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# Herbivory as a Tool in Conservation of Biological Diversity in Rangelands - Review

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## ABSTRACT

There is a global concern on how the biodiversity can be maintained. Competition has a high importance in maintaining diversity, but there are mechanisms like disturbances that eliminate competition that may cause variations in species richness. Animals play a crucial role in influencing species composition and distribution in an environment. Although some studies have shown positive theoretical and practical results of herbivory, consequences are still debated among ecologists. Understanding of the herbivory contribution to biological diversity conservation and responses by plants in most regions can be the basic starting point in predicting the sustainability of plant species that can serve an ecological niche globally. The use of herbivores as biological controls and weed control has offered environmentally friendly alternative to herbicides as well as cost effectiveness and sustainability in biodiversity conservation. Timing of herbivory and herd density utilization, offer a mechanism that can manipulate ecosystem for positive results. Therefore, managing mammal densities rather than monitoring their effects could be a better approach in improving biodiversity. Large herbivores require high quantity and less quality plants and the reverse for small herbivores, thus, the plant abundance and quality requirements should differ for different herbivores depending on body sizes. This behaviour helps create plant heterogeneity or high biodiversity. Thus, this review may provide may provide more information that would be useful in establishing the relationship between herbivore and plant species diversity identifying existing and potential challenges pertaining to variation in the vegetation structure and other indices as influenced by grazing.

***Keywords:*** herd size, insects, species richness, large herbivory, sustainability.

## 1. INTRODUCTION

Biological diversity plan provides a framework for biodiversity conservation in which countries can work on. Maintenance of biodiversity is important for ecosystem health and function, as it regulates species balance and species composition. A diverse habitat has a higher chance of recovery after disturbance compared to a habitat with low biodiversity, for example islands [1]. Biodiversity has been recognised as one of the greater wealth of the planet [2]. Biodiversity is variability within and between species in living organisms up to the ecosystem level with complex compositions and structure in a spatial scale [3].

Many ecologists [4,5], have coined theories that attempt to explain the maintenance of biodiversity and majority of them point in the direction of competition as being very important. Plant species and livestock competition has a high importance on maintaining diversity, but there are mechanisms that eliminate competition that may cause variations in species richness [5]. One of the contributing factors in the elimination of the competition hence influencing diversity is the disturbances [4]. Biodiversity conservation efforts must include disturbance processes and responses [6]. One hypothesis that explains the interaction of disturbances and plant species diversity is called the intermediate disturbance hypothesis. It predicts that plant

composition will be in abundance following moderate to light disturbances and intermediate interval following disturbances [7], the basic assumption being that species have the ability to compete and tolerate disturbances. Plant species composition and their abundance in general is always influenced by the disturbances [7].

Herbivory can affect species richness and these effects depend on class of herbivory in a specific environment [8]. Insect herbivores often reduce plant biomass, but the dominance of certain specialist of herbivory to dominant plant species changes the diversity of plant distribution [9].

Human activities through the introduction of exotic species, (and weeds), and habitat degradation can cause loss of biodiversity [6,10]. Invasion from alien species and weeds can occur quickly, owing to absence of natural enemies [10].

The main question of this paper is; can areas that have been invaded by alien plants and those that have been turned into shrubland due to overgrazing, be restored to original or be managed using herbivory as a tool? This review will discuss; Effects of mammals and insect herbivory on plants, to show their significance in maintaining biodiversity as well as herbivory used as biological control of alien invasive species and weed control in ecological restoration and increasing biodiversity. It will also show ways of how to use the herbivory.

## 2. Mammal and insect herbivory effects on plants

Herbivory is defined as the taxonomically and ecologically diverse species from those visible through zooplankton to large vertebrate including the most conspicuous terrestrial herbivory such as insects and mammals [11]. The view of [12], was that the flow of energy and nutrients alteration of either changes ecosystem function or structure link the belowground with aboveground processes in terrestrial ecosystems. These are functionally related i.e. a change in one component influences all others.

There are several trials that displayed the positive contributions of herbivory on plant species productivity, often referred to as 'grazing optimization', and these include enhancement in the plant primary productivity successes in biomass [13]. For a healthy and productive rangeland there should be lower intensities of herbivores and not holding down the ability of plants to recover from grazing, and should leave sufficient residue for soil maintenance so as to stimulate re-vegetation through raw materials. This will create a balance between herbivory and the plant species diversity [8].

In African savannas herbivores have noticeable effects on plant composition ranging from determination of both species composition and regulation of the balance between tree and herbaceous layers [8, 14]. Large mammals such as bovines have a role when short duration high density grazing system is introduced because they can deal with unpalatable or out of reach vegetation [15]. Mammalian herbivory is most important in moderate production area where vegetation can support moderately high density of herbivores with low food requirements [13].

### 2.1. Nutrient Cycling

Insect herbivory has influence on forest structure composition and function through nutrient cycling [16]. When insect feed on canopy plant material, plant green mass, plant tissue and frass (faeces) are produced which can be deposited on leaves or it reaches the soil through precipitation or directly falling to the ground. Insects deposit 1- 4% of annual nitrogen deposition through frass on plant litter and soil and nitrogen from the frass returned to the soil is double the overall rate since the nitrogen comes from two sources [17], an influence in quality and quantity of litter [18]. Precipitate in the forest mixes with the frass and when it reaches the soil it adds nutrients to the soil. High insect herbivory defoliation affects net primary production negatively and the effects are felt in folds during

outbreak events [12]. In experiment by [19], it was found that, frass may contain labile carbon which can stimulate microbial growth and immobilize extractable nitrogen; this immobilization represents an efficient mechanism for maintaining nitrogen in the forest ecosystem after browsing. Some trials linked browsing by large and small herbivores to altered rates of nitrogen and carbon cycling [17], localized urine and faeces deposition being one example [9,18].

**Plant Growth Promotion and Growth Reduction**

One way in which mammals negatively influence the plant composition is through damaging seeds or when plants are at their vegetative stage [16,20]. Species which are less frequent on the ground can be maintained if insects and large herbivors can preferentially feed on competitive plant species seeds and small plants together with those plants that are at vegetative stages [16,18,20].

Disturbances by digging mammals or trampling create openings in soil, that increase light and nutrient in the soil, and these soil disturbances encourage germination from seed already in the soil [9, 21]. Intermediate digging herbivores create connected tunnels on larger areas disturbing soil, increasing aeration and mixing of soil that may increase plant diversity [9]. High grazing or browsing pressure and selective foraging on rare or high grazing value plant species especially forbs may influence the dominance of only less tolerant plant species [9,21].

Even though it is well known that grazing normally reduce the biomass accumulation, it also has the positive contribution to the quality of the forage through especially nitrogen concentration [22]. This normally happens through reduction of aged plant material and moribund, maintaining young leaves as well as maintaining the raw materials belowground [13].

## 3. Role of herbivory on ecological restoration

### 3.1. Herbivory used as a Biological Control of Alien Invasive Plants

The application of biological control organisms is used in an attempt to lower the intense effects of target and come up with alternative species with a competitive advantage [23]. In other studies, the biological controls were successful with the aim of trying to reduce the spread of invasive species through providing environmentally friendly solution. This can be an alternative to other control in weed management. The biological control normally attacks even non targeted native plants that can compete or play an ecological role in the ecosystems. Depending on the type of weed or invasive plant, one can choose biological control that attack roots or leaves [24]. Some of the host specific biological control agent such as Crytobagous salviniae, are known to have controlled weeds such as Salvinia molesta in Kariba Dam [25].

The use of these biological controls may come with expenses. Some biological controls can induce compensatory growth, and produce defensive secondary metabolites [23]. Above-ground agents can suffer heavy parasitism by native parasitoids or severe predation from generalist predators [24]. Below-ground controls can be a better option, since; they are concealed from predators and parasites [24,26]. Insect which depends on roots as feed can prevents compensatory growth through elimination of new roots development, but mechanical pruning of roots, which has also been tried before, can results on retarding the shoot growth [24]. The frequency of feeding on roots by insect herbivory often results in continuous root damage, of which this can serve as an alternative to mechanical pruning or the use of herbicide [23], and this can the only cost effective method because once initiated, the control is often self-sustaining [26]. Therefore, the weed system needs to be well understood enough so that the relationship between the species can be

controlled to come-up with the dramatic changes in population densities of the control agent [25,24].

### 3.2. Large Mammals used in Weeds Control and to increase Biodiversity.

Manipulation of mammalian herbivory is based on selective grazing, and for weed control to be effective there should be high intensity of grazing which can assist in preventing unwanted plants from regenerating lost tissues leading less production of seeds [27]. Mammals have been used in experimental restoration, to find if their foraging has important impacts on species richness and biodiversity and for weed control [8, 27]. There is not much work published especially on wild mammals but experiments have been done using domesticated mammals like sheep, horse and cattle [27,28]. The methods that are commonly used are construction of enclosures to find out the effects of grazing, intensity of grazing and density of grazing mammals and exclosures that keep animals out of areas.

Sheep have been used as weed control on leafy spurge where chemical and mechanical controls had failed [27]. The sheep grazing reduced the abundance of the plant but could not eradicate the weed hence it was suitable as a long term control [27,28]. The most important things that had to be looked at for the control to be a success was the fact that the sheep were selectively feeding on the weed, at very high intensity and at the precise time when the weeds were very vulnerable. The timing was when the seedlings and young plants had not flowered and no seeds were produced. Grazing by multiple mammals has also been studied in an attempt to find effects of a combination of herbivore species using domesticated animals. In multiple grazing there will be animals that follow the other in grazing succession, since one animal does not tolerate latrine areas of the other and that grazing of one animal expose plant parts grazed by the other. In an experiment with horses and cattle grazing, [28] found that, horses do not tolerate cattle latrine areas but cattle can graze in horse latrine areas. Horses grazed on one type of plant and open patches for cattle to graze on another creating heterogeneity in the vegetation. Cattle herbivory increased total basal cover, good grass coverage while goats reduced forbs, at the same time cattle increased their average daily gain [29]. This is both beneficial to those animals and the plants as well.

Construction of exclosures, have been used to keep mammals out of areas and prevent foraging on plants or restrict how frequent they can utilize plants in these areas [30]. This is because mammals grazing especially wild ungulates are difficult to manipulate, and cannot be moved around, but their densities and intensity of grazing can be regulated to suit localized habitats [21,30]. These exclosures based experiments has allowed scientists to manipulate herbivore composition and established the relationship between browsing animals and the type of grazing system used [21]. Use of semi-permeable exclosure has also been used to study interactions between large and small grazing mammals and to study plant heterogeneity caused by grazing of different species [21].

The following are factors that influence the use of herbivory as a conservation tool are proposed:

#### 3.2.1. Herd size and density

Herd size and density influences grazing selectivity [14, 31,32] nutrient cycling and forage quality. Heavy grazing keeps grassland at young stage with high quality. Thus, two ranches with different herd size and density but the same stocking rates are likely to have difference in grassland structure and composition. Based on this, an area that has weeds that need to be removed will be put under a high pressure grazing using a big herd, while small herds are used to encourage recovery and can be used with other methods of rehabilitation to reverse degradation.

Therefore, managing mammal densities rather than monitoring their effects could be a better approach in improving biodiversity [8]. Studies done on food preference and long term exclosure experiments show that in forest ecosystems forage selectivity can change abundance of palatable species, while generalist foraging increase fitness [14]. Large herbivores require high quantity and less quality plants and the reverse for small herbivores, thus, the plant abundance and quality requirements should differ for different herbivores depending on body sizes [30]. This behaviour helps create plant heterogeneity or high biodiversity. In multiple grazing, plants and animals interact in such a way that they follow one another in a sequence, grazing succession [14].

To give other examples; in [32], at double the stocking rate total live output was almost double times higher in intensive grazing than extensive grazing. As [33] put it; animal production per unit area is highly reduced under extensive grazing. Cattle and bison have been found to be more selective in grazing at large patches than smaller ones. This behaviour changes when now the animals are moving in large herds as they are forced to graze homogeneously [34]. Short, high quality grassland can only be maintained when herbivores attain a critical density and herd size [34].

Large herbivores such as elephants and antelopes in the tropical and Africa and Indian sites regions do not only change the structure and number of plant species but transform forest biome to grassland biome [20]. Large migration with high grazing intensity keep grasses short, at an early phonological stage with high quality preventing cluster grass from invading [34]. The input from mass urinating and dung of migrating animal encourage compensatory growth of grass and induce lawns. In another study, [31], found that rigorous grazing by dense mobile herds of cattle tracking fire patchiness from year to year greatly stimulated N mineralization relative to more diffuse herds. Similarly modelling work showed that N mineralization and aboveground net primary production (ANPP) were enhanced by migration but not sedentary herbivores at high grazing intensities because of forage was left to rest during the growing seasonal in the migration scenario [35]. Researchers have also realized the importance of movement and spatial aspects of pastoralism as the one practiced by the Masai [36]. This therefore means that herd if used has to be coupled with movement to prevent negative effects. Although multiple ungulate species are known also in influencing the species diversity following defoliation without being controlled during grazing, several studies have shown that mass migration in grazing succession following precipitation works well and high densities of ungulates can be adopted or supported [37].

### 3.2.2. Timing of grazing/browsing

Grazing plants at an early growth stage has an effect on the reproductive process, thereby affecting the plant fitness. The parts that are notably removed during herbivory are leaves and meristems where generally reproduction occurs. In [38], plants that had a high leaf and meristem removal had low amounts of flowers and low seed mass. It is believed that leaf removal triggered resource allocation to vegetative parts instead of seed production or reproduction. In [39], the size of reproductive organs reduced with severity of defoliation. Reproduction is important for life cycle to be complete. Herbivory on its own does not normally cause mortality unless if it is intensive and frequent. However, coupled with other phenomena like competition weakened plants will not survive. In an interaction between herbivory and competition compensatory growth should occur. This is a positive response for productivity and species richness in cases where different plant species are affected. Where there are other forces at play the situation may not be favourable. The compensatory continuum hypothesis states that seedling growing under favourable conditions will be less affected by herbivory

while those under unfavourable conditions will have high negative effects [40]. Manipulations of herbivory at early stages of growth therefore should be carefully planned with all other conditions made favourable. The other effect that can be used is the timing of elongation stage time or season when the leaf/meristem removal occurs. Disturbance done during vegetative or seedling stage has less effect compared to removal done closer to late growing season and closer to flowering stage [38] this coincides with high nutrients and water availability.

There is an indication that there is a higher reproductive success on annual and biennial species that have been eaten earlier when compared to those eaten late during the end of growing season. [39] and this normally affects the reproductive stages during next growing season because plants grazed earlier in the season were able to go back to vegetative stages when compared to those grazed late growing season [38,39]. These authors have indicated that both early and late grazing can also have the detrimental impact on certain plants.

## 4. CONCLUSIONS

Mammalian herbivory manipulation is based on selective grazing, and for biodiversity conservation to be effective there should be better intensity of grazing to maximise plants regenerating lost tissues and when the seedlings and young plants had not flowered and no seeds were produced. Therefore, managing mammal densities rather than monitoring their effects could be a better approach in improving biodiversity. Large herbivores require high quantity and less quality plants and the reverse for small herbivores, thus, the plant abundance and quality requirements should differ for different herbivores depending on body sizes. This behaviour helps create plant heterogeneity or high biodiversity. In multiple grazing, plants and animals interact in such a way that they follow one another in a sequence, grazing succession.

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