the wet season. The highest temperature is 12.6°C in March and the lowest is 5°C in December (Vial et al., 2011). However, the temperature of the park normally ranges between 5 and 20°C. The warmest period of the year is between March and April. The coldest period is between November and December, and it can reach up to 1.5°C. Rainfall in BMNP is bimodal, with heavy rain during July to October and short rain during March to June. The annual rainfall ranges from 1000 to 1400 mm (EWNHS, 1996).

Data collection/Questionnaire survey

Questionnaire survey was conducted in 10 villages located within and around the BMNP. The ten villages were selected purposefully based on problems and accessibility. Totally, 365 households (HHs) were surveyed from all villages. The villages with the number of households include: Geremba Dima (35), Hora Soba (35), Gofingira (35), Gojera (35), Shedem (35), Rira (50), Angeso (35), Chiri (35), Irba (35), and Shawe (35). Thirty five households per village except 50 in Rira, because the village is totally inside the park. Selection of samples ensured representation of residents in the study area whereby number of households selected ensured above10% of all households in every respective village.

The study was carried out by means of a semi structured questionnaire and focus group discussion. In addition, direct observation of settlement and human activities in the protected area was carried out in the villages. The household data was collected using a semi-structured survey design, following a similar format to that used by Maddox (2003). One park management staff members and two district agricultural/natural resource management officers

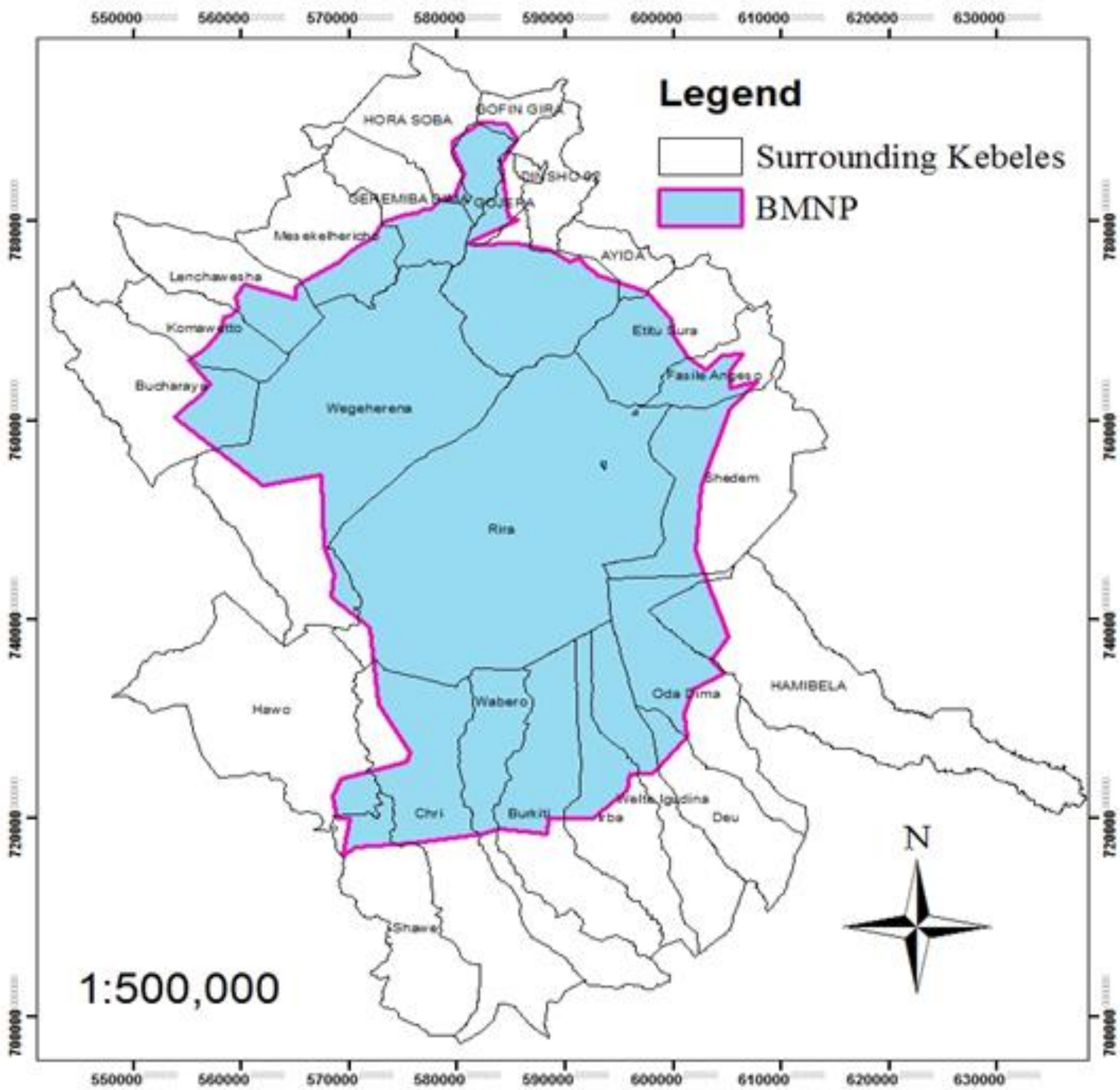

Figure 1. Map of the study area and the surrounding villages.

were involved in the research to facilitate the data collection. The questionnaire was administered to farmers within their area of farming and/or residence (Hill, 2000); at a random manner based on first come first serve basis (Newmark et al., 1994), and alternating male and female respondents as much as possible and different age groups. In every household, the head of the household or other representatives was interviewed. To understand the information, the questionnaires are translated into local language (Oromiffa). The structured questionnaires were administered using face to face interview that provided the family member to answer. Questions covered socioeconomic and demographic information, such as age, sex, education level, and village distance from the park boundary, their income source, trends and reasons of human settlement near/inside the national park, trends of agricultural expansion and livestock grazing and attitudes of settlers towards wildlife. Therefore, the main part of the questionnaire covered questions about the human settlement, livestock grazing, agricultural expansion and other activities that cause challenges on wildlife in the national park. The data were processed and analyzed using Statistical Package of Social Science (SPSS) version 20.0, and descriptive statistics, chi-square tests were also used to determine the nature of the relationships among the variables.

RESULTS AND DISCUSSION

Demographic and educational status

Out of the 365 respondents, 277 (72.0%) and 98 (28.0%) were males and females, respectively. The age groups (years) of the respondents were grouped as 15 to 19 (18.5%), 20 to 29 (22.4%), 30 to 59 (45.2%) and more than 60 (13.9%). Educational level and attitude of the local people are shown in Table 1. More than 37% of the

Table 1. Educational level and attitude of the local people towards the park.

Educational level	N	Percentage	Attitude towards the park		
			Positive (%)	Negative (%)	No idea
Illiterate	135	37.1	43.8	43.4	12.8
Primary education	82	22.5	62.4	33.6	4.0
Secondary education	47	12.8	70.1	22.2	7.7
Informal education	101	27.6	52.9	34.0	13.1
Total/Average	365	100	57.3	33.3	9.4

Table 2. Villages and source of income status of the interviewed respondents.

Village	N	Income sources/Household economy		
		Farming (%)	Livestock (%)	Livestock and farming (%)
Geremba Dima	35	16.1	30.8	53.1
Hora Soba	35	12.3	26.3	61.4
Gofingira	35	13.4	30.1	56.5
Gojera	35	15.3	29.9	54.8
Shedem	35	13.7	30.0	56.3
Rira	50	16	23.1	50.9
Angeso	35	14.5	28.3	57.2
Chiri	35	11.7	22.9	65.4
Irba	35	10.1	29.2	60.7
Shawe	35	7.5	28.3	64.2
Total	365	13.1	28.9	58.0

interviewed respondents were illiterate, 22.5% had primary education, 12.8% had secondary education and 27.6% had informal education. Majority of the respondents (57.3%) had a positive attitude towards the park whereas an average 33.3% had negative attitudes. The difference was statistically significant (χ= 34.45, df=2, P<0.05). Relatively, better-educated groups (primary and secondary education) had more positive attitude than non-educated groups.

The main social economic activities of the respondents were mixed farming and livestock keeping (Table 2). Most respondents were indigenous to the study area. For those who had migrated, there were different reason for why immigrants had moved into the area, including farming (13.1%), livestock keeping (28.9%), and both livestock and farming (58.0 %%). The difference was statistically significant (χ^2 = 31.15, df = 2, P < 0.05). However, this was not significant among villages of farming (χ^2 = 5.17, df = 9, P > 0.05) and livestock/pastoral (χ^2 = 3.49, df = 9, P > 0.05).

Trends of human settlement in the last 10 years are shown in Table 3. Majority of the respondents (above 60%) indicated that in all villages, human settlement has been increasing during the last 10 years. The respondents noted that in all villages human settlement has increased during the last 5 years. Out of the 365 respondents, about 60% responded the trend is increasing. Only 18.9% noted the trend is decreasing. The difference was statistically significant on average trends of human settlement in and nearby the park (χ^2 = 68.47, df = 3, P < 0.05). The views of the respondents did not differ significantly among these study villages.

The major reason of settlement near/inside the national park is shown in Table 4. Shortage of land for forage and for farming as well as both factors is the main reasons of human settlement in the study area. More than 52% mentioned their coming to the area is for livestock forage, 25.6% for farming and 21.5% for both forage and farming. The difference was statistically significant (χ^2 = 17.50, df = 2, P < 0.05).

A trend of agricultural expansion is shown in Table 5. In all the villages, the agricultural expansion has been increasing inside and around protected area. The highest response was in Rira (74.1%). Averagely, 60.7% of the respondents noted as the agricultural expansion is increasing in and around the National Park in the last 10 years. Few respondents (16.8%) stated that agricultural expansion was decreasing in the protected area, and 12.7% were noticed as the same trend of agricultural expansion. The difference was statistically significant (χ^2 = 68.96, df = 3, P < 0.05).

Livestock grazing in and around the park as well as

Table 3. Trends of human settlement in and nearby the park the last 10 years.

Village	N	Trends of human settlement in and around the park (%)			
		Increased	Decreased	The same	Unknown
Geremba Dima	35	59.4	21.9	17.2	1.5
Hora Soba	35	57.3	18.6	16.8	7.3
Gofingira	35	59.2	17.5	14.3	9.0
Gojera	35	55.9	16.8	13.5	13.8
Shedem	35	58.0	18.9	15.7	7.4
Rira	50	75.6	13.5	9.2	1.7
Angeso	35	50.2	18.4	18.3	13.1
Chiri	35	62.5	22.6	14.1	0.8
Irba	35	58.0	21.2	17.5	3.3
Shawe	35	62.5	19.8	15.1	2.6
Total/Average	365	59.9	18.9	15.2	6.0

Table 4. Reason for settlement near/inside the national park.

Village	N	Reason of settle near/inside the national park (%)		
		Lack of land for forage	Lack of land for farming	Both (forage and farming)
Geremba Dima	35	52.2	28.6	19.2
Hora Soba	35	54.4	29.2	16.4
Gofingira	35	58.0	26.5	15.5
Gojera	35	50.2	20.7	29.1
Shedem	35	59.1	29.1	11.8
Rira	50	41.9	20.3	37.8
Angeso	35	55.2	26.3	18.5
Chiri	35	56.3	25.5	18.2
Wabero	35	52.4	23.3	24.3
Shawe	35	49.7	26.4	23.9
Total/Average	365	52.9	25.6	21.5

Table 5. Trends of agricultural expansion in the last 10 years.

Village	N	Trends of agricultural expansion (%)			
		Increasing	Decreasing	The same	Unknown
GerembaDima	35	55.1	18.7	15.5	10.7
Hora Soba	35	57.3	19.1	12.7	10.9
Gofingira	35	61.7	16.0	14.5	7.8
Gojera	35	57.6	17.8	13.3	11.3
Shedem	35	62.9	19.6	9.3	8.2
Rira	50	74.1	8.6	11.0	6.3
Angeso	35	58.5	16.4	15.1	10.0
Chiri	35	57.4	17.6	10.2	14.8
Wabero	35	60.7	18.2	12.5	8.6
Shawe	35	61.5	15.6	13.4	9.5
Total/Average	365	60.7	16.8	12.7	9.8

time of grazing per year/months is shown in Table 6. Nearly half of the respondents (49.6%) graze their livestock inside the national park. About 35 and 15.9% graze livestock both (in and outside the park) and outside

Table 6. Livestock grazing and trends of livestock around the national park in the last 10 years.

Village	N	Livestock grazing (%)				Number of livestock around the national park (%)		
		Inside the park area	Outside the park	Both	Time of grazing in months	Increased	Decreased	The same
Geremba Dima	35	42.1	18.7	39.2	2-4	52.1	15.1	32.8
Hora Soba	35	44.3	19.1	36.6	2-4	53.2	13.4	33.4
Gofingira	35	48.7	16	35.3	2-4	55.5	14.1	30.4
Gojera	35	45.6	17.8	36.6	5-7	50.0	10.5	39.5
Shedem	35	49.9	19.6	30.5	2-4	54.9	14.7	30.4
Rira	50	80	0.0	20	8-10	61.4	9.8	28.8
Angeso	35	45.5	16.4	38.1	2-4	52.2	15.7	32.1
Chiri	35	43.4	17.6	39	2-4	53.9	12.0	34.1
Irba	35	47.7	18.2	34.1	2-4	54.5	13.1	32.4
Shawe	35	48.5	15.6	35.9	2-4	52.2	14.3	23.5
Total/Average	365	49.6	15.9	34.5	2-10	54.0	13.3	32.7

the park, respectively. The difference was statistically significant (χ^2 = 14.48, df = 2, P < 0.05). The time of grazing is varied. However, in Rira village all livestock is grazed inside the national park. The status of livestock around the national park in the last 10 years is increasing (Table 6). Most respondents (54.0%) mentioned the number of livestock is increasing from time to time. However, few respondents noticed decrease (13.3%) and the same (32.7%) number of livestock in the protected area. The difference was statistically significant (χ^2 = 24.89, df = 2, P < 0.05).

DISCUSSION

Collecting baseline information is a vital step in managing protected areas (Kumssa and Bekele, 2008). Therefore, the nature of the study required information from the responsible members of households. This helps to understand the timing, status and location of the challenges as well as the perceptions of local people towards protected areas. During the study period, sex of the respondents was not important in determining the attitude towards the protected area. However, young age groups showed relatively more significantly positive attitude than adult age groups. There was low level of formal education in the area due to tradition of pastoralist societies who do not encourage their children to attend schools instead many of them remain caring or shepherding of livestock.

Educated respondents supported protected areas more than those with no formal education. Conservation may be quite difficult in the future in areas like BMNP with people who are more illiterate. Support for conservation was positively correlated with the level of education of the respondents. Gadd (2005) also observed a similar situation in a study of people's attitudes towards the wildlife in Kenya. Gadd (2005) also observed a similar situation in a study of people's attitudes towards the wildlife in Kenya and Ethiopia, respectively. In the present study, pastoralists move herds into protected areas in search of water and fodder. In doing so, pastoralist comes into direct competition with wildlife. Most respondents (56.2%) considered that the existence of the park had a positive attitude to conservation and indicated that the existence of the park will serve as a means of rangeland for their livestock during the wet season. Few respondents (35.6%) showed a negative attitude towards the park. Fear of displacement from the area by government is the major cause. They suggested that the park has to be free from human intervention. Similarly, a study in Tanzania found that the attitudes of local people were influenced by the services and benefits they personally receive from the protected area (Newmark et al., 1994). Therefore, it needs attention from concerned government and non governmental bodies.

The pastoralist society's income sources of household are mainly livestock keeping and small scale crop cultivations. Most of interviewed households mainly depended on livestock keeping and crop cultivation as sources of household income. This is partly a strategy to meet food demand as well as realizing the cost associated with keeping large herds of cattle. However, most livestock in the area local breed and the productivity is less. As a result, they depend on the number of livestock rather than quality. This might cause negative effect on the vegetation/wildlife habitat of the park.

Like most African countries, humans also put pressure on BMNP by various ways such as expansion of settlements, agricultural expansion, and livestock grazing. Livestock raring and agricultural expansion activities can have a wide negative impact, such as deforestation and loss wildlife habitat. The increased conversions of rangeland habitats have negative impacts on wildlife as the habitat of wildlife is lost especially to bushland, woodland dwellers, and grassland habitats. The new types of land uses, such as agriculture, which have occupied large space have lead to destructions of natural vegetations and reduced area available for wild animals grazing and movements. Kideghesho et al. (2006) also mentioned similar problems of wildlife habitats for cultivation in other African country.

In most African countries, conflicts over natural resources are frequent (Stewart, 2002). The increased human settlement in the area has contributed greatly to lack of free space for animal movements as it can be translated to increased human settlements as observed in the study area during this survey; this observation is also supported by Ndibalema (2010) in Serengeti ecosystem. This has also resulted in shrinkage of the buffer zone area of the park. The park has been under increasing pressure from a rapidly growing pastoralist population and their livestock. High levels of livestock grazing in BMNP may affect the quality of the habitat suitable for the wildlife community. Vial et al. (2011) also noted as livestock grazing is very intense in BMNP. This is particularly the case in the BMNP area, where growing population has developed as threat protected areas directly by encroachment of wildlife area. A major bottleneck is the overstocking rate of livestock and human settlement leading to habitat loss through forest clearing for household consumption and for agriculture. Therefore, the present investigation revealed that the impact of illegal livestock grazing has been affecting the overall habitat of the national park.

Conclusion

Habitat destruction due to human activities is a potential threat to the survival of wildlife species in BMNP. Wildlife is under threat due to illegal human settlement, expansion agricultural lands, and livestock grazing in and around the protected area. Research findings show that there are major land uses changes which are associated with expansion of cropland cultivation and human settlements into areas that previously serves as wildlife habitats. These changes have negative impacts on the natural habitats of wildlife. Therefore, calls for involvement of not only conservationists, but also other stakeholders with different interests in the area and professional background, such as agriculturists, conservationists, demographers, policy makers, and land use planners to minimize the challenges. With this current trend of agriculture expansions and illegal human settlement which has already been put under cultivation of the park, the park will no longer act as a conservation area for wildlife as other protected area of the country. Therefore, provision of appropriate conservation education is important for the local communities/children at different levels of schools (primary, secondary, and high schools). Also, continuous monitoring and evaluation process of effects of settlement in the park are needed for future conservation measures.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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