Effects of different disturbance regimes on grass and herbaceous plant diversity and biomass in Zimbabwean dambo systems

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ABSTRACT
This study examined the species richness, diversity, biomass of grasses and herbaceous plants and seed germination in plots with contrasting disturbance regimes established in a dambo garden, in Chiota, Zimbabwe. The disturbance regimes were burning, clipping, clearing and conventional tillage and were applied annually to each subplot from 2010 to 2012. It was hypothesised that burning increases biomass, species richness and diversity of plants while reducing seed bank diversity. Clearing, clipping and conventionally tilling negatively affect biomass, species richness and diversity. The Shannon–Wiener Index was used to estimate species diversity and the average values obtained ranged 0.53, 0.85, 0.91, 1.3 and 1.70, for the undisturbed, burnt, conventionally tilled, clipped and cleared plots, respectively. The biomass in the experiment ranged from 0.92t ha⁻¹ for the ploughed plot to 20.92t ha⁻¹ for the undisturbed plot. The species richness for the plants decreased in the following order; clearing>conventional tillage>burning>clipping>undisturbed. These results show that disturbance regimes increased species richness but however decreased plant biomass. It is apparent that the management practice that ensures maximum biomass of grasses and herbs in dambos is maintaining them in their natural state. However, clearing seemed to improve species diversity compared to maintaining the dambo in its natural state.

1. Introduction

‘Dambos’ are seasonally waterlogged, predominantly grass-covered, low-lying areas that border headwater drainage lines (Akayombokwa Mukanda 1998). Dambos worldwide provide important natural resources and serve numerous purposes including environmental, hydrological and socio-economic functions. In addition, dambos provide products and possess attributes that are beneficial to almost all forms of life. Some of the functions that dambos provide include groundwater recharge and discharge, flood control, erosion control, sediment and toxicant retention, nutrient retention, water transport and microclimate stabilisation among many other functions (McCartney et al. 2005). Products that are provided by dambos include forage resources, wildlife resources, fisheries, forest resources, agriculture resources, and attributes that this ecosystem provides are biological diversity, aesthetic values and ethnic values (Chabwela 1994; United States Department of Agriculture (USDA) 2015). Dambos are centres of biological diversity, providing water and primary productivity upon which countless species of plants and animals depend for survival.

Dambos are widespread in Zimbabwe and are especially utilised during the dry season (Whitlow 1985), and they act like sponges that soak up water during the wet season and release it during the dry season (Dube 2005). However, these systems are fragile and have deteriorated due to human management activities such as cultivation, grazing and water abstraction. Dambo conservation practices have the potential to maintain different desirable services in this ecosystem, including the maintenance of plant diversity. Conservation practices like reduced tillage and vegetation management that removes undesirable species can help increase dominance by wetland species and thereby maintaining plant diversity and biomass (USDA 2015). Farmers can also use grass/crop combinations to mimic the ecological structure and function of dambos (Scher and McNeely 2008). Reduced dambo disturbance will also help in conserving seed bank diversity (Moffat & Mclachlan 2003).

Excessive pressure on wetlands results in degradation and eventual loss of their functions and biological diversity (Mharapara 1995). Biodiversity is the variety of plants, animals and other species in different ecosystems and helps in maintaining the biological functions of the environment (Naeem et al. 1999). Diversity of plants plays an important role in water purification, climate mitigation, air quality improvement and prevention of soil erosion (Pyne 1997). The
main causes of biodiversity loss are land use and land cover changes which may lead to the dominance of new invasive species at the expense of native plant species (Saha 2003). Biodiversity therefore reflects habitat functional condition and thus the capacity of an ecosystem to provide other services (Scherr & McNeely 2008).

In some parts of Zimbabwe, excessive pressure on dambos is due to intensive utilisation which includes growing vegetables and other food crops as well as grazing by livestock. In dambos, farmers use a variety of methods to prepare land and to control vegetation growth. Methods used include ploughing, cutting, weeding using hoes and burning to clear grass in preparation for tillage (Nyamadzawo et al. 2014, 2015a). In addition, dambos provide grazing for livestock and at times farmers burn to control pests and remove unpalatable grass species. Trilleras et al. (2015) note that such human activities or management practices involved in land management have an impact on the ecosystems. The disturbance regime depends on the duration of management practices as well as the intensity, magnitude and frequency (Trilleras et al. 2015). Burning is a very common method used in Africa for clearing fields, because it is an easy and fast way of clearing large areas of land. It also improves soil fertility and controls pests (Ojeniyi & Adejobi 2002; Waters 2007). Burning can positively affect the growth of grasses (above-ground biomass); fire releases a portion of nutrients previously held in plant biomass and quickly returns it to soil and stimulates new growth (Shah 2012). Mild fire is a necessary disturbance to achieve maximum grass species richness presumably by removing litter and increasing the availability of light (Fynn 2004). According to Vasey et al. (2005), burned areas host significantly higher species diversity; this is because the species exploit the post-fire conditions of reduced thatch and increased nutrients. In some instances, burning negatively affects species diversity and richness of grasses by eliminating some species of plants that are not fire tolerant and promoting the dominance of fire-tolerant species (Whitlow 1985).

According to Mathias and Middleton (1999), without some level of clipping in dambo ecosystems, diversity and biomass may decline because clipping of above-ground portions of emergent species can cause a reduction in oxygen level in the roots which can lead to death of some individual species. Tilling fatally damages grass rhizomes there by reducing the species diversity as well as biomass, but it is likely to encourage buried seeds to re-sprout (Mathias & Middleton 1999). The seed bank species diversity is greatly affected by disturbance regimes. A study by Moffat and Mclachlan (2003) concluded that seed bank species diversity was lower in disturbed sites than in undisturbed sites and that exotic species were mostly found in disturbed sites. Land preparation using the hand hoe is the main farmer tillage practice in most countries of Africa. In Uganda it was estimated that about 90% of the farmers use only hoes, while 8% use ploughs and 2% use tractors (Technical Advisory Division 1998). According to Ghadge and Satapathy (2003), most smallholder farmers in Africa follow traditional methods of cultivation by using indigenous tools like ploughs for land preparation as well as sickles for harvesting. These agricultural practices are strategies to provide food requirements for farmers, but the disturbance regimes could have significant negative effects on biodiversity (Mishra et al. 2003) and biomass of grasses and herbaceous annuals over time and may also have a negative effect on the seed bank composition and viability (Pawar et al. 2014).

The need for food has seen a lot of land cleared for agricultural purposes, including dambos. Dambos provide important resources, especially in semi-arid to arid regions which are prone to dambos. Dambos are cultivated, it is difficult to restore it to its original state (Classen, 2011). While it is a good economic strategy to improve the livelihoods of farmers, it may also result in unintended environmentally damaging actions and loss of plant biodiversity.

There is therefore need to evaluate the effects of different disturbance regimes on the biological characteristics of dambos. Johnstone et al. (2016) points out that disturbance can alter the state of the ecosystem thereby making it prone to degradation. They list disturbance frequency, severity, size and timing as examples of disturbance regimes (Johnstone et al. 2016). To date, little work has been done in Sub-Saharan Africa to determine the effects of the different disturbance regimes in dambos on plant species and biodiversity. Most research work has evaluated the effects of disturbance regimes on soil physical and chemical properties and water quality (Dube 2005; Nyamadzawo et al. 2014; Wuta et al. 2015). While Chigona (2005) studied the effects of cultivation on the biological characteristics of dambos, the study did not look at the specific methods of cultivation and the effects of burning, clipping and clearing using hand hoes. The objective of this study was therefore to evaluate the effects of disturbance regimes (i.e. burning, clearing, clipping and conventional tillage using
hand hoes) on species richness, diversity and biomass of grasses and herbaceous annuals and seed bank diversity. It was hypothesised that burning positively affects the biomass, species richness and diversity of grasses and herbaceous plants but negatively affects seed bank diversity, while clipping, clearing and conventionally tilling negatively affect the biomass, species diversity and richness as well as the seed bank diversity.

2. Materials and methods

2.1. Study site

This study was carried out in Chiota, smallholder farming area, on a dambo experimental site that was established in 2010 to determine the effect of disturbance regimes on soil organic carbon, nutrients and greenhouse gas emissions (Nyamadzawo et al. 2014, 2015a, 2015b). The dambo experimental site is made up of an upslope area or margin where water table rises but does not reach the surface. Main vegetation in this area includes Syzygium huillense scattered shrubs and grasses such as Hyperrenia sp. The mid-slope is the next catena position. It is saturated for a greater part of the year and the vegetation is dominated by grasses and herbs that tolerate waterlogged conditions. After the mid-slope is the lower slope with similar vegetation to the mid-slope. The bottom catena position is located down slope close to the stream and is dry for most of the times. Vegetation is similar to margins.

The field experiment was located in the saturated mid-slope position in the dambo. Chiota is located 70 km south of Harare (31° 05’ S; 18° 11’ E) and is in the Natural Region 11b. The average rainfall is between 700–800 mm and the mean annual temperature is between 16°C and 20°C. This area has mainly sandy soils derived from granite. In Chiota, dambos are found throughout the smallholder farming area, occupying an estimated 195 km², which is about 29.6% of the total land area (658 km²) (Bell & Roberts 1991). The dambos are a resource potentially available for use to all within the community, and current dambo utilisation and activities include grazing of livestock and growing of vegetables as well as other crops during both the dry and wet seasons.

The treatments that were evaluated were established in an area which was in its natural state and had not been tilled. All study plots were similar in initial vegetation structure. Natural dambos in Zimbabwe are seasonally waterlogged grasslands distinguished by a characteristic grass and sedge flora and a general absence of woody species (Whitlow 1984). A general absence of woody species is characteristic except on the fringes and on isolated termite mounds. In cultivated dambos, burning, biomass removal using hoes or clipping and conventional tillage are frequently used. Farmers burn to control pests and diseases and improve soil fertility (Nyamadzawo et al. 2014). A study by Nyamadzawo et al. (2014) reported that in Chiota dambo gardens, 99% of the farmers cultivate their lands using either ox-drawn ploughs (85%) or hoes (14%).

In addition to the field experiment, a greenhouse experiment was conducted during 2012–2013 at the University of Zimbabwe, Crop Science Department (17° 46’ 50.13”S; 31° 02’ 56.13”E). The greenhouse experiment was set up to determine the effect of disturbance regimes on germination of seeds in soils collected from the treatment plots.

2.2. Experimental design and soil sampling

A randomised complete block design was used for the field experiment. The experiment had five treatments, replicated three times and randomly applied in each block (Figure 1). Each plot was 1 m × 3 m and each block was 1 m × 19 m. The farmer practices that were evaluated were burning, clearing, clipping and conventional tillage which were done on an annual basis for 3 years. All treatments were applied every year in October just before the onset of the rainy season. Annual

| BLOCK 1 | Burning | Clipping | Clearing | Natural | Conventional tillage |
| --- | --- | --- | --- | --- | --- |
| BLOCK 2 | Conventional tillage | Natural | Burning | Clipping | Clearing |
| BLOCK 3 | Clearing | Clipping | Conventional tillage | Natural | Burning |

**Figure 1.** Layout of the field experiment in Chiota, showing five treatments (Adapted from Nyamadzawo 2015). Conventional tillage involved tilling using hoes; clipping involved cutting using sickles to 5 cm above ground; clearing involved scrapping off the vegetation using hoes; burning involved setting vegetation on fire during the dry season until all plants were burnt; natural state was the control.
burning involved setting alight the vegetation in the plots during the fire season (August to November), when dambo vegetation is dry. Clearing involved the removal of all the vegetation from the plots by scraping the surface using hoes and the biomass was removed from the plot. Clipping involved the cutting of vegetation using sickles at 5 cm above ground level and all the clipped biomass was removed. Conventional tillage involved digging up to 20 cm depth using a hand hoe. Under conventional tillage, some of the vegetation was incorporated into the soil. With the control, vegetation was undisturbed and was left in its natural state. Plant biomass, vegetation diversity and species richness were determined in all the treatment plots.

The second experiment was carried out in the greenhouse at the University of Zimbabwe. A randomised complete block design was used for this experiment. The experiment had five treatments replicated three times and randomly assigned to each block (Figure 2). Soil samples from the 0 to 10 cm depth were collected from each plot from the field experiment. The soils were collected in November 2012, before seed dispersal had begun. All the soil samples were then packed into polythene bags and taken to the University of Zimbabwe for use in a greenhouse experiment. The soils from the undisturbed, burnt, cleared, clipped and conventionally tilled plots were placed in pots of volume 2120 cm$^3$ and arranged in a randomised complete block design experiment. The soils were watered to field capacity every 3 days and the different species that germinated were left to flower before harvesting. All the plant species flowered within 11 weeks. Species identification was done at the National Herbarium, Department of Research and Specialist Services in Harare. The number of all the different species within each pot was noted to enable the Shannon–Wiener Index calculation.

2.3. Determination of species richness and diversity

Determination of species richness and diversity in the field experiment plots was carried out in April 2013 using the quadrat method as outlined by Dodd (2011). One quadrat of 0.5 m by 0.5 m was randomly thrown in each plot to determine the area of sampling. The number of different plant species in each quadrat was recorded and a sample for each species within the quadrat was collected by uprooting from outside the quadrat. The uprooted plant was placed between two sheets of paper, pressed and taken to the National Herbarium for identification. Species richness and diversity were determined by computing the index of species richness and the Shannon–Wiener Index (Magurran 2004). The formula used for the Shannon Wiener Index is shown as follows:

\[ H' = - \sum P_i \ln P_i \]

where \( P_i \) is the proportion of each species within a quadrat, \( H' \) is the species diversity and \( \ln P_i \) is the natural logarithm of the proportion of each species within the quadrat.

For the greenhouse experiment the number of different plant species per pot was recorded as well as the total number of plants found per pot to enable the calculation of the Shannon–Wiener Index. A sample for each species within the pot was collected by uprooting it from the pot. The uprooted plant was placed between two sheets of paper, pressed and taken to the National Herbarium for identification.

2.4. Determination of biomass

One quadrat of 0.5 m by 0.5 m was used to quantify biomass from the different disturbance regimes in each treatment plot. The quadrat was randomly placed within each plot and all the above-ground biomass of plants within the quadrat were cut and collected. The collection of plant biomass was done in February 2013, towards the end of the third season of the experiment. The collected plants were packed in paper bags, labelled and taken to the laboratory. In the laboratory, the samples were oven dried at 60°C.
for 48 h, after which each sample was weighed and the weights were recorded.

2.5. Data analysis

The MINITAB Statistical software 17.0 (MINITAB Inc 2010) was used to analyse the data using the two-way ANOVA procedure at $p < 0.05$ to determine the significance of each treatment on species diversity, biomass, species richness in the field and species diversity within the seed bank. The least significant differences were used to separate treatment means where there were significant differences.

3. Results

3.1. Impact of disturbance on species richness of grasses and herbaceous plants

A total of 17 different plant species were identified from the field experiment, with an average of 12 different species being found in the cleared plots (Table 1). Species richness was significantly different among the different treatments ($p = 0.013$, $F = 6.38$ and df = 14). The cleared plots had a significantly higher species richness than the undisturbed and clipped plots. The conventionally tilled and burnt plots had the same species richness as the cleared, clipped and undisturbed plots.

3.2. Impact of disturbance on biomass of grass and herbaceous plants

Biomass was significantly different among the treatment means ($p = 0.043$, $F = 3.49$ and df = 14). The biomass in the undisturbed plots was significantly higher than the other treatments, with an average biomass of 20.92 t ha$^{-1}$ (Figure 3). Biomass from the cleared, clipped, conventionally tilled and burnt plots was the same. The grass species *Paspalum urvillei* had the highest biomass in most of the treatment plots and the species *Buchloe dactyloides* had the lowest biomass of 0.0048 t ha$^{-1}$ and was only found in the conventionally tilled plot (Table 2).

3.3. Impact of disturbance on diversity of grasses and herbaceous plants

The cleared plots had a Shannon–Wiener Index of 1.70, and the dominant species in this plot was *Richardia brasiliensis* (Figure 4). The clipped plots had an index of 1.30. The undisturbed plots had a Shannon–Wiener Index of 0.53. The conventionally tilled plots had an index of 0.9. There was no significant difference in the species diversity among the treatments ($p = 0.263$, $F = 1.61$ and df = 14).

![Figure 3](image_url)

Figure 3. Treatments (conventional tillage, natural, clearing, clipping, burning) plotted against the biomass in t ha$^{-1}$. Means are indicated by the broken lines, the median is represented by the line, the length of the bars represents the standard deviation.

Table 1. The list of plant species and their relative counts in the different plots with different disturbance regimes (undisturbed, conventional tillage, clipping, clearing and burning) in Chiotia field experiment after three seasons (2010–2013).

| Plant species         | Undisturbed | Conventional tillage | Clipping | Clearing | Burning |
|-----------------------|-------------|----------------------|----------|----------|---------|
| Cyperus esculentus    | -           | 27                   | 4        | 1        | 25      |
| Bulbostylis buchanani | -           | 8                    | -        | 24       | 8       |
| Sesbania sesban       | -           | 1                    | -        | -        | -       |
| Cyanodon dactylon     | -           | 3                    | 5        | 4        | 7       |
| Kyllinga erecta       | -           | 3                    | 1        | 9        | -       |
| Hibiscus spp          | -           | 1                    | -        | 1        | -       |
| Richardia brasiliensis| -           | 10                   | 1        | 37       | 49      |
| Buchloe dactyloides   | -           | 1                    | -        | -        | -       |
| Paspalum urvillei     | 3           | 1                    | 4        | 11       | 3       |
| Conyla bananensis     | 6           | -                    | 1        | 6        | 1       |
| Senecio strictifolius | 10          | -                    | -        | 4        | 1       |
| Euphobia spp          | 3           | -                    | -        | -        | -       |
| Satyrium trinerve     | -           | -                    | 1        | 2        | -       |
| Senecio strictifolius | -           | -                    | 1        | 1        | -       |
| Commelina forskaoli   | -           | -                    | -        | -        | -       |
| Annual herb*          | -           | -                    | -        | 1        | 2       |
| Euphobia spp 2        | 2           | -                    | -        | -        | -       |

*Not identified herbaceous species
Hyphens (-) indicate absence of the plant species.
Table 2. The list of plant species and biomass in t ha\(^{-1}\) (± standard error) in the different plots with different disturbance regimes (undisturbed, conventional tillage, clipping, clearing and burning) in Chiota field experiment after three seasons (2010–2013).

| Plant species          | Undisturbed | Conventional tillage | Clipping | Clearing | Burning |
|------------------------|-------------|-----------------------|----------|----------|---------|
| Cyperus esculentus      | -           | 0.625 ± 0.327         | 0.005 ± 0.00 | 0.0131 ± 0.012 | 0.21 ± 0.18 |
| Bulbostylis buchanami   | -           | 0.1437 ± 0.0790       | -        | -        | 0.17 ± 0.088 |
| Sesbania sesban        | -           | 0.0079 ± 0.0079       | -        | -        | 0.09 ± 0.09 |
| Cyanodon dactylon      | -           | 0.0616 ± 0.0317       | 0.005 ± 0.00 | 0.336 ± 0.240 | 0.05 ± 0.05 |
| Kyllinga erecta        | -           | 0.0617 ± 0.0517       | 0.001 ± 0.00 | 0.102 ± 0.102 | -        |
| Hibiscus spp           | -           | 0.0088 ± 0.0080       | -        | 0.010 ± 0.010 | -        |
| Richardia brasiliensis | -           | 0.0003 ± 0.0003       | 0.006 ± 0.006 | -        | 0.26 ± 0.26 |
| Buchloe dactyloides    | -           | 0.0048 ± 0.0048       | -        | -        | -        |
| Psopallum urvillei     | 18.56 ± 9.32 | 0.006 ± 0.006 | 4.76 ± 0.19 | 1.04 ± 0.09 | 4.28 ± 0.19 |
| Corlyla bannahensis    | 0.702 ± 0.702 | -               | 0.13 ± 0.13 | 0.409 ± 0.409 | 0.14 ± 0.14 |
| Senecio strictlyfolius | 1.65 ± 1.61  | -                   | -        | -        | 0.02 ± 0.01 |
| Euphobia spp           | 0.0103 ± 0.03 | -               | -        | -        | -        |
| Satyrium trinerve      | -           | -                    | 0.013 ± 0.01 | 0.022 ± 0.021 | -        |
| Senecio strictlyfolius | -           | -                    | -        | 0.165 ± 0.165 | -        |
| Commelina forskoalli   | -           | -                    | -        | 0.028 ± 0.028 | -        |
| Annual herb*           | -           | -                    | 0.013 ± 0.01 | -        | -        |
| Euphobia spp 2         | 0.031 ± 0.031 | -               | -        | -        | -        |

*Not identified herbaceous species.

Table 3. List of plant species from the soil seed bank taken from the different plots with different disturbance regimes (undisturbed, conventional tillage, clipping, clearing and burning) in Chiota field experiment after three seasons (2010–2013).

| Plant species          | Undisturbed | Conventional tillage | Clipping | Clearing | Burning |
|------------------------|-------------|-----------------------|----------|----------|---------|
| Panicum coloratum      | Oldenlandia lancifolia Quercus marilandica Quercus marilandica Acrocerus macrum | -       | -       | -       | -       |
| Cenchrus ciliaris      | Senecio strictlyfolius Oldenlandia lancifolia Oldenlandia lancifolia Quercus marilandica | -       | -       | -       | -       |
| Quercus marilandica    | Cynodon dactylon Oldenlandia lancifolia Oldenlandia lancifolia | -       | -       | -       | -       |
| Oldenlandia lancifolia | Cynodon dactylon Senecio strictlyfolius Oldenlandia lancifolia | -       | -       | -       | -       |
| Cyperus esculentus     | Annual herb* Oldenlandia lancifolia Sabbania sesban Cynodon dactylon | -       | -       | -       | -       |
| Annual herb*           | Sabbania sesban Cynodon dactylon Eragrastis tennifolia Psopallum urvillei | -       | -       | -       | -       |
| Psopallum urvillei     | Annual herb* Cynodon dactylon Eragrastis tennifolia Psopallum urvillei | -       | -       | -       | -       |

*Not identified herbaceous species.

3.4. Diversity of the seeds in the seed bank following disturbance

The plants that germinated from the seed bank in the soil obtained from the conventionally tilled plots (Table 3) had a Shannon–Wiener Index of 2.74. The plants that germinated from the seed bank obtained from the soil from the cleared plots had an index of 2.37, while that from the burnt plots had an index of 1.96. There was no significant difference in the seed diversity among the treatments ($p = 0.806$, $F = 0.40$ and $df = 14$).

4. Discussion

The exploitation of dambos just like any other ecosystem changes their vegetation composition (Vitousek et al. 1997). Different disturbances in dambos changed the vegetation composition and aboveground biomass. Before the experiment the vegetation composition and structure were similar among all plots. The change in vegetation composition was evidenced by the differences in species found in the different treatments when compared to the undisturbed control. The change in biomass was also shown by the differences in biomass obtained from the different treatments compared to the control.

Biomass was significantly higher in the control treatments since there was no disturbance in these plots. Unlike the other plots, grasses in the undisturbed plots had dead plant matter which added to
the total biomass of the plot. However, the biomass in the burnt, cleared, conventionally tilled and clipped plots were similar. The burnt plots according to literature would be expected to have had the second highest biomass production and similar observations were reported by Nyamadzawo et al. (2014). According to Brewer (1999) there is generally an increase in flowering and herbage production after burning grasses although the response also varies with precipitation. In a separate study to determine the effect of burning and biomass removal using the same experimental plots, Nyamadzawo et al. (2014) observed an increase in soil nutrients in the burnt plots. Adeyolanu et al. (2013) reported that burning resulted in an increase in the nutrient contents in Ibadan, Nigeria. Monlen et al. (1997) and Wuta (2003) also reported similar increases in soil nutrient contents, immediately after fire. In addition, burning stimulates new plant growth and produces higher biomass during the rainy season as plants exploit the post-fire conditions of increased nutrient contents (Vasey et al. 2005). However the results obtained deviate from the hypothesis, this could be because fire eliminated some fire-intolerant plant species that produced more biomass and replaced them with some less biomass producing fire-resistant species (David 1993).

The clipped plots had a lower biomass compared to the undisturbed plots because clipping resulted in the removal of the above-ground biomass of grasses and herbaceous plants, this meant the removal of the plants’ photosynthetic tissue, resulting in loss of carbon and nutrients for growth (Ferraro & Oesterheld 2002). This therefore resulted in a decrease in the final vegetative biomass of the plants (Leriche et al. 2003). Although the biomass in the clipped plots was similar to that in the conventional tilled and the cleared plots, it would have been expected to be higher because of compensatory regrowth (McNaughton 1985). Compensatory regrowth is when plants partially or fully compensate for the removal of biomass.

The cleared plots had lower biomass production compared to the undisturbed plots because there was removal of standing biomass during the clearing hence a decrease in biomass. The conventionally tilled plots were expected to have the least biomass because deep tillage takes out the roots of the plants and therefore completely stops propagation from the somatic cells. Generally dambo disturbances can result in reduced plant above-ground biomass. Crosslé and Brock (2002) reported that disturbances may result in some species producing reduced biomass and reproduction. The results for the cleared, clipped and conventionally tilled plots tally with the formulated hypotheses as well as literature.

The analysis of the diversity of grasses and herbaceous plants in the dambos showed that there was no significant difference between the treatments. This result however deviates from literature and the formulated hypotheses which state that there would be a significant difference in the diversity of the disturbed plots compared to undisturbed plots. According to Sanyaolu (2015), burning of vegetation results in decreased biodiversity of herbaceous species, burning may however also increase the diversity of fire-tolerant plant species. The treatments in Chiota showed no significant differences in the diversity of grasses and herbaceous plants in the dambos because the plots were subjected to disturbances for only three seasons. It is possible that if the treatments were for a longer period, significant differences could have been observed, since according to a research done by Busso et al. (2004), undisturbed plots showed a significantly lower species diversity than the burnt treatment after 9 years. In the same experiment it was noted that the species diversity of plants from the undisturbed plots and the burnt plots during the first 4 years of the study was not significantly different. The change in species diversity was only noted after 4 years.

There was a significant difference in the species richness of the cleared plots compared to the control and the clipped plots. According to Truus (2011), clearing and clipping increases species richness but decreases biomass, thus creating more space and favourable conditions for more plant species. Bakker (2007) demonstrated that clipping reduces the vigour of tall plant species that are competitive allowing smaller species to co-exist; this therefore might explain why the species richness in the clipped plots was higher compared to the undisturbed plots. Rerbejen (2002) states that species richness in wetlands increases with grazing, because grazing reduces the dominant species that exclude less competitive species; this therefore allows the less competitive species to thrive. While according to David (1993), fire reduces the species richness of an area by eliminating fire-intolerant species, and this may result in the dominance of less biomass producing fire-resistant species. In this experiment the species richness was significantly different among treatments while the species diversity was not significantly different because species richness only takes into account the number of different plant species present within an environment while diversity takes into account the richness as well as the evenness or distribution of the different plant species within an environment (Bock et al. 2007). According to Wilsey and Stirling (2007), species diversity index does not always positively correlate with species richness. Species richness and diversity can be influenced by different processes, with richness being influenced more by the number of plants present as well as the number of emerging
seedlings, and diversity influenced more by species interaction like competition; this might explain why the species richness and diversity of the same field gave different conclusions.

Germination tests showed that there was a diverse plant population in the dambo. There were five species that germinated in the greenhouses that were not found in the dambo. However, there were no significant differences in the number of species that germinated between treatments indicating that the experiment did not impact on the seed bank over 3 years. According to literature, conventional tillage reduces the number of seeds that germinate by probably burying a large number of seeds deep in the soil although it promotes other species to germinate (Narwal et al. 2006). According to another study by Cheam and Lee (2009) conventional tillage decreases seedling emergence because when tilling, seeds are buried deep into the soil. Maximum emergence is from shallow depths of around 1 cm for the majority of species; large seeded species can germinate from greater depths if conditions are suitable but rarely from 15 cm or more. According to Dekker (1997) cultivated seed banks have numerous species present because of disturbance which helps in seed dispersion. Majority of seeds in no till fields/undisturbed fields are located in the upper 2 cm of the soil profile, and nearly the entire seed bank can be found within 10 cm, while for the cultivated or tilled fields there are deeply buried seeds that probably would not germinate until they are brought near the surface (Dekker 1997).

The majority of species in the seed banks were herbaceous plants compared to the grasses that dominated the above-ground composition. Comparing the above-ground vegetation composition per treatment against its seed bank composition indicates that the seed bank has a more diverse plant community. The reason for the difference may be the soil samples collected were disturbed and inverted during the sampling; this could have brought seeds buried deep into the soil onto the surface and allowed them to germinate, while those seeds already on the surface were buried deep. Another reason for the difference in vegetation composition between the seed bank and the field could be that the greenhouse conditions were conducive for the germination and growth of certain plant species while the conditions in the field could not allow them to grow. There were no other plants disturbing the growth of plants in the greenhouse and this meant less competition among plants for light and nutrition.

Cultivation usually opens up new niches and encourages the proliferation of weeds (Davies et al. 2000), hence the higher species richness in all the plots subjected to disturbances. At low disturbance levels, species richness is controlled by the seed bank while at moderate disturbance levels species richness is controlled by niche availability (Dickson & Foster 2008). This explains why the species richness was higher in the clipped, burnt, cleared and conventionally tilled plots.

5. Conclusions
Different disturbance regimes changed the vegetation composition and above-ground biomass in the dambo. The change in vegetation composition was evidenced by the differences in species found in the different treatments when compared to the undisturbed control. Dambo disturbances resulted in a significant reduction of plants biomass. The undisturbed plots had the highest biomass, followed by the burnt plots, clipped plots, cleared plots, and the plots with the least biomass were the conventionally tilled plots. There was no significant difference in the species diversity of the plants between the different disturbance regimes. Clipping, clearing, burning and conventional tilling of dambos increased the species richness of plants relative to the control. There were no significant differences in the seed bank germination between the different treatments. From the study carried out it is concluded that while disturbance regimes in dambos increase plant species richness, they however decrease the biomass of plants. It is apparent that the management practice that ensures maximum biomass of grasses and herbs in dambos is maintaining them in their natural states. However, clearing seemed to improve species diversity compared to maintaining the dambo in its natural state.

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