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ORIGINAL ARTICLE

Examining Variations in Biomass, NPP, and Plant Diversity in the Saheibung I Grassland Ecosystem

Kamthenlal Dimngel* and Th. Binoy Singh
Department of Life Science, Manipur University, Canchipur Imphal, Manipur-795003
***Corresponding author's Email:** atingdimngel@gmail.com

ABSTRACT
The Saheibung Grassland Ecosystem, situated at an altitude of 1300–1450 msl in Kangpokpi District, Manipur, represents a high-altitude, unprotected landscape with diverse ecological dynamics. Characterised by a mix of peaks and gentle slopes, this ecosystem exhibits significant seasonal variability in soil and biomass parameters. Soil moisture ranges from a peak in October (53.81%) to a low in April (13.81%). Soil density varies seasonally, with the highest value in July (1.01 g/ccm^{-1}) and the lowest in December (0.72 g/ccm^{-1}), while porosity shows an inverse trend, peaking in September (80.07%) and dipping in January (63.28%). Biomass assessments reveal that live biomass is highest in October (938.08 g/m^{-2}) and lowest in March (37.091 g/m^{-2}). Standing dry biomass peaks in April (166.13 g/m^{-2}) and is lowest in October (46.57 g/m^{-2}). Litter biomass is maximum in November (89.68 g/m^{-2}) and minimum in June (14.36 g/m^{-2}). Total above-ground biomass reaches its maximum in October (1010.33 g/m^{-2}), driven by live biomass, while below-ground biomass peaks in November (562.56 g/m^{-2}) and is lowest in April (122.88 g/m^{-2}). Net primary productivity (NPP) follows seasonal trends, highest during the rainy season, moderate in summer, and lowest in winter. The grassland harbours 33 plant species, with Poaceae contributing the most (10 species), followed by Asteraceae (6 species) and Cyperaceae (3 species). Other families are represented by a single species each. These findings highlight the ecological complexity and biodiversity of this high-altitude grassland.
Keywords: *Grasslands, Exhibits, Variability, Biomass, NPP, Productivity.*

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INTRODUCTION

Grassland ecosystems play a critical role in maintaining ecological balance by regulating carbon cycles, supporting biodiversity, and providing ecosystem services. In this context, understanding biomass distribution, net primary productivity (NPP), and plant diversity is essential for assessing ecosystem health and its capacity to respond to environmental changes. Grasslands like Saheibung I, located in biodiversity hotspots, are particularly vital for their unique flora and fauna. These systems are influenced by complex interactions between climatic, edaphic, and anthropogenic factors, making them dynamic and vulnerable to degradation. Biomass, the total mass of living plants in a given area, serves as an indicator of an ecosystem's capacity for energy storage and nutrient cycling [1] Net Primary Productivity, which quantifies the rate at which plants convert solar energy into biomass after accounting for respiratory losses, reflects the efficiency and vitality of an ecosystem [2]. Moreover, plant diversity is crucial for maintaining ecosystem stability and resilience, as species interactions underpin key processes such as pollination and nutrient cycling [3]. This study examines the Saheibung I grassland, focusing on its biomass, NPP, and plant diversity to gain insights into its ecological dynamics and inform conservation strategies.

MATERIAL AND METHODS

The study was conducted in the Saheibung I grassland ecosystem, located within the high-altitude Koubru Hill Range in Kangpokpi District, Manipur. This grassland lies between the coordinates 93°45'42"E and 24°51'57"N, with an elevation ranging from 1300 to 1450 meters above sea level. Known as one of the most frequently visited natural sites in the region, it holds ecological, cultural, and recreational significance.

Despite its importance, the ecosystem faces increasing threats from human activities, including land conversion for agriculture, grazing pressure, and unregulated developmental processes. These pressures make it a vulnerable landscape requiring immediate conservation efforts to safeguard its biodiversity and ecological services. The unique high-altitude environment of this grassland supports a rich variety of flora and fauna, contributing significantly to the region's overall biodiversity. Enhanced protection and sustainable management practices are imperative to ensure the long-term health of this fragile ecosystem.

The study examines biomass, net primary productivity (NPP), and plant diversity in the Saheibung I grassland using established methodologies. Biomass was assessed using the Short-term Harvest Method [4], with total biomass (g/m^2) calculated as the sum of above-ground biomass (AGB, comprising live, dead, and litter biomass) and below-ground biomass (BGB). NPP was estimated using the Summation of the Positive Increment Method [5], with above-ground and below-ground NPP (ANP and BNP) calculated separately. Plant diversity was documented through photographic records and herbarium preparation for unidentified species, supported by literature review, with utmost care to avoid disturbing the fragile ecosystem. The methodology ensured accurate biomass and productivity measurements while preserving the ecological integrity of the study site.

RESULTS AND DISCUSSION

Biomass is the total mass of living organisms in a given area, essential for ecosystem productivity, nutrient cycling, and energy flow. It supports biodiversity, carbon storage, and renewable energy production, making it vital for ecological and economic sustainability. Seasonal changes in biomass occur due to variations in temperature, light, and precipitation, influencing growth and reproduction (Fig. 1). For instance, plant biomass peaks in summer and declines in winter. These fluctuations impact food webs, primary productivity, and resource availability across ecosystems.

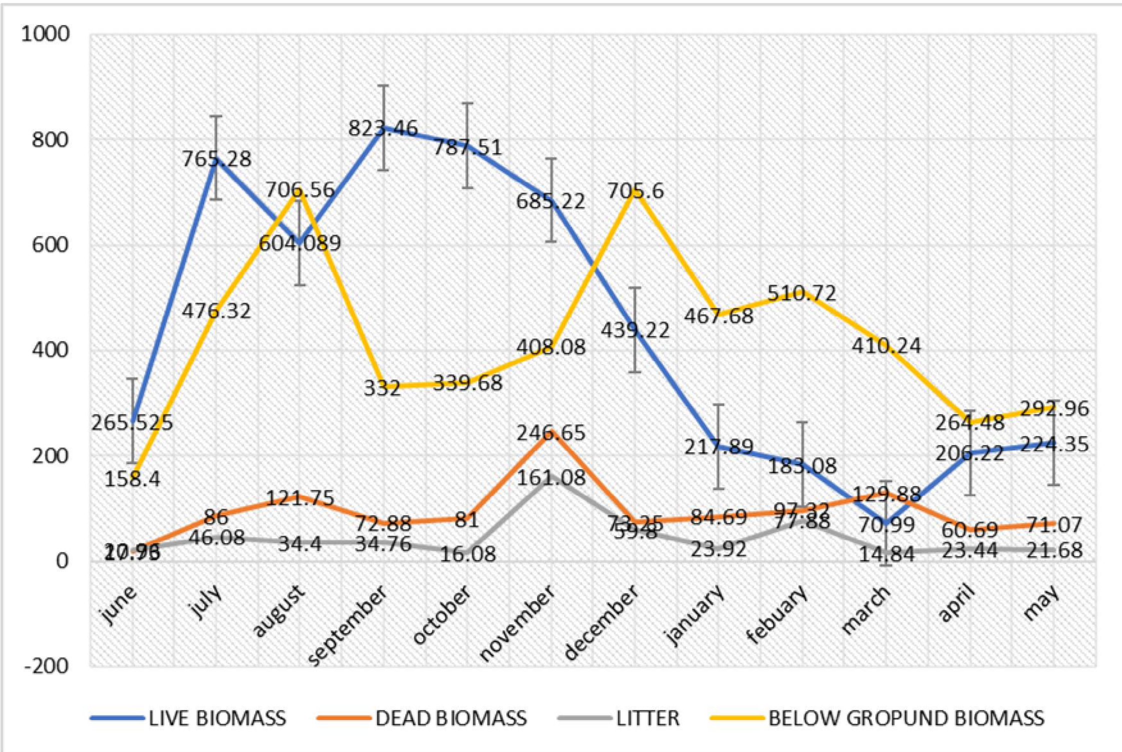

Figure 1: Monthly variation of biomass from the study site.

Based on the data from the table, the following results and discussion can be derived regarding biomass dynamics at Site I

Live Biomass: Live biomass at Site II reaches its peak in October (938.08 g/m^2) and its lowest in March (37.091 g/m^2). This suggests that plant growth is maximized in October, likely due to favourable climatic conditions [4].

Standing Dry Biomass: The standing dry biomass is highest in April (166.13 g/m^2) and lowest in October (46.57 g/m^2). This may reflect the transition from a growing to a more dormant phase as environmental factors like temperature and water availability shift [5].
Litter Biomass: Litter biomass peaks in November (89.68 g/m^2) and reaches its lowest in June (14.36 g/m^2). This suggests that plant senescence and leaf drop occur primarily in the post-monsoon period [4].
Above-Ground Biomass (AGB): AGB is highest in October (1010.33 g/m^2) and lowest in January (230.63 g/m^2), indicating that above-ground plant growth is maximized in the late rainy season [5].
Below-Ground Biomass (BGB): BGB is highest in November (562.56 g/m^2) and lowest in April (122.88 g/m^2). Increased root growth post-monsoon likely aids nutrient absorption and root establishment [5].
Total Biomass: Total biomass peaks in November (1436.58 g/m^2) and is lowest in March (258.291 g/m^2), reflecting the overall productivity of the ecosystem across seasons [4].
The seasonal variations in biomass observed in the Saheibung I grassland ecosystem are influenced by climate, particularly temperature, rainfall, and soil moisture. The peak in live biomass during October reflects the growing season's peak productivity, facilitated by optimal climatic conditions [4] (Table 1). In contrast, the drop in live biomass during March is likely attributed to reduced water availability as the region approaches the dry season. Standing dry biomass is highest in April, suggesting that this period is marked by the accumulation of dry plant material, potentially due to dormancy as water resources become scarce [5]. The accumulation of litter in November further supports this, as plants shed their leaves and other parts, contributing organic matter to the soil. The trends in AGB and BGB indicate that the grassland experiences maximum above-ground growth during the growing season and heightened root activity in the post-monsoon period, which is essential for nutrient uptake [5]. Total biomass, which peaks in November, demonstrates the grassland's highest productivity after the monsoon season. Overall, these findings emphasise the importance of seasonal climatic changes in driving biomass production and ecosystem dynamics in grasslands. Such fluctuations in biomass across different components (live biomass, dry biomass, litter, AGB, and BGB) are essential for understanding productivity patterns in this ecosystem [4,5].

Table 1: Monthly variation of npp from the study site.

	May	Jne	Jly	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apl	May
Biomass	250.715	462.615	881.36	1312.375	1127.52	1425.85	1436.58	1191.53	686.79	897.467	258.291	406.14	446.400
NPP		211.90	419.21	431.015		11.06	10.73			210.677		147.849	40.26

NPP- Net Primary Production, g/m^2- gram per meter

The Net Primary Productivity (NPP) of the Saheibung I grassland ecosystem, calculated using the Summation of the Positive Increment Method (5), exhibited distinct seasonal variations driven by climatic factors. The highest NPP was recorded during the rainy season (871.655 g/m^2), reflecting the peak plant growth period when ample soil moisture, favorable temperatures, and abundant nutrients created optimal conditions for photosynthesis and biomass accumulation. During the summer, NPP decreased to 400.369 g/m^2, indicating the gradual onset of water stress and higher evapotranspiration rates, which limited plant growth despite residual moisture from the rains. The lowest productivity was observed in winter (211.90 g/m^2), attributed to reduced temperatures and shorter photoperiods, which curtailed photosynthetic activity and plant metabolism.
The annual total NPP, amounting to 1483.924 g/m^2, underscores the grassland's significant productivity potential under its prevailing climatic conditions. The dominance of NPP during the rainy season highlights the critical role of precipitation in driving productivity, consistent with observations in other tropical grasslands [5]. Seasonal declines in NPP during summer and winter demonstrate the grassland's sensitivity to water availability and temperature fluctuations, with plants exhibiting adaptive strategies to cope with unfavourable conditions. These findings emphasise the dependence of grassland ecosystems on climatic factors, particularly rainfall, for sustaining primary productivity. The seasonal patterns also

suggest that the rainy season serves as a critical period for carbon fixation and energy flow within the ecosystem. Understanding these dynamics is vital for the effective management and conservation of tropical grasslands, particularly in the face of changing climate scenarios.

Table 2: Plants found in study site.

Sl. No	Name of Plants	Orders	Family
1.	*Cynodont dactylon*	Cyperales	Poaceae
2.	*Arundinella nepalensis*	Poales	Poaceae
3.	*Axonopus compressus*	Poales	Poaceae
4.	*Carex cruciate*	Poales	Cyperaceae
5.	*Digitaria longiflora*	Poales	Poaceae
6.	*Eragrostis unioloides*	Poales	Poaceae
7.	*Kylinga nemoralis*	Poales	Cyperaceae
8.	*Chromolaena odorata*	Asterales	Asteraceae
9.	*Ageritina Adenophora*	Asterales	Asteraceae
10.	*Urena lobata*	Malvales	Malvaceae
11.	*Chrysopogan aciculatus*	Poales	Poaceae
12.	*Ageratum conyzoides*	Asterales	Asteraceae
13.	*Lindernia crustacea*	Lamiales	Linderniaceae
14.	*Centilla asiatica*	Apiales	Apiaceae
15.	*Crepis mollis*	Asterales	Asteraceae
16.	*Pteridum aqualinum*	Polypodiales	Dennstaedtiaceae
17.	*Phyllanthes urinaria*	Malpighiales	Phyllanthaceae
18.	*Melastoma melabathricum*	Myrtales	Melastomaceae
19.	*Ruibus ellipticus*	Rosales	Rosaceae
20.	*Imperita cylindrica*	Poales	Poaceae
21.	*Polentilla reptans*	Rosales	Rosaceae
22.	*Tagetus erectus*	Asterales	Asteraceae
23.	*Drymaria cordata*	Caryophyllales	Caryophyllaceae
24.	*Crassocephalum crepidoides*	Asterales	Asteraceae
25.	*Plantago major*	Lamiales	Plantaginaceae
26.	*Biden biternate*	Asterales	Asteraceae
27.	*Acmella oleracea*	Asterales	Asteraceae
28.	*Blechnum orientale*	Polypodiales	Blechnaceae
29.	*Juncus effusus*	Poales	Junaceae

The survey of Saheibung I grassland identified 29 plant species, reflecting a diverse ecosystem with plants belonging to several orders and families (Table 2). The dominant order, Poales, includes grasses and sedges such as *Cynodon dactylon*, *Eragrostis unioloides*, and *Imperata cylindrica*, primarily from the family Poaceae, and *Carex cruciata* from *Cyperaceae*. These species are critical for soil stabilization, erosion prevention, and nutrient cycling. Grasses dominate the ecosystem, emphasizing the grassland's role in supporting herbivores and maintaining its structure. Additionally, their ability to sequester carbon highlights their ecological importance in combating climate change.

The order Asterales, with species like *Ageratum adenophora*, *Bidens biternata*, and *Acmella oleracea* from the family Asteraceae, also plays a significant role in the grassland. These flowering plants provide essential resources for pollinators such as bees and butterflies, which are crucial for maintaining biodiversity and supporting other plant species through pollination. However, invasive members of this group, such as *Chromolaena odorata* and *Ageratum conyzoides*, present a challenge by threatening native plant diversity through competitive exclusion.

Ferns such as *Pteridium aquilinum* and *Blechnum orientale*, belonging to the orders Polypodiales and families Dennstaedtiaceae and Blechnaceae, respectively, are notable for their ability to thrive in shaded and moist habitats. These plants act as pioneer species in disturbed areas, showcasing the resilience and adaptive capacity of the grassland ecosystem. Woody plants like *Rubus ellipticus* and *Melastoma malabathricum*, from the orders Rosales and Myrtales, contribute to habitat diversity, offering food and shelter for birds and small mammals.

The grassland also hosts plants with ethnobotanical significance, such as *Centella asiatica* (family Apiaceae) and *Plantago major* (family Plantaginaceae). These species hold medicinal value and reflect the traditional ecological knowledge of the local communities. Their presence highlights the grassland's cultural and economic importance, in addition to its ecological contributions.

Despite its richness, the grassland faces ecological threats. The presence of invasive species like *Chromolaena odorata* and *Ageratum adenophora* poses a significant challenge to the ecosystem. These species can outcompete native plants, leading to reduced biodiversity and alterations in ecosystem functions. Human activities such as overgrazing and land-use changes further threaten the balance of this habitat. Active conservation measures, including the removal of invasive species and restoration of degraded areas, are essential to protect the native flora.

CONCLUSION

The study of biomass dynamics and plant diversity in the Saheibung I grassland provides critical insights into its ecological productivity and resilience, emphasizing the strong influence of climatic factors such as rainfall, temperature, and soil moisture on ecosystem processes. Peak biomass and net primary productivity (NPP) during the rainy season highlight this period's importance for photosynthesis and carbon fixation, while reduced productivity in summer and winter reflects the grassland's sensitivity to water scarcity and temperature fluctuations, alongside its adaptive strategies. The identification of 29 plant species, predominantly grasses and sedges from the Poales order, underscores the grassland's ecological roles in supporting herbivores, stabilizing soil, and maintaining biodiversity. The diversity is further enriched by flowering plants, ferns, and woody species, enhancing ecosystem complexity and services. However, the threat from invasive species and human activities calls for robust conservation efforts, including invasive species management and habitat restoration. This study underscores the ecological significance of the Saheibung I grassland, its vulnerability to climatic and anthropogenic pressures, and the urgent need for sustainable management to safeguard its productivity and biodiversity in the face of climate change.

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