



## Floristic Diversity and Net Primary Production in the M'fimi Basin (DRC): Correlational Analysis and Ecological Implications

[Diversité floristique et production primaire nette dans le bassin de la M'fimi (RDC) : analyse corrélative et implications écologiques]

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### Abstract

Net primary production (NPP) is a key indicator of ecosystem health and agricultural sustainability. In the context of the Democratic Republic of Congo, specifically the M'fimi River watershed in Mai-Ndombe Province, this study examines the impact of species diversity on fresh forage mass and water content, key elements for crop productivity. The main objective of this study is to analyze how the number of plots influences these essential variables and to assess the correlative relationships between biodiversity and primary production. The methodology employed consists of a statistical evaluation using analysis of variance (ANOVA) and Pearson's correlation method. Data were collected from 15 numbered plots, in which fresh forage mass, dry mass, and water content were measured. A DataFrame was created using Python Anaconda libraries such as pandas, enabling in-depth analysis of the relationships between the different variables. The results show no significant correlation between the number of plots and the mass of fresh forage, with a p-value of 0.8896. In contrast, a moderate positive correlation ( $r = 0.559$ ,  $p = 0.030$ ) was observed between the number of species per plot and the mass of forage, highlighting the importance of biodiversity for crop production. A negative trend was also identified, indicating that plots located in areas less favorable to biodiversity exhibit lower fresh forage production. This study recommends appropriate natural resource management and the improvement of plant diversity to maximize biomass production. These results underscore the need for an integrated approach that considers environmental conditions to optimize agricultural productivity and ensure ecosystem sustainability. The lessons learned from this research highlight the importance of biodiversity in crop productivity, which could contribute to sustainable agricultural development strategies in the DRC.

**Keywords:** Biodiversity, Primary Production, Net Primary Production (NPP), ANOVA and Correlation, Aquatic Ecosystems.

### Résumé

La production primaire nette (PPN) est un indicateur essentiel de la santé des écosystèmes et de la durabilité agricole. Dans le contexte de la République Démocratique du Congo particulièrement sur le bassin versant dans la rivière de M'fimi dans la province de Mai-Ndombe, cette étude examine l'impact de la diversité des espèces sur la masse de fourrage frais et la teneur en eau, des éléments clés pour la productivité végétale. L'objectif principal de cette étude est d'analyser comment le numéro des placettes influence ces variables essentielles et d'évaluer les relations corrélatives entre la biodiversité et la production primaire. La méthodologie employée consiste en une évaluation statistique utilisant l'analyse de variance (ANOVA) et la méthode de corrélation de Pearson. Les données ont été collectées à partir de 15 placettes numérotées, dans lesquelles la masse de fourrage frais, la masse sèche et la teneur en eau ont été mesurées. Un DataFrame a été créé avec des bibliothèques Python Anaconda telles que pandas, permettant une analyse approfondie des relations entre les différentes variables. Les résultats montrent qu'il n'existe pas de corrélation significative entre le numéro des placettes et la masse de fourrage frais, avec une valeur p de 0.8896. En revanche, une corrélation positive modérée ( $r = 0.559$ ,  $p = 0.030$ ) a été observée entre le nombre d'espèces par placette et la masse de fourrage, soulignant l'importance de la biodiversité pour la production végétale. Une tendance négative a également été identifiée, indiquant que des placettes situées dans des zones moins favorables à la biodiversité présentent une PPN plus faible. Cette étude recommande une gestion appropriée des ressources naturelles et l'amélioration de la diversité végétale pour maximiser la production de biomasse. Ces résultats soulignent la nécessité d'une approche intégrée qui tient compte des conditions environnementales afin d'optimiser la productivité agricole et d'assurer la durabilité des écosystèmes. Les leçons tirées de cette recherche mettent en avant l'importance de la biodiversité dans la productivité des cultures, ce qui pourrait contribuer à des stratégies de développement agricole durable en RDC.

**Mots-clés :** Biodiversité, production primaire, production primaire nette (PPN), ANOVA et corrélation, écosystèmes aquatiques.

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<https://orcid.org/0009-0008-3848-4166> ; Reçu le 27/02/2026 ; Révisé le 25/03/2026 ; Accepté le 17/04/2026

DOI : <https://doi.org/10.59228/rest.026.v5.i2.262>

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## 1. Introduction

Research on net primary production (NPP) in plant ecosystems is crucial for understanding the ecological and agronomic dynamics that influence natural resource productivity. Considering the interactions between species diversity, forage mass, and water content is an important research focus, particularly in rural areas of the Democratic Republic of Congo (Massama-Esso & Agbamaro, 2025; Ndasishimiye et al., 2023). Studies have shown that floristic diversity, by promoting complementarity between species, can increase biodiversity and improve the productivity of agroecological systems (Amrani & Chehema, 2020). This dynamic is particularly relevant in a context of increasing ecological pressure.

However, much previous research highlights significant gaps in our understanding of the factors influencing NPP. The majority of studies, such as those by Ouattara et al. (2016), did not sufficiently explore the role of varied environmental conditions, including the impact of water management practices on PPN. Furthermore, the impacts of ecological gradients, such as soil type and climate variations, were underestimated, thus limiting our ability to predict seasonal productivity in different contexts. A recent study by Mensah et al. (2025) highlights the need for further research on the interaction between biodiversity and productivity, examining the effects of climate change on local ecosystems. Manzocchi et al. (2024) analyze the factors influencing silage quality from permanent grasslands, reinforcing the importance of understanding ecological interactions to improve agricultural production. Finally, the study by Diatta et al. (2023) highlights the dynamics of standing forage mass of herbaceous forages under grazing in the Senegalese Sahel, emphasizing the importance of management practices.

The objectives of this research are clear: firstly, to fill the gaps identified in the scientific literature by studying the impact of plots on fresh forage mass and, secondly, to assess the correlation between species diversity and net primary production. Based on contemporary ecological theories, this study seeks to provide quantitative evidence that informs natural resource management, pragmatizing the link between biodiversity and productivity (Amegnaglo et al., 2018). Rodríguez et al. (2025) explore the relationship between grassland floristic diversity, productive

performance, and carbon storage capacity, providing a relevant context for this approach.

To achieve these objectives, we adopted a methodology based on robust statistical analyses, including analysis of variance (ANOVA) and Pearson's correlation coefficient. These statistical techniques, applied via Python, allow us to assess the complex relationships between variables and visualize the results through clear graphs. Furthermore, rigorous data collection and analysis protocols, adhering to current scientific standards, are implemented to ensure the reliability and validity of the results obtained (Lakhyar-Ennajari, 2021). These methods represent an essential tool for understanding the nuances and variations in net primary production.

## 2. Material et methods

### 2.1. Presentation of the study environment

Figure 1 illustrates the M'fini watershed in the Mai-Ndombe province of the DRC, with botanical sampling points clearly marked by red dots on the map. These points represent the specific locations of the samples, essential for analyzing plant diversity. After numerous surveys, we delimited our study area to 15 observation plots. These plots were established along the M'fini River, extending from plot number 1 downstream to plot number 15 upstream, near the rural commune of Kutu, at the precise geographic coordinates of 018°08'42.2'' East longitude, 02°43'44.5'' South latitude, and 302 m altitude at the level of the territory's administrative building. The plots, numbered 1 to 11 on the left bank and 12 to 15 on the right bank, were chosen for their ecological and morphological interest. This configuration allowed for complete inventories of the forage grasses present in the study area.

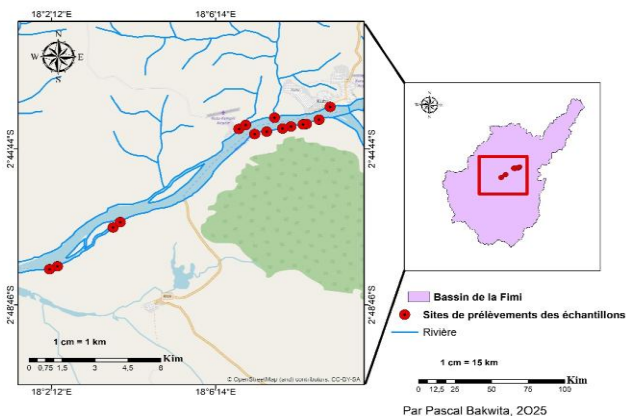


Figure 1. Botanical Sample Collection Sites

## 2.2. Data Collection

Data collection took place from May 30 to June 27, 2025, and involved collecting botanical samples from various sites to create herbarium and laboratory specimens. During this period, in situ analysis of the water's physicochemical parameters focused on key elements such as temperature, pH, total dissolved solids (TDS), and depth. Various appropriate equipment was used to carry out this collection. A Garmin 64 GPS was used to record the geographic coordinates of the selected sites. Each sample was carefully placed in plastic bags according to species for proper preservation. A TEMIUM precision balance was used to weigh the samples, and pruning shears were used for harvesting. Appropriately sized wooden presses were used to preserve and dry the samples. In addition, packing bags and newspaper were used to protect and dry the samples. Four wooden stakes were used to delineate the observation plots. A tarpaulin was also used for drying, and a machete facilitated access to the different sites (Ahouangan et al., 2010). For the analysis of physicochemical parameters, a pH meter and a TDS meter were essential to determine the water's acidity and dissolved solids concentration (Ouattara et al., 2016). A probe thermometer was used to measure the water temperature in the field. In the laboratory, instruments such as a HERAEUS oven and an OHAUS precision balance allowed us to rigorously dry and weigh the botanical samples. This methodology ensured accurate and reliable data for the study (Idrissa et al., 2020).

## 2.3. Data analysis

### 2.3.1 Regression Modeling of Relationships Between Variables Using ANOVA

This method begins with the use of Python and the following libraries: pandas, statsmodels, and matplotlib (Mampuya et al., 2026; Mampuya Nzita et al., 2025). The data is organized into plots numbered from 1 to 15, each associated with values for fresh forage mass, dry mass, and moisture content. A DataFrame is created containing two columns: the plot numbers and the moisture content values. Analysis of variance (ANOVA) assesses the significance of the differences between these plots. A regression model is established using the formula  $\text{Moisture\_Content\_kg} \sim C(\text{Site})$ , with a least-squares fit. The ANOVA test is performed using the appropriate function in statsmodels, producing a results table that presents the sum of squares, degrees of freedom, and p-value. For further analysis, a Tukey HSD test compares the means between the plots. The results include mean

differences, p-adjustments, and confidence limits, visualized by a multiple comparisons plot. This approach provides essential information on the impact of plots on crop production (Aastveit and Martens, 1986).

### 2.3.2 Pearson Correlation Method for Plot Analysis Variables

This method also uses Python with pandas, NumPy, Seaborn, Matplotlib, and SciPy.stats. A DataFrame is created using a dictionary containing information on the plot number and the number of species per plot (Mampuya et al., 2026; Mampuya Nzita et al., 2025). The mass of fresh forage is calculated by summing the biomasses. After verifying data consistency, a correlation matrix is generated using pandas. corr() method to explore linear relationships. Ap\_value\_matrix function is defined to establish a matrix of p-values using Pearson correlation, applying scipy.stats' pearsonr to each pair of variables. The correlation between the number of species, the mass of forage, and the plots is assessed, also calculating t-values and 95% confidence intervals. The results include the Pearson correlation coefficient, t-values, degrees of freedom, p-value, and confidence interval limits, facilitating the interpretation of the interactions between the variables (Irwin and McClelland, 2002).

## 3. Results

### 3.1. Results

#### 3.1.1. Net Primary Production at Different Sites

Table I provides a detailed overview of the net primary production observed at various study sites. Each plot is numbered for easy reference and includes several key columns.

Table I. Net Primary Production at Different Study Sites

Plot Number	Number of Species / Plot	Species	Fresh Forage Weight (kg)	Dry Weight (kg)	Water Content (kg)	Water Content (%)	Average dry Weight (kg)	Average water Content (kg)
1	9	<i>Commelina diffusa</i> Burm.f.	1,92	0,13	1,79	93,00	1,82	3,12
		<i>Commelina benghalensis</i> L.	4,81	0,83	3,98	83,00		
		<i>Lasimorpha senegalense</i> (Schott) Engl.	3,06	0,34	2,72	88,00		
		<i>Alchornea cordifolia</i> (Schum.etThonn.) Muell.Arg	9,54	3,28	6,46	67,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
2	8	<i>Polygonum lanigerum</i> R. Br var	3,90	3,35	0,55	14,00	2,78	2,61
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Pteridium aquilinum</i> (L.) Kuhn	4,39	3,70	0,69	15,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Alchornea cordifolia</i> (Schum.etThonn.) Muell.Arg	9,54	3,28	6,46	67,00		
3	7	<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00	2,16	2,99
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Alchornea cordifolia</i> (Schum.etThonn.) Muell.Arg	9,54	3,28	6,46	67,00		
		<i>Nymphea latus</i> Lin.	1,41	0,07	1,33	94,00		
4	7	<i>Ludwigia hyssopifolia</i>	25,62	23,63	1,99	8,00	5,53	3,08
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Alchornea cordifolia</i> (Schum.etThonn.) Muell.Arg.	9,54	3,28	6,46	67,00		
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		

5	7	<i>Dissotis erecta</i> (Guill. et Perr.) Dandy	7,54	2,05	5,49	72,00	2,45	3,58
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Alchornea cordilofia</i> (Schum. et Thonn.) Muell. Arg.	9,54	3,28	6,46	67,00		
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
6	7	<i>Cercestis congensis</i> Engl.	5,97	1,28	4,68	78,00	2,34	3,47
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Alchornea cordilofia</i> (Schum. et Thonn.) Muell. Arg.	9,54	3,28	6,46	67,00		
7	7	<i>Hypselodelphys poggeana</i> (K. Schum.) Milne-Redhead	6,38	1,47	4,92		2,36	3,50
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Alchornea cordilofia</i> (Schum. et Thonn.) Muell. Arg.	9,54	3,28	6,46	67,00		
8	6	<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00	2,51	3,27
		<i>Alchornea cordilofia</i> (Schum. et Thonn.) Muell. Arg.	9,54	3,28	6,46	67,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Aframomum alboviolaceum</i> (Ridl.) R. Schum.	6,29	1,43	4,87	77,00		
<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00				
<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00				
<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00				
<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00				

		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
10	6	<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00	2,51	3,27
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Alchornea cordilofia</i> (Schum.etThonn.) Muell.Arg.	9,54	3,28	6,46	67,00		
11	6	<i>Leersia hexandra</i> Sw	5,64	1,14	4,49	79,00	2,51	3,27
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Heteranthoecia guineensis</i>	1,28	0,06	1,23	95,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Alchornea cordilofia</i> (Schum.etThonn.) Muell.Arg.	9,54	3,28	6,46	67,00		
12	7	<i>Pteridium centrali africanum</i> (Hiern.)	5,44	1,07	4,38	80,00	2,31	3,43
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Alchornea cordilofia</i> (Schum.etThonn.) Muell.Arg.	9,54	3,28	6,46	67,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
13	6	<i>Cyperus papyrus</i> L.	5,76	4,62	1,14	20,00	2,74	2,38
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
14	6	<i>Landolphia ovariensis</i> P. Beauv.	8,29	2,47	5,81	70,00	2,38	3,16
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		
		<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et Chase	6,88	1,71	5,18	75,00		
		<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
		<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
		<i>Leersia hexandra</i> Sw	5,64	1,14	4,49	79,00		
15	7	<i>Costus phyllo Cephalus</i> K. Schum	2,32	0,19	2,12	91,00	2,18	3,10
		<i>Cyperus esculentus</i> L.	5,63	4,47	1,14	20,00		

	<i>Echinochloa pyramidalis</i> (Lamarch) Hitchcoch et chase	6,88	1,71	5,18	75,00		
	<i>Vossia cuspidata</i> Greff	5,52	4,42	1,10	20,00		
	<i>Heteranthoecia guineensis</i> (Franchet) Robyns	1,28	0,06	1,23	95,00		
	<i>Leersia hexandra</i> Sw.	5,64	1,14	4,49	79,00		
	<i>Alchornea cordilofia</i> (Schum.etThonn.) Muell.Arg.	9,54	3,28	6,46	67,00		
<i>Total weight (kg)</i>		<i>581,80</i>	<i>828,32</i>	<i>321,07</i>	<i>-</i>	<i>2,58</i>	<i>3,15</i>

Table I presents the net primary production recorded at the fifteen study sites, specifying for each plot the number of species inventoried as well as the values for fresh drilling mass, dry weight, and moisture content of the different species. In terms of species richness, the number of species per plot varies between 6 and 9, reflecting significant ecological heterogeneity between the sites. Plots 1 and 2 stand out for their high diversity (9 and 8 species, respectively), while plots 8, 9, 10, 11, 13, and 14 have only 6 species each, and as well, the overall average indicates a water biomass greater than dry mass, reflecting dominant humidity and moderate variability between plots.

3.1.2. Evaluation of the impact of plots on fresh forage mass: an ANOVA analysis

Table II illustrates the results of an analysis of variance (ANOVA) designed to examine the relationship between the number of plots and fresh forage mass in the context of net primary production

Table II. ANOVA between plot number and fresh forage mass of Net Primary Production

Source of Variation	Sum of Squares (sum_sq)	Degrees of Freedom (df)	Statistic (F)	p-value (PR(>F))
C (Plot Number)	79.6201	14.0	0.5577	0.8896
Residual	825.9579	81.0		

The sum of squares (79.6201) indicates the amount of variation in the data that can be explained by the differences between these plots. This shows that, although there is some variation in the forage measurements, this overall effect is not very large compared to the total variation, which is also taken into account in the second row. The degrees of freedom (14.0) refers to the number of different groups we are comparing. Since we have 15 plots, this results in 14

groups (because we subtract one group), which helps us understand how many possibilities were considered. Next, the F-statistic (0.5577) is a number that indicates the strength of the effect of the number of plots. In other words, the higher this number, the more likely the observed differences between plots are to be significant. In this case, 0.5577 is relatively low, suggesting that the differences between plots are not pronounced enough to be considered important. The p-value (0.8896) is crucial here. Simply put, this value tells us whether the results we found are likely due to chance or whether the number of plots has a real impact on forage mass. A p-value of 0.8896 is very high, meaning there is an 88.96% chance that the observed differences are due to chance. In general, a p-value less than 0.05 indicates a significant difference. Thus, in this case, we do not have strong evidence to conclude that the number of plots affects forage mass. The residual represents the variation in the data that cannot be explained by the number of plots. A sum of squares of 825.9579 shows that there is a large unexplained variation, suggesting that other factors, such as climatic conditions (temperature, humidity, rainfall, and sunshine), soil type, plant species, plant age, pest and disease management, and weed competition, could influence forage mass.

3.1.3. Analyse ANOVA de la masse sèche des placettes : Exploration des variations

Table III illustrates the results of an analysis of variance (ANOVA) designed to examine the relationship between plot number and dry mass in the context of net primary production.

Table III. ANOVA between Plot Number and Dry Mass of Net Primary Production

Source of Variation	Sum of Squares (sum_sq)	Degrees of Freedom (df)	Statistic (F)	p-value (PR(>F))
C (Plot Number)	50395.89	14.0	1.1634	0.3176
Residual	269185.88	87.0		

The sum of squares is 50395.89. This value represents the amount of variation observed in the dry mass measurements that can be attributed to differences between the various study sites (plots). However, this sum is relatively modest compared to the total variation, which also includes other unexplained factors. The degrees of freedom associated with the plot effect is 14.0. This means that, in this analysis, we have 15 plots in total (hence 14, since we subtract 1). This helps us understand the number of different groups we are comparing, which is essential for determining the robustness of the results. The F-statistic, which is 1.1634, assesses the strength of the effect of the number of plots on dry mass. In general, the higher this statistic, the more likely it is that the observed differences between groups are significant. In this case, the value of 1.1634 is relatively low, indicating that the differences between the plots are not pronounced enough to be considered significant. The p-value (0.3176) is crucial here. Simply put, it indicates the probability that the observed differences are due to chance. A p-value less than 0.05 is often used as a threshold to determine whether the results are significant. In this case, a p-value of 0.3176 is high, meaning there is a 31.76% chance that the variations in dry mass measurements are simply due to random fluctuations and not a true impact of the plots. The residual represents the variation in the data that cannot be explained by the number of plots. With a sum of squares of 269185.88, this value indicates that there is a large amount of unexplained variation, suggesting that other factors, outside of the plots, such as climatic conditions (temperature, humidity, rainfall and sunshine), soil type, plant species, plant age, pest and disease management, as well as competition with weeds, also influence dry mass production.

3.1.4. ANOVA on the influence of the number of plots on water content

Table IV illustrates the results of an analysis of variance (ANOVA) designed to examine the relationship between plot number and water content in the context of net primary production.

Table IV. ANOVA between plot number and water content in net primary production

Source of Variation	Sum of Squares (sum sq)	Degrees of Freedom (df)	Statistic (F)	p-value (PR(>F))
C (Plot Number)	8.683963	14.0	10.122906	0.999953
Residual	434.026379	86.0		

Here, we examine the differences in water content between the different plots. This means we want to know if the plot number influences the amount of water it absorbs or retains. The figure of 8.683963 represents the sum of squares, which is a statistical measure indicating the variability of the data. This shows how much the water content values vary from plot to plot. The 14 degrees of freedom refer to the number of plots minus one (15 plots - 1). This helps define the number of comparisons that were made to determine if there are any significant differences. With an F-statistic value of 10.122906, this indicates the strength of the relationship between the plot number and water content. A high F-value suggests that there may be differences of interest, but this needs to be confirmed by the p-value. The p-value is 0.999953, which is extremely high. This means we don't have strong statistical evidence to say there's a significant difference in water content between the different plots. In other words, it suggests that the differences we observe could very well be due to chance.

3.1.5. Correlations between Species Diversity and Net Primary Production: A Pearson Analysis

Table V illustrates the results of an analysis of variance (ANOVA) designed to examine the Pearson correlation of net primary production across different sites.

Table V. Pearson Correlation of Net Primary Production at Different Study Sites

Relationship	Correlation Coefficient (Pearson)	t	df	p-value	Confidence Interval (95%)	
					Lower Limit	Upper Limit
Number of Species/Plot and Fresh Forage Mass (kg)	0.559	2.430	13	0.030	0.185	0.933
Number of Species/Plot and Plot Number	-0.686	-3.396	13	0.005	-0.974	-0.398
Fresh Forage Mass (kg) and Plot Number	-0.572	-2.514	13	0.026	-0.938	-0.206

The first correlation looks at the relationship between the number of species in each plot and the fresh forage mass (in kilograms). The correlation coefficient is 0.559, which shows a moderate positive correlation. This means that in plots where species diversity goes up, the fresh forage mass tends to increase as well. In other words, a plant-rich environment produces more biomass, which is key for a healthy ecosystem. Such diversity allows different

species to use available resources like light, water, and nutrients in complementary ways, maximizing overall biomass production. The p-value of 0.030, which is below the 0.05 significance level, confirms this correlation is likely not due to chance. Also, the confidence interval between 0.185 and 0.933 supports the idea that the number of species really has a meaningful effect on fresh forage mass.

The number of species per plot and the plot numbers have a strong negative correlation, with a coefficient of -0.686. This means as plot numbers increase, species count decreases. This trend might suggest that plots with higher numbers are in less favorable areas for species diversity. If these plots have fewer species, it could also mean they have lower net primary production (NPP), possibly due to environmental challenges like limited water or nutrients. The p-value of 0.005 shows this is highly statistically significant, and the confidence interval from -0.974 to -0.398 confirms this relationship is real and significant.

The relationship between fresh forage mass and plot numbers shows a coefficient of -0.572. This negative correlation means fresh forage mass decreases as plot numbers go up. This supports the idea that higher-numbered plots produce less plant biomass overall. Such a drop in fresh forage mass directly leads to lower NPP in those plots. This could be due to unfavorable environmental factors or other plant growth limitations. The p-value of 0.026, also below 0.05, confirms this correlation is statistically significant. The confidence interval from -0.938 to -0.206 backs up this interpretation, suggesting the location of plots has a clear effect on biomass.

These correlations show that species diversity and plot location are closely linked to plant biomass production, and by extension, NPP. Plots with higher species diversity seem to have more significant NPP, while those in less favorable areas (higher plot numbers) show much lower biomass production. This highlights how important resource management and environmental conditions are for supporting more productive ecosystems.

## 4. Discussion

### 4.1. Net Primary Production at Different Sites

Table I shows net primary production observed across fifteen study sites, including data on species count, fresh forage mass, dry weight, and water content of various species. Species richness per plot ranges from 6 to 9, indicating notable ecological variation.

Plots 1 and 2 stand out for the highest diversity, with 9 and 8 species respectively, while plots 8, 9, 10, 11, 13, and 14 have only 6 species. This variability aligns with Ouattara et al. (2016), who emphasize the importance of species diversity for ecosystem resilience and productivity. Comparative studies, like Ahouangan et al. (2010), also confirm that species richness can influence forage productivity, supporting our findings in the most diverse plots. Additionally, Idrissa et al. (2020) show that varied ecological environments lead to uneven species distribution, which we also observed.

### 4.2. Impact of Plots on Fresh Forage Mass: ANOVA Analysis

The ANOVA shows that differences in fresh forage mass explained by plot differences are minimal. The F-value (0.5577) and p-value (0.8896) suggest plot effects on fresh forage mass are not significant, meaning other factors like climate and resource management might be influencing these results. Further studies, including Ouattara et al. (2016), confirm that other environmental variables are crucial to understanding plant productivity (Ouattara et al., 2018).

### 4.3. ANOVA on Dry Mass of Plots: Exploring Variations

ANOVA on dry mass shows a sum of squares of 50395.89, with a modest F-value (1.1634) and a high p-value (0.3176). This supports the idea that there are no significant differences between plots in terms of dry mass. Similar research, such as Ahouangan et al. (2010), stresses the importance of exploring other variables that might explain this diversity in production.

### 4.4. ANOVA on Plot Number Influence on Water Content

This analysis reveals a sum of squares of 8.683963, but a high F-value (10.122906) balanced by a p-value close to 1 (0.999953), indicating no significant evidence that plot location affects water content. This matches findings by Idrissa et al. (2020), where water resource variability seems influenced by multiple factors.

### 4.5. Correlations Between Species Diversity and Net Primary Production: Pearson Analysis

Correlations show significant relationships, especially between species diversity and fresh forage mass ( $r = 0.559$ ,  $p = 0.030$ ), confirming that more diverse environments produce more biomass. However, a negative correlation between plot number and species diversity ( $-0.686$ ,  $p = 0.005$ ) suggests plots less favorable to biodiversity also have lower NPP.

These observations are supported by [Amrani & Chehma \(2020\)](#), highlighting the role of diversity in ecosystem productivity. These results emphasize the importance of species diversity in ecosystem productivity, confirming earlier studies ([Ouattara et al., 2016](#); [Idrissa et al., 2020](#); [Thiebeau and Recous, 2016](#)).

This research suggests that proper resource and environmental management is essential to maximize biomass production. [Rodríguez et al. \(2025\)](#) confirm the positive link between prairie floral diversity and productive performance. [Diatta et al. \(2023\)](#) show short-term dynamics of standing herbaceous forage mass depending on grazing or protection, suggesting management practices can influence diversity-biomass relationships. Many studies highlight environmental factors. [Massama-Esso & Agbamaro \(2025\)](#) emphasize how different agroecosystems affect flora and carbon storage, which indirectly impacts biomass production. [Adama & Souleymane \(2025\)](#) show diversity and flora distribution depend on agro-pastoral arrangements, supporting the idea that resource management influences diversity. It would be useful to further explore environmental factors affecting these results, including soil composition and climate conditions. [Obenakou \(2024\)](#) studies floral diversity in traditional worship sites not directly related to agricultural production but underscores biodiversity importance in different contexts. [Ndayishimiye et al. \(2013\)](#) propose a biodiversity conservation method that could be relevant for sustainable agricultural ecosystems management. To improve forage mass, it's recommended to increase plant diversity in plots.

Greater plant species diversity can lead to more efficient use of available resources and better resilience to environmental changes ([Vroh et al., 2015](#)). It's also important to carefully study soil and climate conditions, as these play key roles in primary production. A deep understanding of these conditions will help adjust farming practices for local optimization ([Bambara et al., 2017](#)). Finally, integrating these study results into management programs is essential to optimize productivity in local agricultural ecosystems.

A science-based, integrated approach will support informed decisions and sustainable improvement in agricultural production ([Ouattara et al., 2016](#)).

## 5. Conclusion

This study highlights the importance of biodiversity for net primary production (NPP) in aquatic ecosystems, specifically in the M'fimi watershed in the Democratic Republic of Congo. Results show that higher species diversity is linked to increased fresh forage mass, underlining biodiversity's crucial role in ecosystem health. However, statistical analyses via ANOVA reveal that variations in fresh forage mass and water content are not significantly influenced by plot numbers, suggesting other environmental factors like climate and soil type might be more decisive. The observed positive correlation between species diversity and plant production suggests a need for natural resource management focused on enhancing biodiversity. Plots identified as less favorable to biodiversity, with higher numbers, also show lower NPP, calling for special attention to less productive areas. Overall, the study recommends sustainable farming practices that include strategies to optimize biodiversity, improve environmental conditions, and maximize biomass production. The findings call for further research into environmental factors influencing productivity and for management policies that support ecosystem sustainability.

## Acknowledgment

The authors express their deep gratitude to the rural commune of Kutu, in the Mai-Ndombe province, for its warm welcome, logistical support and effective collaboration, which enabled the reliable collection of data necessary for this study.

## Funding

There was no funding for this article.

## Conflict of Interest statements

The authors declare no conflict of interest in the publication process of the research article.

## Ethical Considerations

This article was prepared in accordance with ethical research principles, ensuring compliance with current standards. It is important to note that no human or animal data were used in this study, ensuring full compliance with ethical requirements. The authors also declare that they have no conflicts of interest regarding this research, which reinforces the study's credibility. The data used for this analysis were obtained ethically and legally, complying with all relevant regulations. Finally, the study results were presented honestly and

transparently, without any data manipulation, to ensure the scientific integrity of the entire work.

### Authors contributions

Each author played a key role in the development and finalization of the research article.

P.B.N: was responsible for drafting and preparing the original version. He also focused on data collection and analysis and validated the final version.

A.M.N: was responsible for reviewing the survey, helped improve the quality of the original version, and performed the final revision, ensuring the article was ready for publication.

C.L.A. and C.N.L: oversaw the entire process, ensuring that all steps were followed correctly.

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