

Plant Species Composition and Distribution in Relation to Wildebeest Calving Periods in the Short Grassland Plains in Serengeti Ecosystem

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Abstract

The wildebeest migration plays a crucial role in shaping the Serengeti Ecosystem, influencing the composition, diversity, and abundance of plant species that support the population. This study examines the impact of wildebeest grazing during three distinct periods: before, during, and after calving, in the short grassland habitats of the Serengeti Ecosystem, particularly in the Ngorongoro Conservation Area, Loliondo Village Land, and the Pololeti Game Reserve. A survey was conducted with 12 transect lines, each 2.5 km in length, with four lines in each zone (Southern, Eastern, and Northern) for vegetation and forage sampling. The results revealed a total of 123 plant species from 26 families. Of these, 59.3% ($n = 73$) were classified as herbs, 32.5% ($n = 40$) as grasses, 4.9% ($n = 6$) as sedges, and 3.3% ($n = 4$) as climbers. The plant composition across different wildebeest time periods and sites showed variations in species number, abundance, and plant heights. The interaction between plant composition, site, and calving period revealed significant differences in species numbers ($P = 0.0001$, $P = 0.0021$, respectively), indicating that site location played a greater role than wildebeest calving periods. Additionally, plant heights were significantly different in relation to wildebeest grazing periods (before, during, and after calving) ($P = 0.0016$). Furthermore, the results indicate that mean plant heights were most affected during the calving period, likely due to intense foraging driven by high wildebeest density. In conclusion, the study underscores the importance of wildebeest in maintaining variations in grassland habitats and plant heights within the short grassland ecosystem. Future studies should focus on long-term monitoring of plant life forms to better understand the causes of variations observed across the surveyed sites

within the wildebeest calving range.

Keywords

Grassland Habitat, Life Forms, Serengeti Ecosystem, Species Composition, Wildebeest Grazing

1. Introduction

The African savannah is a vast ecosystem characterized by open grasslands with scattered trees, shaped by seasonal rainfall and periodic fires [1]. In African protected areas, herbivore grazing patterns in savannah habitats are influenced by seasonal rainfall, forage availability, and predator-prey dynamics [2]. Herbivores often move in large herds, especially during migrations between wet and dry season ranges, driven by the search for fresh grazing areas as the seasons change [3]. Large herbivores such as wildebeests, zebras, and gazelles follow specific grazing patterns that contribute to the ecological balance of the ecosystem.

A study by [4] showed that herbivores tend to move in response to the availability of fresh grass, often tied to the timing of the rainy season. This seasonal movement helps prevent overgrazing in specific areas by allowing grazed regions time to recover and regenerate, thereby maintaining the overall health of the ecosystem. In this context, grazing habits refer to: i) Feeding behavior, such as selective grazing, which can lead to the dominance of less preferred or unpalatable species. For example, in our study area, we observed that *Chloris pycnothrix* tends to dominate grass communities. ii) The removal of large amounts of grass biomass, as large herbivores require more food to meet their energy needs. This grazing can increase the availability of low-growing plant species, which are more accessible to smaller herbivores like gazelles. These smaller herbivores, in turn, influence plant diversity by preventing certain species from becoming dominant [3]. Furthermore, herbivore presence affects the structure of the savannah. Their grazing promotes the growth of nutritious vegetation, supporting a wide range of species, including smaller herbivores and predators [4].

Grassland habitats in savannas play a crucial role in supporting herbivores by providing essential resources such as food, shelter, and ecological stability. The primary food source for herbivores like zebras, wildebeests, and antelopes comes from grasses, which are rich in nutrients and energy [5]. These herbivores rely on grass to meet their dietary needs, with the seasonal growth of grass offering a cyclical food source that aligns with the wet and dry seasons in the savanna [6]. Grazing by herbivores helps maintain the open structure of grasslands by preventing the overgrowth of shrubs and trees, thereby ensuring the continued availability of space and food for herbivores [7]. Additionally, herbivores contribute to nutrient recycling by consuming plant material and returning nutrients to the soil through excretion, which supports plant growth [8]. Grasslands also support smaller herbivores, such

as insects and rodents, which in turn serve as prey for predators—creating a balanced food web within the ecosystem [9]. Overall, grasslands are integral to the survival and ecological function of herbivores in savannas, providing the essential resources needed to sustain both plant and animal life in these ecosystems.

The wildebeest migration in the Serengeti ecosystem is one of the most remarkable natural phenomena in the world, occurring annually. Approximately 1.5 million wildebeest, along with hundreds of thousands of zebras and gazelles, undertake a circular migration across the Serengeti-Mara ecosystem, which spans both Tanzania and Kenya [10] [11]. This migration is primarily driven by the need to find fresh grazing and water in response to seasonal rainfall. As the herds follow the rain, their grazing patterns support the regeneration of vegetation by reducing overgrazing in any single area [4]. In turn, the large congregations of wildebeests attract predators such as lions (*Panthera leo*), cheetahs (*Acinonyx jubatus*), and spotted hyenas (*Crocuta crocuta*), helping to maintain predator-prey dynamics and overall biodiversity in the Serengeti ecosystem [12].

The migration begins in the southern and eastern Serengeti, where wildebeests give birth to their calves during the short rains. This timing ensures that the newborns have access to nutrient-rich grasses that emerge after the rains [13]. During the wet season, two distinct herds can be identified: the Laetoli/Kakesio Herd, found in the southern Serengeti within the Laetoli and Kakesio regions; and the Loliondo/Pololeti Herd, which uses the Angata Kheri area within the Loliondo Village Land [11]. Wildebeest grazing thus supports a complex web of ecological interactions, contributing significantly to the health and stability of the Serengeti's ecosystems [4].

Within the short grassland habitats of the Ngorongoro Conservation Area (NCA), Loliondo Village Land, and Pololeti Game Reserve in the Serengeti Ecosystem, wildebeests utilize these areas for calving due to the presence of nutrient-rich grasses. These grasses support the health and growth of newborn calves during the calving season, increasing their chances of survival. These habitats are characterized by abundant resources and strategic locations that are critical to the wildebeest migration cycle and population dynamics within the Serengeti.

As a key grazing species, wildebeests play a vital role in shaping vegetation dynamics, making it essential to understand how their grazing behavior influences biodiversity, vegetation structure, and the resilience of grazing rangelands in these areas. Their broad migration patterns are influenced by specific environmental cues, including temperature fluctuations, localized rainfall, soil moisture, and forage availability, which trigger daily or weekly movements. Despite this general understanding, there is limited detailed data addressing the following research questions:

- a) How do grass species composition, abundance, and coverage vary across the short grasslands (southern NCA, northern, and eastern Loliondo) during wildebeest presence: before calving, during calving, and after calving?
- b) How are indicator species (*i.e.*, plant species most preferred by grazing wildebeest) distributed across specific sites before, during, and after calving?

c) How does vegetation structure—considering different plant lifeforms such as grasses, herbs, and sedges—vary before, during, and after calving in wildebeest grazing areas (southern NCA, and northern and eastern Loliondo)?

d) To what extent does wildebeest grazing influence the height and regrowth patterns of different vegetation lifeforms before, during, and after calving across the study sites (southern NCA, and northern and eastern Loliondo)?

2. Methods

2.1. Study Area Description

The Serengeti ecosystem contains the largest protected tropical grassland and savanna in the world. It is largely defined by the annual migration of wildebeests and spans latitudes 1°28' to 3°17'S and longitudes 33°50' to 35°20'E, covering an area of approximately 30,000 km² [9]. The ecosystem includes several protected areas (PAs) on the Tanzanian side, such as Serengeti National Park, Ngorongoro Conservation Area, various game reserves (Kijereshi, Ikorongo, Grumeti, Pololeti, and Maswa), Loliondo Village Land, Wildlife Management Areas (Ikona and Makao), and Mwiba Wildlife Ranch [14]. The region is home to diverse ethnic groups, including hunters and gatherers, pastoralists, and agro-pastoralists [15]. However, rapid human population growth and associated agricultural expansion around the boundaries of these protected areas are reducing available resources for wildlife [16]. The main grazing species in the ecosystem include wildebeest, zebra (*Equus burchellii*), Thomson's gazelle (*Gazella thomsonii*), buffalo (*Syncerus caffer*), and topi (*Damaliscus korrigum*), alongside large carnivores [10]. Rainfall varies across the ecosystem, with mean annual precipitation increasing from around 350 mm in the southeast—within the rain shadow of the Crater Highlands—to about 1200 mm in the northwest [17]. The wet season runs from November to May, while the remaining months constitute the dry season.

This study was conducted in the Ngorongoro Conservation Area (NCA), which was divided into three zones: the Southern Zone (Southern NCA), the Eastern Zone (Pololeti Game Reserve and Salei Grassland), and the Northern Zone (Loliondo's Angata Kheri and Sukenya Plains). In each zone provide a suitable habitat for wildebeest during the breeding season. The southern zone, which consists of areas such as Ubuntu, Laetoli and Kakesio are found in the Ngorongoro Conservation Area. The eastern zone is open grasslands which expands to the Great Rift Valley that splits the Serengeti and Maasai Steppe ecosystem. The northern zone consists of open grasslands however surrounding the grasslands are *Vachellia* woodlands, with two distinct habitats which include the Angata Kheri in the southern part of the Northern Zone and Sukenya Plains in northern part of the northern zone. Angata Kheri is in the south of Loliondo's Waso, which is mainly an open grassland, however the Angata Kheri and Sukenya areas have a small plain with whistling acacia thorns (*Vachellia drepanolobium*) trees.

The study was conducted across three main survey zones within the Ngorongoro Conservation Area (NCA): the Northern, Eastern, and Southern zones (Figure 1).

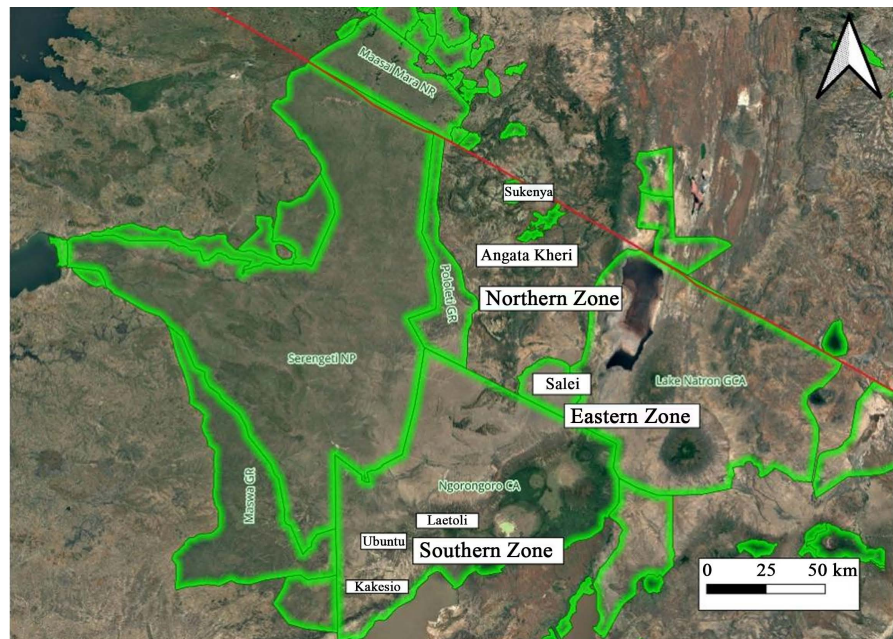


Figure 1. A map showing the main surveyed zones of the NCA including Southern, Eastern and Northern zones.

2.2. Data Collection

The study established a total of 12 transect lines of 2.5 km in length, four in each zone (Southern, eastern and northern) for vegetation sampling. In each zone, the transects were established randomly at least 5 km apart along the direction for foraging wildebeest [18]. On each transect, six sampling points were marked using GPS with 500-meter intervals [19]. Within each sampling point a major circular plot of 20 meters radius was established with five circular quadrats measuring 1 sqm placed one at center and four corners (north, south, east and west) for vegetation sampling [20]. The transects and plots were designed with replicate of four times per zone [21]. A total of 1080 observations were made from 12 transects selected in 6 major points each with 5 quadrants sampled 3 times (before, during, and after). The assumption that since the survey areas are grassland vegetation the plant diversity across would be lower than within, therefore with many observations/samplings within would help obtain more information than between. In each quadrat, the vegetation cover was estimated visual based on the proportion of bare land. All plant species were identified and individuals of each species counted within the quadrat as measure of species richness and abundance, respectively. The height of the individuals was measured by using an ordinary measuring tape (tallest, medium and shortest if there was an occurrence of more than once).

2.3. Analysis

The composition of plants was analyzed descriptively. In this case, data on species recorded, counts, and stem heights were pooled together to provide the total species composition in each plot and wildebeest calving periods. The total count of

species and individual stems of all species was calculated per plot for number of species and abundance, respectively. The importance value index (IVI) was calculated as a sum of percentage values of species relative frequency and relative density. To assess the variations in plant species, abundance, and height between wildebeest calving periods and zones and their interaction, the species and individual stems densities, and height of plants at plot level was calculated and subjected to analysis of variation using Two-way ANOVA. A Post hoc test was performed using Tukey's HSD test at 5% level of significant within the ANOVA results to examine the differences between time periods by contrasting the estimated means. The visual plotting of data for each variable was used to check for normality assumption. Also, homogeneity was performed.

3. Results

3.1. Floristic Composition

A total of 123 plant species belonging to 26 families were recorded from the three study sites across the three observation periods (**Appendix**). Of these, 59.3% (n = 73) were categorized based on growth habits as herbs, 32.5% (n = 40) grasses, 4.9% sedges (n = 6), and 3.3% climbers (n = 4). Between sites, about 89 species were recorded in Migration sites while 86 and 48 were recorded in Southern, Northern, and Eastern sites respectively. The composition of plants between wildebeest time periods and sites (**Figures 2-4**) shows the presence of variations in the number of species, abundance, and plant heights.

3.2. Species Importance Value Index (IVI)

The results in **Appendix** show the species with the highest importance value index (IVI) greater than one percentage for the period before, during, and after wildebeest calving in each zone. In Eastern zone, the topmost three plant species for the period before wildebeest calving were *Eragrostis racemosa* (Thunb.) Steud., *Cynodon dactylon* (L.) Pers., and *Indigofera* sp, while for the period during wildebeest calving were *Indigofera* sp, *Sporobolus ioclados* (Nees ex Trin.) Nees., and *Cynodon dactylon* (L.) Pers., and for the period after wildebeest calving were *Indigofera* sp, *Sporobolus ioclados* (Nees ex Trin.) Nees., and *Cynodon dactylon* (L.) Pers. In Northern zone, the topmost three species for the period before wildebeest calving were *Eragrostis tenuifolia* (A.Rich.) Hochst. ex Steud., *Cynodon dactylon* (L.) Pers., and *Chloris pycnothrix* Trin., while for the period during wildebeest calving were *Euphorbia prostrata* Aiton, *Chloris pycnothrix* Trin., and *Cynodon dactylon* (L.) Pers., and for the period after wildebeest calving were *Eragrostis tenuifolia* (A.Rich.) Hochst. ex Steud., *Kylinga erecta* Schumach., and *Chloris pycnothrix* Trin. In southern zone, the topmost three plant species for the period before wildebeest calving were *Chloris pycnothrix* Trin., *Solanum campylacanthum* Hochst. ex A.Rich., and *Euphorbia prostrata* Aiton, while for the period during wildebeest calving were *Chloris pycnothrix* Trin., *Euphorbia prostrata* Aiton, and *Digitaria* sp, and for the period after wildebeest calving were *Chloris pycnothrix* Trin., *Solanum cam-*

pylacanthum Hochst. ex A.Rich., *Kylinga erecta* Schumach.

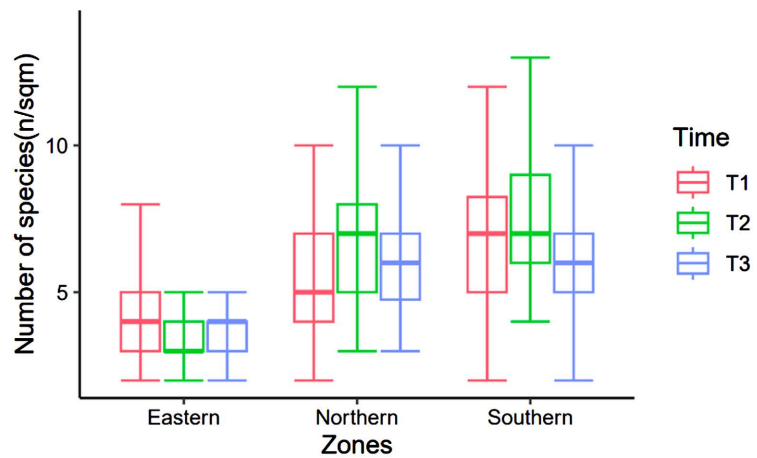


Figure 2. Box-plot showing number of plant species per quadrat in different wildebeest calving periods and zones.

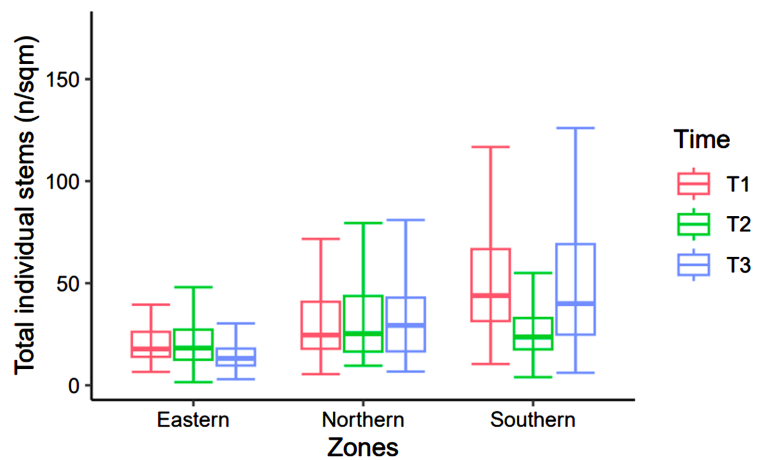


Figure 3. Box-plot showing plant total species abundance per plot in different wildebeest calving periods and zones.

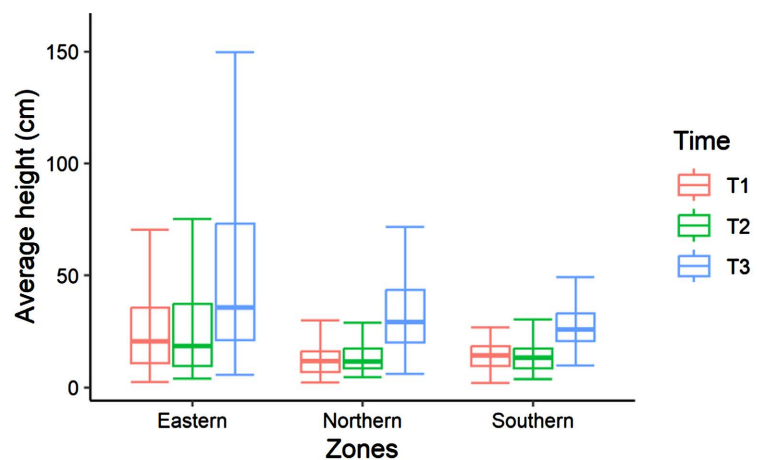


Figure 4. Box-plot showing mean plant heights (cm) in different wildebeest calving periods and zones.

3.3. Variation in Plant Composition

The analysis of variation results in **Table 1** shows that the mean number of species was not significantly different ($P = 0.0722$) between wildebeest calving periods. Conversely, the site and the interaction between site and calving period showed a significant difference in the number of species ($P = 0.0001$, $P = 0.0021$, respectively). The results indicate that the observed variations in the number of species are largely explained by the differences in site or location than wildebeest calving periods. This partly could be because of the difference in environmental conditions between sites. Also, it could be that the species are widely distributed within sites and that the effect of wildebeest calving did not accumulate enough to cause significant variations in species within the period applied for this study.

Table 1. Analysis of variation for wildebeest calving period and sites on the number of plant species based on two-way ANOVA model.

Variable	DF	Sum sq	Mean sq	F value	P value ($>F$)
Calving period	2	18	9.2	2.6	0.0722
Site	2	401	200.6	57.3	0.0001
Calving period*site	4	113	28.2	8.1	0.0021
Residuals	1068	3735	3.5		

From post hoc test result in **Figure 5**, the wildebeest calving period had a significantly higher number of species than the at calving period ($P = 0.0046$) and the number of species at calving period was significantly lower than after calving period ($P = 0.0001$). On the other hand, after calving period had lower number of species than before but the difference was not significant ($P = 0.5883$).

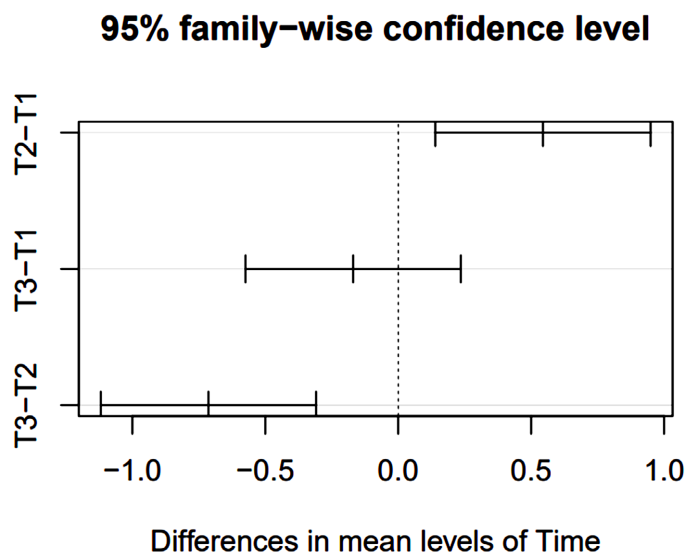


Figure 5. Post hoc Tukey test of the estimated means for number of species between wildebeest calving periods based on two-way ANOVA.

The results in **Table 2** show that the mean abundance of plant species at plot level was significantly difference ($P = 0.0003$) between the before, at, and after wildebeest calving periods. Similarly, both the site variable and the interaction between wildebeest calving periods and site showed a significant difference in mean species abundance ($P = 0.0002$, $P = 0.0501$, respectively). The post hoc analysis revealed that the abundance of plants was higher before wildebeest calving than both at and the after periods. This could be that during at wildebeest period their density was higher leading to low forage selection, thereby all plants become foraged and disfavor plant with low tolerant level.

Table 2. Analysis of variation for wildebeest calving period and sites on the abundance of plants based on two-way ANOVA model.

Variable	DF	Sum sq	Mean sq	F value	<i>P</i> value (>F)
Calving period	2	13665	6832	31.5	0.0003
Site	2	10679	5339	24.6	0.0002
Calving period*site	4	2058	514	2.3	0.0501
Residuals	2483	53790	217		

The Turkey post hoc test results in **Figure 6** show that the mean plant abundance during the period at calving was significantly lower than before calving period ($P = 0.0001$). The abundance after calving period was lower than the before period but the difference was not significant ($P = 0.0691$) and was also insignificantly higher than at the wildebeest calving period ($P = 0.0603$).

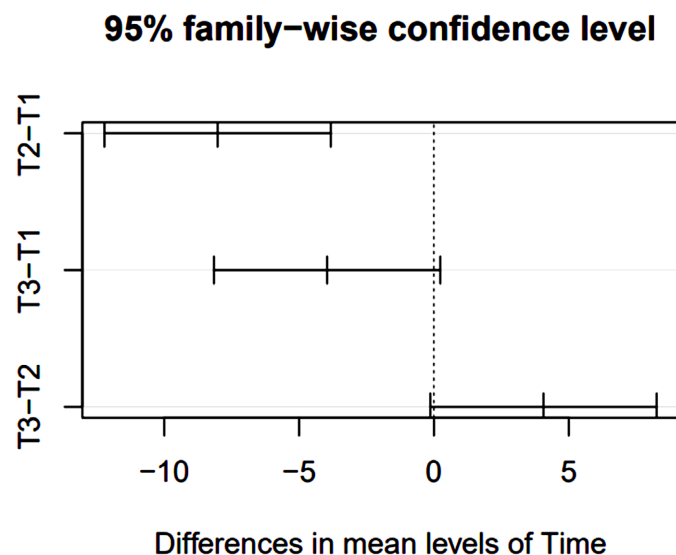


Figure 6. Post hoc Tukey test of the estimated means for plant abundance between wildebeest calving periods based on two-way ANOVA.

The results of analysis of variance in **Table 3** showed that plant heights were

statistically significant different in relation to wildebeest period before, at, and after calving ($P = 0.0016$). The results showed consistent fashion in both sites-southern, northern, and eastern zones ($P = 0.0001$). However, the insignificant difference at 5% level of significance ($P = 0.0744$) was observed for interaction between wildebeest calving period and site. The results indicate that the mean plant heights were affected during the period at wildebeest calving which could be due to heavy foraging because of high wildebeest density. The increased mean plant height observed during the period after wildebeest which corresponds to their low density indicates a growth response after heavy foraging.

Table 3. Analysis of variation for wildebeest calving period and sites on the heights plant species based on two-way ANOVA model.

Variable	DF	Sum sq	Mean sq	F value	<i>P</i> value (>F)
Calving period	2	105.5	52.7	106.6	0.0016
Site	2	177.4	88.6	179.3	0.0001
Calving period*site	4	4.2	1.1	2.1	0.0744
Residuals	2483	1228.2	0.49		

In addition, the Turkey post hoc test results in **Figure 7** show that the plant heights during period at calving was significantly lower than before calving period ($P = 0.0467$). In addition, the plant height during and after the calving period was significantly higher than both the before and at wildebeest calving periods ($P = 0.0001$, $P = 0.0001$, respectively).

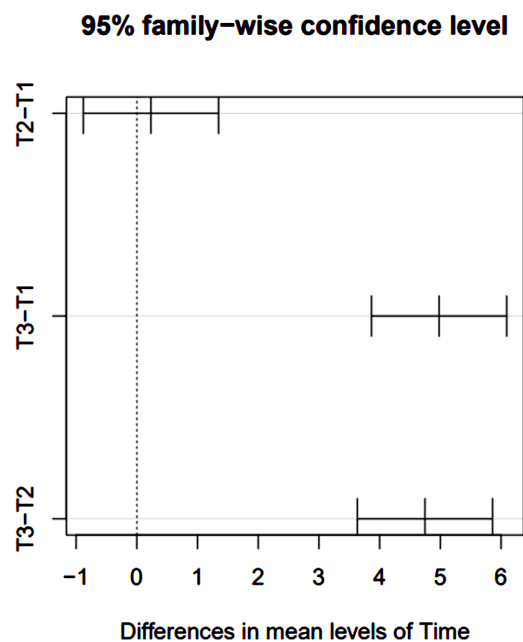


Figure 7. Post hoc Tukey test of the estimated means for plant heights between wildebeest calving periods based on two-way ANOVA.

4. Discussion

The findings from this study highlight the roles of different vegetation lifeforms in supporting wildebeest populations before, during, and after the calving period within selected sites of the Serengeti ecosystem's short grassland habitat. A total of approximately 123 plant species were recorded across the migration sites. The composition of plant species, their abundance, and average height varied between sites and time periods, reflecting changes in wildebeest density and foraging behavior. Before calving, vegetation height was relatively low across all study sites. This shorter vegetation suggests extensive grazing activity in preparation for calving, likely reducing plant height significantly. Such early grazing may be linked to the selective pressure wildebeests place on dominant plant species, a process that contributes to ecological balance by preventing overgrowth, as noted in earlier studies [22]. Although this period is marked by extensive grazing by wildebeest, of the topmost three species with highest importance value index (IVI) grasses form dominated. Their IVI could imply that they are widely distributed and successfully adapted to varying conditions ecological disturbances such as grazing, reflecting broad ecological tolerance and competitive ability, which indicate their key role in maintaining essential ecosystem functions such as provisioning and nutrient cycling in the wildebeest migration routes and ecosystem in general.

During calving, there was a noticeable shift in species composition and abundance, primarily due to selective feeding behavior. Wildebeests showed a preference for nutrient-rich grass species, which played a key role in shaping vegetation dynamics [23]. The abundance of preferred forage species slightly increased during this period, likely due to reduced grazing intensity during calving, which coincides with the onset of rainfall. This pattern aligns with the observations of [8], who reported that wildebeests prefer fresh, short grasses that emerge with the early wet season rains. After calving, vegetation showed signs of recovery, particularly in the southern sites, where plant height increased consistently [24]. This recovery is likely influenced by the short dry season from February to mid-March, during which some wildebeests migrate out of the Laetoli/Kakesio area into Maswa Game Reserve, returning when the long rains begin. This temporary reduction in herbivore pressure, combined with the resumption of rainfall, creates an optimal window for vegetation to regenerate and grow taller.

Migration reduces grazing pressure on vegetation in the southern regions, allowing plants to regenerate [25]. The consistent increase in plant height observed in these areas suggests a significant reduction in grazing intensity, enabling regrowth. However, this recovery was not uniform across all sites. In the northern and eastern regions, vegetation height was more inconsistent, indicating localized variations in recovery potential. These variations are likely influenced by site-specific factors such as soil fertility, rainfall distribution, and grazing intensity. These findings are consistent with the study by [25], which emphasized the role of herbivore movement in facilitating vegetation regrowth.

The study findings revealed that plant height varied across different lifeforms,

with grasses showing a greater capacity for recovery following grazing compared to herbs and sedges. Grass species, particularly in the Southern NCA site, demonstrated a more structured regrowth pattern, while the Northern and Eastern sites exhibited more variable trends. These findings align with those of [9], who reported that grasses in migratory grazing systems have evolved adaptive mechanisms to withstand herbivory pressure.

This variability in plant height recovery suggests that different sites exhibit distinct levels of resilience, likely influenced by environmental factors such as soil conditions and moisture availability. The observed differences are consistent with previous research on wildebeest grazing dynamics and their ecological impacts before, during, and after calving. For instance, the variation in vegetation height across sites appears to correspond with the timing of wildebeest departure [26]. Additionally, the study highlights the site-specific nature of grazing impacts, supporting findings by [27], who emphasized the need for localized conservation strategies to maintain and improve grassland habitats. Understanding changes in plant height may require further investigation, including assessments of climate data and soil quality. Contrary to the general findings of this study, other research points to complex interactions between environmental stressors and plant growth patterns, which may offer a more comprehensive understanding of the trends observed [28].

The presence of livestock in different zones plays a significant role in shaping grazing dynamics, vegetation composition, and, ultimately, the ecological interactions between wildebeests and their habitats. In the Southern NCA, particularly in Kakesio and Laetoli, cattle are absent due to the risk of malignant catarrhal fever, which is transmitted from wildebeests to cattle during the calving period [29] [30]. However, sheep and goats are present during this time. Goats, being browsers rather than grazers, primarily feed on shrubs and herbs instead of grasses. This browsing pressure may contribute to the increasing presence of invasive plant species in the southern zone. In contrast, cattle are present in the Northern and Eastern zones, especially in Angata Kheri and the Sukenya Plains. During the wildebeest calving period, herders typically move their cattle away from these areas. After calving, from March to May—when the long rains return—herders bring their livestock back. This seasonal and spatial separation between livestock and wildebeests naturally supports rangeland sustainability, promotes biodiversity conservation, and helps reduce conflicts between wildlife and pastoralist communities. Since wildebeests heavily depend on high-quality forage immediately after calving, the temporary absence of cattle reduces competition for fresh grass. Limiting or managing livestock access in key calving grounds may significantly reduce grazing pressure, supporting the regeneration of critical forage and enhancing the overall health of the ecosystem.

5. Conclusion and Recommendations

The study concludes that wildebeest grazing significantly influences vegetation

lifeforms at different sites before, during, and after the calving period. Before calving, heavy grazing by wildebeests reduces vegetation height, preventing overgrowth and maintaining balance in the grasslands. During calving, wildebeest selective feeding leads to shifts in species composition, abundance, and plant height variation. Notably, the Southern NCA site exhibited more structured regrowth patterns compared to the Northern and Eastern sites. The findings highlight that the presence of livestock in wildebeest calving areas can exacerbate overgrazing after calving, hindering vegetation recovery. Since wildebeests migrate freely across the surveyed sites, understanding the spatial-temporal changes in vegetation abundance and diversity over the long term is essential for informed decision-making regarding the conservation of rangelands. The study recommends establishing restrictions on livestock grazing in key wildebeest calving areas to allow vegetation to regenerate when the wildebeest are absent. Additionally, conservation efforts should be tailored to specific zones to account for the vegetation's response to environmental factors. Finally, adaptive management strategies, including long-term monitoring and community-based conservation initiatives, should be implemented by prioritizing the species with high importance value index to ensure long-term ecosystem functionality and healthy rangelands for sustaining the wildebeest population and other wild ungulates in the ecosystem.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

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