Transient feedback in woody vegetation response in aftermath of elephant culling history at Sengwa Wildlife Area, Zimbabwe


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Accepted February 16, 2016

In Zimbabwe changes in woodlands caused by elephants and other factors were studied at Sengwa Wildlife Research Area with a long history of documented elephant population build up to 1965 followed by 24 years of sustained culling and 26 years of vegetation regeneration in aftermath of elephant culling. The hypothesis posited in literature of extirpation of woodlands by the elephant Loxodonta africana Blumenbach was investigated. A vegetation survey was conducted using belt transects to test the hypotheses that vegetation structure and relative abundance of certain plants differ from formerly degraded plots within the protected area. Nine sites consisting of paired plots on degraded and undegraded woodlands were selected. At each site composition, structure and damage levels were measured. Woody plants were assessed using 13 parameters. Formerly over utilized patches showed no significant differences (T – test p>.05) in height, girth and number of stems with regeneration plots. The hypothesis is rejected in a study that has seen the historically high densities of elephants alter forest structures where the vegetation may now be showing strong regeneration under the influence of adaptive management. The action variables limiting state in the transition of woody vegetation towards a climax include termite activity, disease, herbivory and drought among other factors. The results do not lend evidence to foreclose options in protecting woodlands by keeping elephant populations at certain low densities as this learning curve in adaptive management has shown in the study. The findings contribute to an understanding of earth observation processes, such as land cover change, climate change and biodiversity conservation.

Key words: Elephant –habitat interactions, vegetation change, semi-arid areas, Zimbabwe.
INTRODUCTION

Many studies show the impact of elephant on the African landscape (Osborn, 2002, Nellis and Bussing, 1991, Ben-Shahar, 1999, O’Connor et al. 2007) but few studies show the impact of the African elephant (*Loxodonta africana* Blumenbach) on woody vegetation in the aftermath of recorded culling history. At Sengwa Wildlife Research Area (SWRA) elephant culling commenced after a long period of observed tree damage and disappearances from around 1965 to 1989. The problem of elephant numbers first surfaced in the early 1960s. Cumming (1981) suggested that available elephant range was reduced from 1955 to 1980 and elephant density increased from 1955 from 0.2 individuals/km$^2$ to 0.8 individuals/km$^2$ and 1.2 individuals/km$^2$ between 1965 and 1978. Population reductions were carried out through culling operations (Ministry of Environment Climate and Water, 2015). The first cull of 500 elephants was carried out in 1966/67. The last large cull was conducted in 1989. Long-term vegetation changes have taken place in the post culling history following new adaptive management initiatives aimed at restoring woodlands in the general area of the elephant range (Northern Sebungwe Region), Zimbabwe (Figure 1). Up until 2004 SWRA was a strict research area but that was changed in favour of a hunting concession in order to raise the vital conservation funds and keep the elephant population low. Muvengwi et al., (2011) observed that vegetation is subjected to short-term, high-intensity utilization in the dry season when plant biomass is minimal. Such high intensity use at a time when the plant stress is at its maximum has greater negative impact on the habitat. The rapid breakdown of vegetation due to heavy effect of elephant use has been recorded in several studies by Ben-Shahar (1999), Osborne (2002), O’Connor et al (2007).

In earlier times elephant movements were largely 'natural', occurring mainly in response to environmental influences but this observation may have changed in later years following compression by human encroachment on the edges of protected areas. Chafota and Owen-Smith, (1996) advocates that intervention should definitely be considered as limits to 'acceptable habitat change' are deemed to have been exceeded in some areas. The difficulty is that the debate on acceptable limits to habitat change and elephant effects on biodiversity becomes inconclusive and endless. Ultimately decisions on interventions have to involve a 'value judgement'. Concern about rising elephant densities and impacts have been recorded especially a worsening impact on vegetation around artificial waterholes. Connybeare (1991) found dramatic changes around watering points in Hwange National Park.

Studies by Tafangenyasha (1998) and Tafangenyasha (2001) suggest that the African elephant can have profound vegetation changes over time to the detriment of ecosystem health. Density, occupancy and distribution of elephant have been shown to have local effects on vegetation patterns (Connybeare, 1991, Walker, 1998). But what if the dominant mega herbivore was dramatically reduced? Vegetation studies in the aftermath of sustained mega herbivore culling are few. The extent of vegetation scale depends on prevailing climates, management actions and social demands of local communities. Connybeare (1991) undertook an elephant occupancy study on Kalahari sands in Hwange National Park and showed that elephant were key ecosystem modifiers. A new study should integrate the effects of elephant occupancy, vegetation data in the light of new management interventions. The prevalence of recent

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droughts in Southern Africa suggest climate may have a controlling effect on vegetation condition. Mazvimavi (1998, 2003, and 2010) outlined drought cycles and normal seasons in a recent climate analysis of Zimbabwe meteorological patterns. It seems uncertainties in incidences of episodic events create the imperative to monitor vegetation. The availability of plant species of choice inside the SWRA may have a bearing on elephant movements to the edge of the protected area (Osborne, 2002). The high animal stocking

Figure 1. Location of Sengwa Wildlife Research Area (SWRA) in north-western Zimbabwe and a detailed vegetation map of the area (Patches of miombo woodland are labelled A - M).
densities may influence adaptive management in order to invoke a regeneration in the whole ecosystem. It can be surmised that elephant occupancy, distribution and population affect vegetation over time and the need arises to manipulate scale direction towards a healthy rangeland system. Walker (1998) posited several scenarios that is obtain in Savana rangelands but that the direction of scale dependence was largely a result of intensity of disturbance and future events following disturbance. Few studies, (For example, Nangendo et al. 2005) have measured the regeneration scenario of woody vegetation in the aftermath of culling in order to direct the next management steps. In this study the herbivore directed extirpation of woodlands hypothesis is re-examined de-novo. What are the feedbacks of vegetation in a period spanning 25 years after elephant elimination?

STUDY AREA

Sengwa Wildlife Research Area (SWRA) is situated at the southern end of Chirisa Safari Area (18° 10’ S, 28° 14’ E) in Gokwe South District, north-western Zimbabwe (Figure 1). Covering an area of about 373 km², the area was set aside in the late 1960s for long-term wildlife and ecological research. There are a series of black-and-white aerial photographs from as far back as 1964. Three sets of detailed colour photography at scales of 1:10 000 and some at 1:5 000 were examined. The surface geology comprises of Lower and Upper Karoo age. The study area constituted by the Lower Karoo is represented by the Madumabisa mudstone formation a weathering grey carbonaceous shale with _Endothiodon_ spp fossil wood and _Lamellibranchs-Pellaedonodonta_ spp and _Ostracods-Darwinuda_ spp (Selibas, 1972). The Upper Karoo which overlies the mudstones gives rise to geologically and ecologically significant colluvial deposits with carbonaceous and siliceous matrices. The geological formations have been dissected by the north flowing rivers that are an important source of water for the animals. SWRA is semi-arid ecosystem with low and irregular rainfall, high evapotranspiration and cyclical droughts. High evapotranspiration mean soils dry up quickly reducing amount of water available for plant uptake. Figures 2-3 suggest that severe droughts are a long term feature in the study area and region. Several topographic and vegetation maps of the area were used to make possible the study on homogeneous Madumabisa mudstones. Data on animal numbers and seasonal movements are available from counts done during organized patrols, along permanent transects and aerial surveys since the late 1960s.

There is a wide variety of vegetation types, 26 types having been described and mapped by Craig (1982). A wide range of research projects have been done in the SWRA since its establishment to establish diet preferences of herbivores and forage availability. The elephant (_Loxodonta Africana_ Blumenbach) ranks as one most common and dominant herbivore in SWRA (Cumming 1981, 1982, 2008). The wasteful feeding behaviour was mitigated against by a sustained culling programme terminated in 1989. Few studies have been conducted to understand the response of woody vegetation in the aftermath of culling. The SWRA has a diverse large animal mammal community of 7 species of large carnivores and 18 species of large herbivores. The area is home to diverse communities of birds, small mammals and reptiles. Some common wild animals in the SWRA are given in Figure 4.

When an elephant range area reserve is fenced and supplied with water from permanent rivers, elephant population irruptions take place, necessitating culling. A comparison can be made between patches formerly degraded and undegraded in the aftermath of culling. This technique has been made by Nangendo in
Figure 2. Long term rainfall record (Mean=670.4 mm, n=50 years, CV=25.6%) at SWRA (Modified after Moyo, 2011). Note that missing cases are responsible for the crunch after 2007 in the figure.

Figure 3. Longterm rainfall patterns of Zimbabwe (After Mazvimavi, D. 2010).
Murchison Falls NP in Uganda, Tafangenyasha and Campbell (1998) in Sinamatella area of Hwange National Park and by Osborne (2002) in SWRA to study elephant impact on vegetation. Two assumptions were made about the history of the woodlands examined in this study. The first is that there is no difference in the woodland structure and composition of vegetation in over utilized and undegraded plots after culling had ceased. The second is that changes to the vegetation in SWRA were caused by elephants and fire. The 2014 elephant aerial survey of the Sebungwe Region showed a major decline in standing elephant populations from 13000 to 3500 (Dunham, 2015). The extent of gap colonization by non-native plant species were observed in the study area. The information obtained in the study should influence management decisions on appropriate park ecosystem health and understanding of changes in vegetation composition and structure and habitat preferences.

METHODS

Previously, Craig (1982) used aerial photography, Surveyor General Map’s topographical maps and ground woody species identification in delineated vegetation strata to compile vegetation maps and to study spatial distribution of plant species. The 2015 vegetation condition assessment used the Craig (1982) vegetation maps of the major woody types present to randomly locate vegetation.
sampling points in new earth observations. The methods used to measure environmental attributes follow Tafangenyasha (1998, 2001). A total of 13 environmental variables were enumerated, measured and scored using Osborne (2002) and Tafangenyasha (1998, 2001). The environmental variables include 1) species, 2) girth, 3) height, 4) percent canopy cover (CCOVER), 5) percent fire damage (FIREDAMGE), 6) percent drought damage, 7) percent termite damage (TDAMAGE), 8) distance to permanent water (DISTWATER), 9) percent elephant damage (ELDAMAGE), 10) number stems per plot, 11) number species per plot, 12) species density (number species per square metre), and 13) Shannon Weaver diversity index (H'). The environmental variables not reported here are summarised in other reports elsewhere. Vegetation sampling campaigns between March and July 2015 was done on foot in randomly located sampling sites of key woody types.

A 50 m x 20 m non-permanent belt transect (Anderson and Walker, 1974) was adopted as a most efficient sampling system. Anderson and Walker (1974) defined trees as woody plants taller than 3m with stem diameter greater than 5 cm was considered to be a “tree”. Plants were identified in the field or a sample was collected for later identification at SWRA herbarium. Multi-stem coppicing plants were measured from ground level if the original stem was greater than 5 cm. The height was measured using a graduated pole. Dead trees were enumerated. Damage was estimated using the Braun-Blanquet scale 0-100%. Obvious fire or human damage was also noted. Data were recorded on data sheets designed by Anderson and Walker (1974). Species richness is estimated with the total number of observed species. Species richness (usually notated S) of a dataset is the number of different species in the corresponding species list. Richness is a simple measure. The Shannon Diversity Index is calculated by multiplying a species proportional abundance by the natural log of that number:

$$H = - \sum p_i \ln p_i$$

where \(p_i\) is the proportion of individuals found in the species “i”. This index assumes that individuals are sampled randomly from an infinite or very large population. Similarly, it supposes that all species are represented in the sample.

**Data analysis**

Data capture on Excel spreadsheets commenced. In order to determine whether different areas, specifically sample plots, could be distinguished from each other based on impacts of elephant on woody vegetation, we performed two different analyses, i.e., first, a Principal Component Analysis (PCA), Factor Analysis (FA) and second, a Hierarchical Cluster Analysis (HCA). Multivariate statistical techniques, such as PCA, FA and discriminant analysis HCA, were applied for the evaluation of temporal/spatial variations and the interpretation of a large complex woody vegetation of the SWRA using data sets generated during the growing season 2015. The PCA was performed in STATISTICA for Windows using the following variables: tree heights, species richness per plot, species diversity, basal areas, woody plant densities and number of stems per plant. The HCA was performed using the unweighted pair-group average method with a matrix of 18 plots. The results of PCA/FA revealed that most of the variations were explained by height, girth, canopy cover, elephant damage, termite damage in individual plots. Discriminant analysis showed the best results for data reduction and pattern recognition during both spatial and temporal analysis. Thus, this study illustrates the usefulness of PCA, FA and DA for
the analysis and interpretation of complex datasets and in woody parameters, identification of disturbance sources/factors, and understanding of temporal and spatial variations of vegetation characteristics. STATISTICA Release 7 software analysis of vegetation data showed underlying important changes in the study area. Correlations between vegetation variables and environmental data were undertaken and scatterplots of key environmental attributes were obtained.

RESULTS

A total of 18 paired plots on nine sites were sampled. Figures 3-7 show Principal
Figure 6. Principal component analysis output (PCA-biplot) of investigated sample plots in environmental variables. Notes: Principal Component 1 explained 19.05 % and Principal Component 2 explained 15.97 % of the variance in the data.

Component Analysis output (PCA-biplot) of investigated sample plots in environmental variables. Principal Component 1 explained 19.05 % and Principal Component 2 explained 15.97 % of the variance in the data. The HCA dendrogram distinguished to a greater extent plots from the different elephant density areas based on environmental variables and structure. The 18 sample plots were grouped into 4 sub-clusters (Figure 8). First, sub-cluster 1 was composed of sample plots drawn from areas sampled in the low distance to water and high woody height areas. Second, there was a high similarity of sample plots drawn from the high and medium elephant density areas in sub-clusters 2. Sub-cluster 2 comprised of woody canopy cover, and fire damage. Third, sub-cluster 3 consisted of sample plots from the high termite damage, drought damage, fire damage and canopy cover. Fourth, sub-cluster 4 consisted of sample plots from the high woody girth, elephant damage, termite damage, drought damage and fire damage.

Spearman rank correlation showed strong positive relationship between elephant damage and termite damage (Table 1). There was a strong positive relationship between fire damage and elephant damage using Spearman
Figure 7. Principal component analysis output (PCA-biplot) of investigated sample plots in environmental variables. Notes: Principal Component 1 explained 19.05 % and Principal Component 2 explained 15.97 % of the variance in the data.

Figure 8. Hierarchical Cluster Analysis (HCA) dendrogram of environmental variables relationships in the sub clusters in the study area.
rank correlation (Table 1). The metrics collected between degraded and undegraded plots showed variations that are summarised in Table 2. Degraded plots measured smaller mean girth (12.2 cm) and mean height (446.7 cm) when compared to undegraded plots (13.6 cm and 460.2 cm, respectively, Table 2). Mean percentage canopy cover, elephant damage and termite damage was higher on undegraded plots compared to degraded plots (Table 2). Drought damage on woody plants was about the same between degraded (0.1%) and undegraded plots (0%) (Table 2). Degraded plots measured the highest mean distance (1026.8 cm) to water compared to undegraded plots (885.4 cm) (Table 2). Formerly over utilized patches showed no significant differences(Student T test p>.05) in height, girth

### Table 1. Spearman rank order correlations. Marked correlations p<.0500.

<table>
<thead>
<tr>
<th>Variable</th>
<th>girth</th>
<th>Height</th>
<th>Cancov</th>
<th>elepdam</th>
<th>termdam</th>
<th>Firedam</th>
<th>drought</th>
<th>distwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girth</td>
<td>1.000000</td>
<td>0.148117</td>
<td>-0.061549</td>
<td>-0.039798</td>
<td>0.037501</td>
<td>-0.113255</td>
<td>0.077225</td>
<td>-0.181368</td>
</tr>
<tr>
<td>Height</td>
<td>0.148117</td>
<td>1.000000</td>
<td>-0.136300</td>
<td>0.069995</td>
<td>0.042135</td>
<td>0.070255</td>
<td>0.107290</td>
<td>-0.062310</td>
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<tr>
<td>Cancov</td>
<td>-0.061549</td>
<td>-0.136300</td>
<td>1.000000</td>
<td>0.138890</td>
<td>0.187441</td>
<td>-0.191991</td>
<td>-0.103764</td>
<td>0.046908</td>
</tr>
<tr>
<td>Elepdam</td>
<td>-0.039798</td>
<td>0.069995</td>
<td>0.138890</td>
<td>1.000000</td>
<td>0.67685</td>
<td>-0.274888</td>
<td>-0.115730</td>
<td>0.218141</td>
</tr>
<tr>
<td>Termdam</td>
<td>0.037501</td>
<td>0.042135</td>
<td>0.187441</td>
<td>0.67685</td>
<td>1.000000</td>
<td>-0.099209</td>
<td>-0.057969</td>
<td>0.339750</td>
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<tr>
<td>Firedam</td>
<td>-0.113255</td>
<td>0.070255</td>
<td>-0.191991</td>
<td>-0.274888</td>
<td>-0.099209</td>
<td>1.000000</td>
<td>0.488771</td>
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<tr>
<td>Drought</td>
<td>0.077225</td>
<td>0.107290</td>
<td>-0.115730</td>
<td>-0.274888</td>
<td>-0.057969</td>
<td>1.000000</td>
<td>-0.123096</td>
<td>1.000000</td>
</tr>
<tr>
<td>Distwater</td>
<td>-0.181368</td>
<td>-0.062310</td>
<td>0.218141</td>
<td>0.339750</td>
<td>0.108297</td>
<td>0.212697</td>
<td>0.339750</td>
<td>1.000000</td>
</tr>
</tbody>
</table>

### Table 2. Descriptive statistics of variables measured in study plots.

<table>
<thead>
<tr>
<th></th>
<th>Degraded plots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Girth, cm</td>
<td>183</td>
</tr>
<tr>
<td>Height, cm</td>
<td>183</td>
</tr>
<tr>
<td>Ccover, %</td>
<td>182</td>
</tr>
<tr>
<td>Eledamag, %</td>
<td>102</td>
</tr>
<tr>
<td>Tdamag, %</td>
<td>82</td>
</tr>
<tr>
<td>Firedamag, %</td>
<td>102</td>
</tr>
<tr>
<td>Drought damage, %</td>
<td>87</td>
</tr>
<tr>
<td>Distwater, cm</td>
<td>183</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Undegraded plots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>Girth, cm</td>
<td>177</td>
</tr>
<tr>
<td>Height, cm</td>
<td>177</td>
</tr>
</tbody>
</table>
| Ccover, %            | 174 | 53.2759 | 20.00000 | 100.000 | 11.574 cm | 60
| Eledamag, %          | 68  | 22.4118 | 0.00000 | 100.000 | 26.3406  |
| Tdamage, %           | 36  | 6.6389  | 0.00000 | 100.000 | 19.0475  |
| Firedamag, %         | 111 | 0.0000  | 0.00000 | 0.000  | 0.0000   |
| Drought Damage,%     | 118 | 0.0000  | 0.00000 | 0.000  | 0.0000   |
| Distwater, cm        | 177 | 885.3842 | 5.00000 | 5000.000 | 938.8143 |
Table 3. Summary Student T-Tests results for vegetation characteristics obtained during a belt transect survey in the study area.

<table>
<thead>
<tr>
<th>Degraded plots</th>
<th>Undegraded plots</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>444.8</td>
</tr>
<tr>
<td>Girth (cm)</td>
<td>12.7</td>
</tr>
<tr>
<td>No. stems/plot</td>
<td>177</td>
</tr>
<tr>
<td>No. species/plot</td>
<td>3.3</td>
</tr>
<tr>
<td>Species density (no/m²)</td>
<td>0.24</td>
</tr>
<tr>
<td>Shannon Weaver</td>
<td>1.2</td>
</tr>
</tbody>
</table>

and number of stems per plot (Table 3). Table 3 showed no significant differences in number of stems per plot, species density (number per m²) and Shannon Weaver diversity indices. The results presented in Table 3 are surprising considering the recorded negative effects of elephant on Savanna wooded vegetation. The results suggest that the historically high densities of elephants altered forest structures and the vegetation may not be showing strong differences between formerly heavily utilised and relatively unutilised patches after repeated culling events. The general findings are outlined below:

a) A general recovery of woody vegetation in previously damaged sites is shown by counts of stems with few signs of fresh damage.
b) No significant differences in numbers of stems/trees between degraded and undegraded plots.
c) Low incidences of burn marks
d) Low damage levels by elephant.
e) High levels of termite activity on woody stems and litter cannot be explained at this stage.

DISCUSSION

The vegetation in SWRA maybe regenerating in many of the study sites. SWRA was under severe pressure from increasing mega herbivore populations in the past. Guy (1974) postulated that an individual adult elephant may fell 1500 trees per year. Guy (1974) observed major changes on impact levels on the woody vegetation (Table 4). In the aftermath of 1989 elephant culling the woody vegetation may have undergone regeneration due to low elephant densities < 1.0 individuals per square kilometre. Herbivory most notably elephant feeding activity initiate tree damage and later in concert with other herbivores and environmental factors degraded rangeland sites may be maintained (Tafangenyasha and Campbell, 1998). Episodic events such as fire, drought and termite population irruptions probably delay recovery
towards a climax by reducing development of vegetation through creation of sub-optimal growth patterns. Woody plant disappearance may be a common feature from persistently disturbed sites. Gaps created in the woodlands have been colonised by opportunistic non-native invaders such as *Lantana camara* L. Species vulnerable to extirpation by elephant are those: whose attributes predispose adults to pollarding, uprooting or ringbarking; adults' coppice poorly, hence mortality occurs; mortality may be compensated by regeneration and recruitment owing to the impact of low elephant populations. The woody community in the test and control sites showed no significant differences (p > 0.05) in girth, height, number of stems, species density and Shannon diversity values.

A mixture of plants provides forage for a variety of insect and vertebrate species. A mixture of plants will contain some plants that can survive drought, insect plagues, and disease outbreaks so that a site will have some soil protection/forage/etc. in drought years. The community benefits from a mixture of plants; soils improve with nitrogen fixers, deep rooted plants bring nutrients up from soil layers below other plants roots, some species work together so that both can survive. The action variables reducing state in the transition of woody vegetation towards a climax probably include termite activity (Dangerfield, 1990, Dangerfield et al. 1998) disease (Zimbabwe Forestry Commission, undated), herbivory (Osborne, 2002) and drought (Tafangenyasha, 1998) among other factors (such as edaphic factors). Zimbabwe Forestry Commission (undated) suggests that diseases and pest challenges play a minor role in tree loss in a floristic complex forest. Tafangenyasha et al., (2011) noted that soil density itself a function of several factors may reduce rate of gap recolonization in Savanna rangelands. Threat of local woody extirpation may have decreased because of a decreased probability of encounter with elephant due to previously sustained elephant culling programmes. Guy (1989) noted that exclosures had been useful for examining changes that occur in woodland isolated from the effects of fire or grazer, or both. A reduction in elephant population should decrease local elephant density and attendant density-dependent effects of decreased foraging impacts, and rangeland degradation. The discrete patterns displayed by ordination dendrograms DA (Discriminant Analysis)) and FA(Factor Analysis) explain the essential mechanistic properties of the transient characteristics in woody vegetation change towards a climax that portends the potential of climate vegetation interaction.

The inherent push and pull duality in the performance of woody vegetation may be a result of many enabling and disenabling environmental forces kept in check by management action on overall park management policy. It can be surmised that for the next few years woody vegetation may not be constrained by elephant alone. This is because number of elephants in the general area of the Sebungwe declined by 76% since 2001, while the number of all elephant carcasses increased by 70 % (Dunham, 2015). The results suggest that historically high densities of elephants altered forest structures and vegetation may now be showing strong regeneration. The action variables limiting state in the transition of woody vegetation towards a climax probably include termite activity, disease, herbivory and drought among other factors. Walker (1998) called for the art and science in wildlife management by collation of long term data to cover various incidences of episodic events.

**CONCLUSION**

The hypothesis of woodland annihilation by elephant on a long term basis is rejected in the
study. The historically high densities of elephants altered forest structures to a level that could not be restored in the absence of management intervention measures. Using adaptive management that controlled elephant populations the vegetation in the study area may be on the path to regeneration and restoration. Three important observations emerged from the study:

a) Woody vegetation data assessment suggest regeneration in the wooded compartments of the study area of SWRA. The findings in the present study suggest a need to carefully consider the extirpation of woody plants de-novo in elephant range areas especially in the aftermath of a sustained history of culling.

b) Termite activity maybe increasing in most woody vegetation type a phenomenon not easily understood but one that may be related to growing aridity.

c) Woody vegetation regeneration towards a climax may be limited by herbivory, fire, diseases, pests and drought. The findings contribute to an understanding of earth observation processes, such as land cover change, climate change and biodiversity conservation.

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