

Effect of Land Fencing on the Productivity and Quality of Sahelian Grasslands: Case Study of the Ferlo, Northern Senegal

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Abstract

The objective is to determine the effect of the protection on the production and quality of fodder in the rangelands of the Great Green Wall (GGW) of Senegal in Ferlo during three successive years. The quadrat point method, and the full harvest method were used. The results reveal a rich flora of 56 species, 40 genera and 20 families. Between the first and last year of monitoring, the net pastoral value varied from 54.88% to 83.21% in the 2013 plot: from 22.53% to 80.41% in the 2009 plot and from 46.86% to 83.97% outside. The quality fodder is estimated at 3.07 tones DM/ha in the 2013 plot: 0.76 tones DM/ha in the 2009 plot and 0.91 tones DM/ha outside. The carrying capacity is lower than 1, which is low overall. The protection does not seem to have a significant effect on the quality of the pastures. On the other hand, it seems to be conducive to the production of abundant fodder.

Keywords

Carrying Capacity, Protection, Ferlo, GGW-Senegal

1. Introduction

Land degradation is a major problem affecting numerous regions of the world, including Senegal. According to the United Nations Convention to Combat Desertification (UNCCD), the level of land degradation in Senegal is 34%, represent-

ing a degraded surface area of 6,860,900 ha. The Ferlo, like all Sahelian regions, is undergoing significant degradation due to climate change and human activities. This degradation has affected the herbaceous stratum (the main source of fodder for livestock) and is detrimental to the local economy, which is mainly dependent on pastoral activities [1].

In response to this situation, the UNCCD's target 15.3 of the 15th Sustainable Development Goal aims "by 2030, to combat desertification, rehabilitate degraded land and soil, including land affected by desertification, drought and floods, and strive for a world without land degradation". According to the Ministry of Environment and Sustainable Development in its 2015 National Sustainable Development Strategy, Senegal has also committed to the Land Degradation Neutrality (LDN) initiative with a view to achieving the target 15.3 to reach the goal of neutrality, by 2035 requires a sustained effort of 480,263 ha per year or an annual progression rate of 7% compensation for losses from 2020. As such, the Great Green Wall project, launched by the African Union, has been adopted in Senegal to combat the harmful effects of soil degradation and desertification in the Sahara and Sahel, particularly in the Ferlo ecosystems [2].

In this perspective of reconstitution of Ferlo's landscapes, an understanding of the overall forage situation (potential phytomass production, pastoral value, forage production and quality, carrying capacity) is fundamental to the monitoring and evaluation of rangelands in Sahelian ecosystems, particularly those of the Ferlo. Indeed, lack of knowledge of the relationship between forage requirements and the ecological potential of rangelands is the main problem hampering the sustainable management of silvopastoral resources [3]. Hence the interest of this study, which seeks to examine the effects of fencing on the quality and production of Sahelian grasslands. It seeks to understand how fencing as a pasture and natural resource management practice can influence the quality and productivity of Ferlo pastures. Specifically, it's aimed to determine the floristic composition along protection levels first, assess each management system's pastoral value, and estimate each type's biomass production and livestock carrying capacity. The study was carried out at three sites in Widou Thiengoly, corresponding to two protected areas, a 2009 and a 2013 fenced plot and the communal rangeland without protection.

2. Materials and Methods

2.1. Study Area

Widou Thiengoly is located in the western part of the Ferlo (Sahelian part of Senegal). The region extends from the Senegal River valley to the bangs of the Groundnut Basin, covering more than 60,000 km² [4]. Administratively, it is located in the Louga region, within the department of Linguère, specifically in Tésékéré municipality (**Figure 1**).

Widou's climate is typically Sahelian, with two alternating seasons, a rainy and dry season (20). The rainy season lasts two to three months, often between July,

August, and September. It rains yearly in the area about 200 to 400 mm. Rains are spatially and temporally unstable, with a coefficient of variation between 30 and 40% [5] [6]. The lowest temperatures in the area are recorded in December, January, and February, with temperatures fluctuating between 19°C and 21°C. March, April, May and June are the warmest months, with temperatures fluctuating between 40°C and 43°C. Air humidity is higher between August and September (74%) and lower between February and March (31%). Average monthly evaporation is 401mm/year or 401mm.yr⁻¹ in September [7].

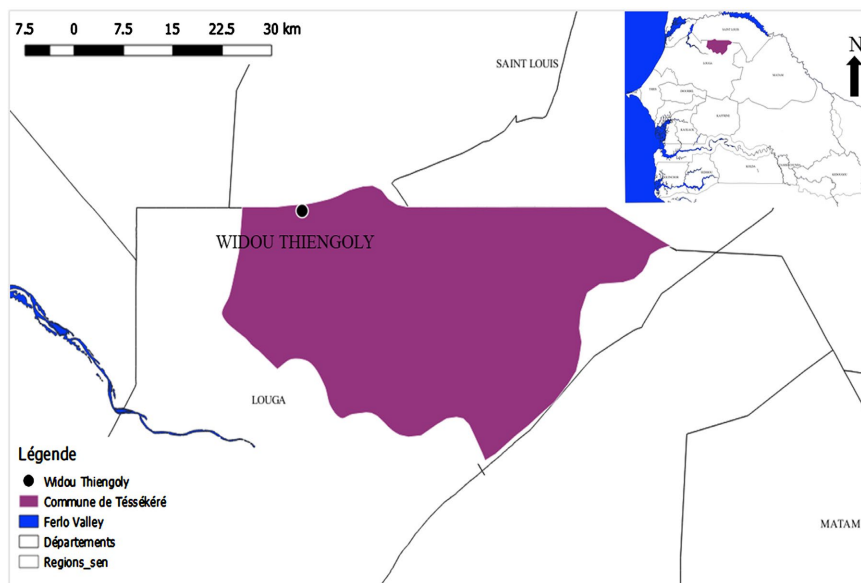


Figure 1. Location of Widou Thiengoly village (Source: Senegal Center for Ecological Monitoring, SCEM).

In morpho-edaphic terms, Widou belongs to the sandy Ferlo, which is part of the sandy dune formations of the Senegal-Mauritania basin, characterized by a succession of dunes and shallow lowlands [8] [9]. In this area, the soils type differs according to whether they are found on the top of a dune or at the bottom of a slope [5]. Indeed, the lowlands have a higher clay content than the dune tops. According to reference [8], three soil units are found at Widou. These are tropical ferruginous soils with little or no leaching, reddish-brown ferruginous subarid iso-humic soils, and a combination of the two abovementioned two units.

The study area is in the thorny steppe area, where pterophytes and phanerophytes predominate. Adaptation to severe climatic conditions explains the prevalence of these biological types in the area [10]. Towards the end of winter in October and September, the Ferlo vegetation forms a continuous herbaceous carpet dotted with trees and shrubs. Woody vegetation in the northern part of the Ferlo, where our study station is located, is characterized by a dominance of *Balanites aegyptiaca* (L.) Del., *Calotropis procera* Ait., and *Boscia senegalensis* (Pers) Lam. The herbaceous stratum is dominated by annual species, notably grasses (*Poaceae*) [8].

2.2. Methods

2.2.1. Floristic Inventory in the Selected Sites

The present work was carried out at three sites in October of 2014, 2015 and 2016 years. The observations during this period are due to the fact that it coincides with the end of the winter when the grass cover is always present in Sahelian rangelands. The level of protection is one of the parameters that motivated the choice of the sites. Three sites with different levels of protection were chosen for this study (**Figure 2**). Plot 2013 (5 ha) is reforested, fenced and guarded. The 2009 plot (2203 ha), which has no guard, has also been reforested and fenced with gaps in places allowing cattle to access it, giving the plot a semi-protected status. The third site was the community rangelands with no protection, which called “off-plot”. Therefore, the community rangelands corresponded to the controls. Generally, we would call these sites: “full enclosure”, “partial enclosure” and “open” (**Figure 2**).



Figure 2. Localization of the study sites.

2.2.2. Data Collection

The vegetation surveys are carried out using the “double meter” method. This method, described by [11], is an adaptation of the “quadrat points” method developed in New Zealand by [12]. The method involves identifying species near one hundred points regularly placed along a 10 m line (a line marked by a Penta decameter) in the vegetation to be studied. This method was chosen because it is best suited to Sahelian herbaceous formations whose average height exceeds 25 cm but is still less than 1 m high. The main downside of this method, as with all needle-based methods, is that the needles used in quadrat point observations are sometimes very thin, but also that wind can alter the number of contacts of the grasses with the stem. The first step in applying this method in the field is to mark a 10 m line using a decameter held taut above the herbaceous stratum and fixed by two stakes at either end (**Figure 3**). Then, along this line and every 10 cm, a needle graduated in deci-

meters is immersed vertically into the herbaceous vegetation and held in place. Finally, all species in contact with the needle are recorded, along with their number of contacts along the graduated sections of the needle. The information obtained is recorded on a form where 100 reading points are reserved for each species on the 10 m section. **Figure 3** schematically illustrates the method.

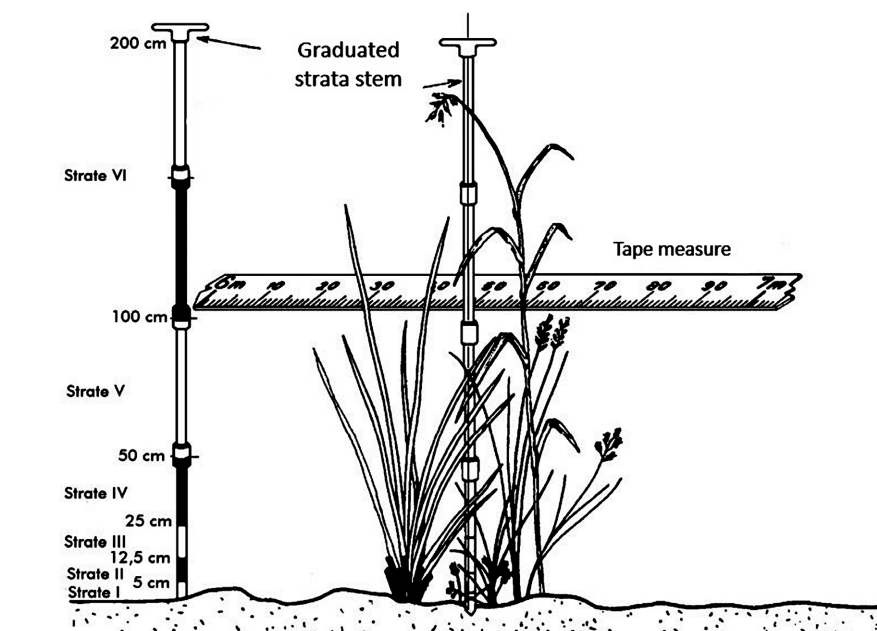


Figure 3. Schematic illustration of the quadrat point method (Daget and Poissonnet, 2010).

Five lines were randomly installed at each site. The number of lines per site was chosen to ensure an accurate estimate of their composition [13]. Line installation takes into account topographical units (slope, dune top and depression) and tree shading. The found species were identified directly in the field using “Les Plantes à fleurs Afrique tropicale” [14], and “La flore du Sénégal” [15]. The species that could not be identified in the field were placed in herbarium and brought back to the laboratory in Dakar, where they were identified using the herbarium.

2.2.3. Data Processing

The data from the field was processed with the Excel spreadsheet and R software for statistical analysis. From Excel the following parameters were determined:

Specific presence contribution (*SPC*): It corresponds to the ratio of the specific frequency of one species to the sum of the specific frequencies of all species. It expresses the relative importance of species and is reminiscent of the dominance abundance index [3].

$$SPC\% = \frac{SPFi \times 100}{\sum SPFi}$$

SPFi: Specific presence frequency corresponding to the percentage of points where the species was encountered.

Pastoral value: Species' pastoral value is obtained firstly by calculating their gross pastoral value obtained by multiplying their specific contribution by their specific quality index (*Sqi*). The specific quality index of a species reflects its zootechnical interest and has been established, more or less empirically, by considering its growth rate, palatability, assimilability, leaf and stem morphology, and forage value.

In the Sahelian ecosystems at Ferlo, the species quality index is established on a rating system from 0 to 3 [16]; [3], which means on a 4-class system (0, 1, 2 and 3) as follows:

Good pastoral value (*GPV*), species with a specific index equal to 3;

Medium pastoral value (*MPV*), species with a specific index equal to 2;

Low pastoral value (*LPV*), species with a specific index of 1;

Without pastoral value (*NPV*), species with a specific index equal to 0.

The gross pastoral value of a pasture is obtained by adding the values obtained from the multiplication of the contributions of the various species by their corresponding index.

$$Gpv = k \sum_{i=1}^n (SPC \times Sqi)$$

$$K = 1/N = 1/3$$

N = maximum scale index equal to 3

The net pastoral value is obtained by weighing the gross pastoral value to the overall vegetation cover [3] [17] [18].

$$Npv = IGQ = (Gpv \times OVC) = 1/3 \sum_{i=1}^n (SPC \times Sqi) \times OVC$$

Npv: Net pastoral value

GQI: Global Quality Index

Gpv: Gross pastoral value

SPC: Specific presence composition

Sqi: Specific quality index of grassland

OVC: Overall vegetation cover $1/3 = k$

Estimation of grassland production and forage quality: The grass biomass of the three study sites was estimated from samples harvested in October of the third year of the survey, using the integral harvesting method [19]. It is the most direct method for measuring the epigeous phytomass of the grass layer. It consists of cutting the grass at ground level (5 cm), using a biomass plot or square measuring 50 cm on each side, equivalent to 0.25 m². The harvested material was weighed on-site using a spring-loaded scale to obtain its fresh weight. The samples were then dried in an oven at 55 - 60° until a constant dry weight was obtained. The weight obtained after drying was used to calculate the grass production per unit area for each measurement. Thus, the production of aerial or epigeous phytomass corresponds to the sum of fresh mass (epigeous biomass) and standing dry mass ("necro-mass") [3] [17] [18]. It is expressed in kilogram dry matter per hectare

(kg DM ha⁻¹ or Tons DM ha⁻¹. Knowledge of the herbaceous phytomass (Hp) applied to the net pastoral value helps obtaining the production of “qualified” forage (Pqf); [3] [16]-[18].

$$Pqf = Hp \times GQI$$

Pqf = Production of quality forage

Hp = Herbaceous phytomass

GQI = Global quality index

Carrying capacity: The carrying capacity of a rangeland expresses its ability to feed livestock; it is measured by the number of animals fed in relation to the grazing area and consumption duration [11]. It is calculated based on rangeland productivity and the feed requirements of tropical livestock units (TLU) [3] [18]. The calculation is based on the hypothesis that livestock must absorb daily dry matter corresponding to 2.5% of their weight.

Thus, for 250 kg of TLU, 6.25 kg of dry matter per day is required. [3] [17]. Reference [20] estimates that only a third of the forage stock at the start of the dry season is consumable by livestock.

$$CC = (Pqf \times k) / (6,25 \times 240)$$

CC = Carrying capacity

Pqf = Production of quality forage

k = 1/3 = potential use of biomass coefficient.

240 = dry matter utilization period in days, corresponding to the dry season duration, which lasts a maximum of 8 months.

6.25 Kg = Daily requirement for a 250 Kg animal.

3. Results

3.1. Floristic Composition and Relative Pastoral Value

The herbaceous flora recorded at Widou during the study period is rich in 56 species divided into 40 genera, belonging to 20 botanical families of varying importance depending on the year (Table 1).

Table 1. Floristic composition and pastoral value per site over three years.

			2014			2015								
<i>Floristic composition</i>			Plot 2013	Plot 2009	Off plot	Relative pastorage value (Rpv)			Plot 2013	Plot 2009	Off plot	Relative pastorage value (Rpv)		
Species	Families	Sqi	Specific presence contribution (SPC)			Plot 2013	Plot 2009	Off plot	Specific presence contribution (SPC)			Plot 2013	Plot 2009	Off plot
<i>Peristrophe bicalyculata</i>	<i>Acanthaceae</i>	1	5.05	0	0	5.05	0	0	0	0	0	0	0	0
<i>Gisekia pharnacioides</i>	<i>Aizoaceae</i>	1	1.9	2.69	3.9	1.9	2.69	3.9	0.29	0.13	0	0.29	0.13	0
<i>Achyranthes argentea</i>	<i>Amaranthaceae</i>	1	1.27	1.07	0	1.27	1.07	0	0	0.64	0	0	0.64	0
<i>Achyranthes aspera</i>	<i>Amaranthaceae</i>	1	0	0	0	0	0	0	4.22	0	0	4.22	0	0

Continued

<i>Pancratium trianthum</i>	<i>Amaryllidaceae</i>	1	0	0	0	0	0	0	0	0.13	0	0	0.13	0
<i>Cleome viscosa</i>	<i>Araceae</i>	0	0	0	0	0	0	0	0	1.48	0.62	0	0	0
<i>Heliothropium strigosum</i>	<i>Boraginaceae</i>	0	0	4.84	0	0	0	0	0	0	0	0	0	0
<i>Commelina forskalaei</i>	<i>Commelinaceae</i>	2	0	0	0	0	0	0	0	0.06	0	0	0.12	0
<i>Ipomaea Coptica</i>	<i>Convolvulaceae</i>	2	1.42	0.54	0	2.84	1.08	0	2.43	0	0	4.86	0	0
<i>Ipomaea Kotschyana</i>	<i>Convolvulaceae</i>	2	0	0	0	0	0	0	0	0.64	0	0	1.28	0
<i>Ipomaea triloba</i>	<i>Convolvulaceae</i>	2	0	0	0	0	0	0	2.83	0	0	5.66	0	0
<i>Cucumis melo agrestis</i>	<i>Cucurbitaceae</i>	1	0.63	0	0	0.63	0	0	0	0	0	0	0	0
<i>Momordica balsamina</i>	<i>Cucurbitaceae</i>	1	0.32	2.15	0	0.32	2.15	0	0	0	0	0	0	0
<i>Momordica charantia</i>	<i>Cucurbitaceae</i>	1	0	0	0	0	0	0	1.21	0	0	1.21	0	0
<i>Abilgardia hispidula</i>	<i>Cyperaceae</i>	1	0	0	0	0	0	0	0	0	0.05	0	0	0.05
<i>Cyperus esculentes</i>	<i>Cyperaceae</i>	2	10.9	0	0.87	21.8	0	1.74	8.44	0	4.44	16.9	0	8.88
<i>Phyllanthus maderapatensis</i>	<i>Euphorbiaceae</i>	0	0	0	0	0	0	0	0	0.06	1.34	0	0	0
<i>Phyllanthus niruri</i>	<i>Euphorbiaceae</i>	0	0	0.54	1.95	0	0	0	0.12	0	0	0	0	0
<i>Phyllanthus pentandrtus</i>	<i>Euphorbiaceae</i>	0	0	0	0.87	0	0	0	0	0.13	0.05	0	0	0
<i>Alysicarpus ovalifolius</i>	<i>Fabaceae</i>	2	3.48	2.69	2.38	6.96	5.38	4.76	4.92	0.97	2.78	9.84	1.94	5.56
<i>Indigofera aspera</i>	<i>Fabaceae</i>	2	0	0	0	0	0	0	0	0.71	0	0	1.42	0
<i>Indigofera hirsute</i>	<i>Fabaceae</i>	2	0.63	0	3.9	1.26	0	7.8	12.6	14	19.7	25.2	28.1	39.4
<i>Indigofera senegalensis</i>	<i>Fabaceae</i>	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Senna obtusifolia</i>	<i>Fabaceae</i>	1	0	1.07	0	0	1.07	0	0	0	0	0	0	0
<i>Tephrosia purpurea</i>	<i>Fabaceae</i>	2	1.58	0	0	3.16	0	0	0	0.26	0	0	0.52	0
<i>Zornia glochidiata</i>	<i>Fabaceae</i>	2	4.26	1.07	1.08	8.52	2.14	2.16	5.96	1.67	2.32	11.9	3.34	4.64
<i>Limeum viscosum</i>	<i>Limeaceae</i>	1	0	0	0	0	0	0	0	0	0	0	0	0
<i>Boerhavia erecta</i>	<i>Nyctaginaceae</i>	1	0	5.38	4.76	0	5.38	4.76	1.56	0.39	0.36	1.56	0.39	0.36
<i>Rogeria adenophylla</i>	<i>Malvaceae</i>	0	0.47	0.54	0	0	0	0	0.17	0	0	0	0	0
<i>Aristida adscensionis</i>	<i>Malvaceae</i>	2	0	0	0	0	0	0	0	0.32	0.26	0	0.64	0.52
<i>Aristida funiculata</i>	<i>Pedaliaceae</i>	2	0	0	2.16	0	0	4.32	0	0	0	0	0	0
<i>Aristida mutabilis</i>	<i>Poaceae</i>	2	18.5	28	38.5	37	55.9	77.1	6.71	8.44	6.76	13.4	16.9	13.5
<i>Aristida stipoides</i>	<i>Poaceae</i>	2	0	0	0	0	0	0	0	0	0	0	0	0
<i>Brachiaria lata</i>	<i>Poaceae</i>	3	0	0	0	0	0	0	0	4.83	2.84	0	14.5	8.52
<i>Brachiaria ramosa</i>	<i>Poaceae</i>	3	0	6.45	0.87	0	19.4	2.61	0.64	4.06	0.31	1.92	12.2	0.93
<i>Cenchrus biflorus</i>	<i>Poaceae</i>	3	7.74	1.61	1.95	23.2	4.83	5.85	4.45	1.29	1.6	13.4	3.87	4.8
<i>Chloris pilosa</i>	<i>Poaceae</i>	3	0	0	0	0	0	0	4.74	0.52	0.36	14.2	1.56	1.08

Continued

<i>Dactyloctenium aegyptium</i>	Poaceae	2	1.26	9.14	6.28	2.52	18.3	12.6	5.38	22.9	14.3	10.8	45.7	28.6
<i>Digitaria horizontalis</i>	Poaceae	2	0	2.15	0	0	4.3	0	2.31	4.51	3.87	4.62	9.02	7.74
<i>Dinebra retroflexa</i>	Poaceae	2	0	0	0	0	0	0	0	0	0.26	0	0	0.52
<i>Diplachne fusca</i>	Poaceae	2	0	0	0	0	0	0	0	0.26	0.15	0	0.52	0.3
<i>Enteropogon prierurii</i>	Poaceae	3	2.69	1.61	4.76	8.07	4.83	14.3	18.3	6.89	14.5	54.9	20.7	43.5
<i>Eragrostis ciliaris</i>	Poaceae	3	0	0	0	0	0	0	2.14	2.12	0.72	6.42	6.36	2.16
<i>Eragrostis sp</i>	Poaceae	3	0	0.54	0	0	1.62	0	0	0	0	0	0	0
<i>Eragrostis tenella</i>	Poaceae	3	0	0	1.08	0	0	3.24	0	0	0	0	0	0
<i>Eragrostis tremula</i>	Poaceae	3	3.95	0	1.51	11.9	0	4.53	5.09	6.37	9.95	15.3	19.1	29.9
<i>Panicum pansum</i>	Poaceae	3	0	0	0	0	0	0	0.23	0	0	0.69	0	0
<i>Pennisetum violaceum</i>	Poaceae	3	0	0	0	0	0	0	0	0.13	0	0	0.39	0
<i>Schoenefeldia gracilis</i>	Poaceae	3	12.2	18.8	14.1	36.5	56.5	42.2	0.81	15.1	10.4	2.43	45.2	31.1
<i>Tripogon minimus</i>	Poaceae	2	0	0	0	0	0	0	0.29	0.9	0.36	0.58	1.8	0.72
<i>Portulaca oleracea</i>	Poaceae	0	0	0	0	0	0	0	0.35	0	0.05	0	0	0
<i>Oldenlandia corymbosa</i>	Poaceae	0	0	0	0	0	0	0	0	0	0.05	0	0	0
<i>Spermacoce ruelliae</i>	Portulacaceae	1	16	0	2.59	16	0	2.59	1.85	0	1.39	1.85	0	1.39
<i>Corchorus aestuans</i>	Rubiaceae	1	0	0	0	0	0	0	0	0.06	0.15	0	0.06	0.15
<i>Corchorus tridens</i>	Rubiaceae	1	0.16	0	0	0.16	0	0	1.21	0.06	0.1	1.21	0.06	0.1
<i>Tribulus terrestris</i>	Tribulaceae	2	5.69	9.14	6.49	11.4	18.3	13	0.75	0	0	1.5	0	0

Sqi = Specific quality index of grass; Rpv = $SPC \times Sq_i$; SPC = Specific presence contribution.

The herbaceous flora of the study sites shows a specific variability depending on the year. During the 1st year, 31 species were recorded ascribed to 27 genera and 15 families. In the 2nd year, the number of taxa observed increased slightly. It rose to 45 species belonging to 24 genera and 17 families. In the final year of the survey, the species richness fell back to that of the 1st year, with 32 species in 27 genera and 12 families.

Aristida and *Eragrostis* with 4 species each were the most represented genera. They were followed by *Indigofera*, *Ipomoea*, and *Phyllanthus* with 3 species each over the three years. *Achyranthes*, *Momordica*, *Brachiaria*, and *Corchorus* were followed by only 2 species, and each of the remaining genera had one species.

The relative importance of families shows that the *Poaceae* are the most represented, with a frequency of 37.5%, followed by the *Fabaceae* (12.5%). *Convolvulaceae*, *Cucurbitaceae*, and *Euphorbiaceae* accounted for 5.4% of species each. These five families grouped more than 65% of all species inventoried. **Figure 4** shows the specific presence contribution of the various families listed at Widou.

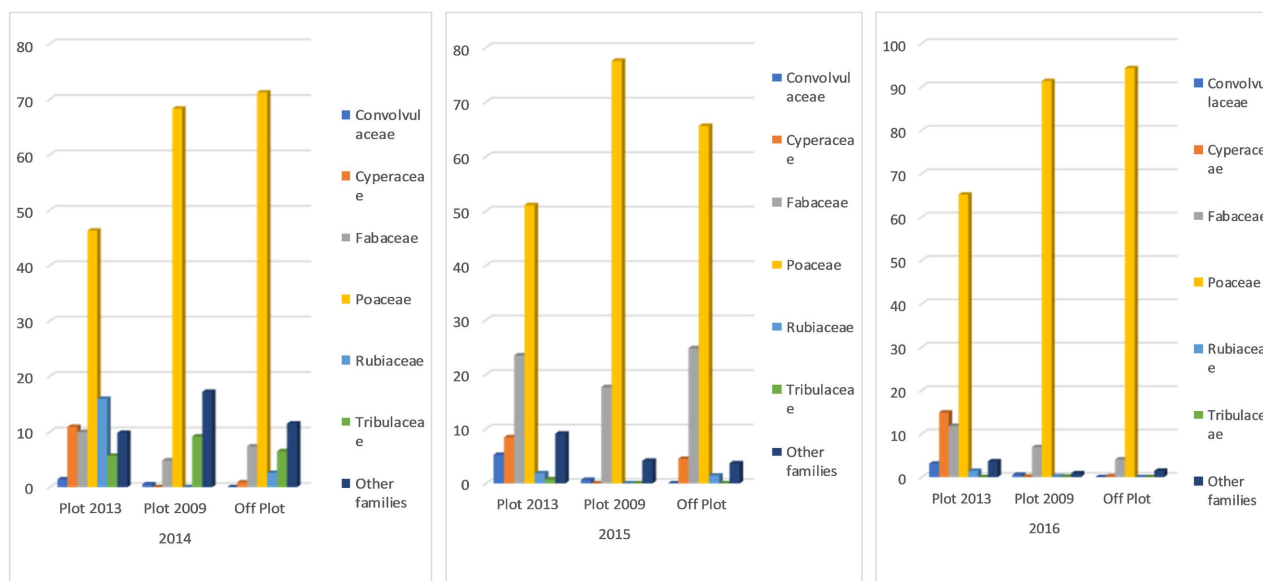


Figure 4. Specific presence contribution spectrum of families recorded at Widou in October over three years.

In the 2013 plot, the herbaceous flora recorded in October of the 1st year of observation had 21 species grouped in 21 genera belonging to 15 families. The genera *Achyranthes*, *Ipomoea*, *Momordica*, and *Eragrostis* were the most represented, with 2 species each. Overall, the grass covered 82.2% of the soil, while the specific cover was generally low. *Aristida mutabilis*, *Spermacoce ruelliae* and *Schoenefeldia gracilis* made the highest specific contributions this year. In the second year, the 2013 plot hosted 28 species that belong to 25 genera and 14 families. The most common genera were *Ipomoea* and *Eragrostis*, each containing two species. The herbaceous ground cover in the second year was 99.8%, with a low specific cover. *Indigofera hirsuta* and *Enteropogon prierii* were the most frequently encountered species in the plot, with a specific contribution of 12.6% and 18.3%, respectively (Table 1). However, in the third year, the grassland flora regressed, covering 22 species clustering in 20 genera and 7 families. Despite the drop in taxa compared with the previous year, the overall vegetation cover showed little change. It was 98.6%, with low species cover except *Cyperus esculentus* (14.7%), and *Chloris pilosa* (14.5%). *Ipomoea* and *Eragrostis* (2 species each) were the dominant genera in the herbaceous cover of the 2013 plot. Over the three years of observation, 34 species were recorded in the 2013 plot.

In the 2009 plot, observations of the herbaceous cover comprised 44 species, 33 genera, and 18 families over the three years observations. In the first year, it had 20 species distributed in 20 genera and 11 families, with a low soil coverage of 33%. *A. mutabilis* and *S. gracilis* were the dominant species in the vegetation cover, with specific contributions of 27.96% and 18.82%, respectively. In the second year, the floristic composition of the grasses found in the 2009 plot was fairly exhaustive, with 31 species belonging to 25 genera and 11 families (Table 1). The most common genera were *Phyllanthus*, *Corchorus*, *Eragrostis*, *Indigofera*, and *Brachiaria*, each with two species. The soil was covered at 98.8% by grasses, but specific or species cover

was low except for *Dactyloctenium aegyptium* (22.6%), *S. gracilis* (14.9%) and *I. hirsuta* (13.9%). The soil cover in the last year of observation was lower than that of the previous year. It consisted of 22 species ascribed to 20 genera and 9 families (**Table 1**). *A. mutabilis*, *E. prieurii*, *D. aegyptium*, *Digitaria horizontalis*, and *S. gracilis* were the most represented species. Their specific contribution was 23.9%, 14.5%, 13.8%, 11.2%, and 10.7% respectively. The soil was 99.9% covered by the herbaceous layer, with a specific cover of less than 10%, except for the dominant species, which accounted for more than 70% of the overall cover.

Over three years, the herbaceous vegetation outside the plots contained 36 species belonging to 27 genera and 12 families. The dominant genera were *Phyllanthus*, *Indigofera*, *Eragrostis* (3 species each), *Achyranthes*, *Ipomoea*, *Aristida*, *Brachiaria*, and *Corchorus* (2 species each). During the first year of survey, 19 species were found outside the plots and were divided into 16 genera within 8 families, with *Aristida*, *Eragrostis*, and *Phyllanthus* (2 species each) as the dominant genera. In this area, the soil coverage was 67.8%, and the specific coverage was less than 10%, except *A. mutabilis* at 26.1%. It's dominated the herbaceous cover with a specific contribution of 38.53%. In the second year, the herbaceous cover found outside the plots had 29 species belonging to 24 genera and 9 families. The dominant genera were *Aristida*, *Brachiaria*, *Corchorus*, *Eragrostis*, and *Indigofera*, each containing two species. *Indigofera hirsuta* (19.7%), *E. prieurii* (14.5%) and *D. aegyptium* (14.3%) made the greatest contribution to the overall soil cover of 96.8%. In the third year, the grassland flora outside the plot showed a floristic richness of 17 species belonging to 15 genera and 5 families (**Table 1**), and about 98% of the soil was covered. Only *E. prieurii* (26.5%), *S. gracilis* (16.4%), and *D. aegyptium* (15.7%) had a species cover of over 10%.

In summary, an analysis of the specific herbaceous composition at the three study sites over the past three years may suggest that protection improves the specific diversity of the herbaceous cover.

3.2. Grassland Production and Quality

3.2.1. Pastoral Value

The results on pastoral value are presented in **Table 2**, which shows the specific contributions by forage category as well as pastoral value by site and year.

Table 2. Specific contributions by forage category and pastoral value per year and site.

	2014			2015			2016		
	P 2013	P 2009	Off P	P 2013	P 2009	Off P	P 2013	P 2009	Off P
GPV	26.54	29.03	24.24	36.38	41.28	40.64	57.56	42.64	57.58
MPV	31.8	35.13	41.13	35.09	37.09	36.79	25.58	37.53	27.97
LPV	8.43	4.12	3.75	3.45	0.47	0.69	1.25	0.33	0.15
Gpv	66.77	68.28	69.12	74.92	78.84	78.12	84.39	80.5	85.7
Npv	54.88	22.53	46.86	74.77	77.89	75.62	83.21	80.41	83.97

GPV = Good pastoral value; MPV = Medium pastoral value; LPV = Low pastoral value; Gpv = Gross pastoral value; Npv = Net pastoral value.

The herbaceous cover in the 2013 plot over the three years of observation shows that the relative pastoral value per species goes from medium to low. In the first year, *A. mutabilis* (36.96), *S. gracilis* (36.48), and *Cenchrus biflorus* were the species with the highest relative values (**Table 1**). However, during 2015, *E. prieurii* (54.83) and *I. hirsuta* (25.24) contributed most to pastoral value. In year 3, *E. prieurii* (82.64), *Chloris pilosa* (44.05), and *Cyperus esculentes* (29.8) still dominated the plot. The gross pastoral value of the 2013 plot was estimated at 66.77%, 74.92%, and 84.39% in years 1, 2, and 3, respectively. Good Pastoral Value (*GPV*) and Medium Pastoral Value (*MVP*) species contributed most to this value in all three years. The global quality index (*GQI*) or net pastoral value of the 2013 plot was 54.88% (2014), 74.77% (2015), and 83.21% (2016).

In the 2009 plot, the relative values of the species were also medium to low. In October 2014, *A. mutabilis* (56.92) and *S. gracilis* (56.46) had the highest relative values. This year's grass cover's net pastoral value was low ($Npv = 22.53\%$) due to its low soil cover. In the second year of observation, *D. aegyptium* (45.72%), *S. gracilis* (45.20%), and *I. hirsuta* (28.07) showed the highest relative values. The gross pastoral value of grassland in the 2009 plot in this year was 78.84%. The global quality index was 77.89%, which varied according to the different forage categories. The third year of monitoring was characterized by a gross pastoral value of 80.5%. This value, weighted by cover, gives a net pastoral value of 80.41%. *A. mutabilis* (47.34), *E. prieurii* (43.62), *S. gracilis* (32.18), *D. aegyptium* (27.66%), and *D. horizontalis* (22.34) showed higher or lower relative values. During these three years, species in the *GPV* and *MPV* categories mostly contributed to the global quality index value of the *GQI*.

The same trends were noted outside the rangelands as in the other two sites. The species outside the rangelands had low relative values, except *A. mutabilis* [77.06 (2014); 36.23 (2016)], *S. gracilis* [42.21 (2014); 31.1 (2015); 50.18 (2016)], *E. prieurii* [43.48 (2015); 81.24 (2016)], *I. hirsuta* 39.40 in 2015, *E. tremula* [29.86 (2015); 29.67 (2016)], and *D. aegyptium* [28.57 (2015); 31.98 (2016)], which showed higher relative values (**Table 1**). The gross pastoral value of grassland outside the plots was estimated at 69.12%, 78.12%, and 85.7% for 2014, 2015, and 2016 respectively. The global quality index obtained by multiplying the gross pastoral value with coverage was 46.86% (2014), 75.62% (2015), and 83.97% (2016) as shown in **Table 2**.

The results on grass quality show that the herbaceous biomass of all three study sites is of good quality, except the 2009 plot and the outer pastures, where the cover was of low quality in the first year. In all study sites, the lowest IGQ value was recorded in the first year and increased exponentially in subsequent years. An analysis of variance on pastoral value, described in **Table 3**, shows that *Npv* has no significant difference between study sites and years.

3.2.2. Grass Production, Forage Quality

The dry matter produced at Widou varied according to the site's level of protection. It was estimated at 3.69 tons DM/ha, 0.95 tons DM/ha, and 1.08 tons DM/ha

in the 2013 plot, 2009 plot, and in community pastures without protection, respectively. The produced dry matter, correlated with the net pastoral value of the grasslands, enabled the production of quality forage (*Pqf*) at each site. *Pqf* was thus estimated at 3.07 tons DM/ha, 0.76 tons DM/ha, and 0.91 tone DM/ha in the 2013 plot, 2009 plot, and outside the plots, respectively.

The analysis of variance on forage phytomass shows that there is a highly significant difference between grass productivity on the fenced plot and that under grazing (Table 4). As a result, it can be seen that fencing favors the development of the herbaceous cover.

3.3. Carrying Capacity

The grazing area's carrying capacity was low, but highly varied depending on the site studied. It was estimated at 0.61 TLU/ha/yr, 0.15 LU/ha/yr, and 0.18 TLU/ha/yr in the 2013 plot, 2009 plot, and off-plot. Table 4 summarizes the various parameters calculated per site during October of the last year of the study.

The results indicate that pastoral values only vary a little across the studied sites, except in year 1, where considerable differences were noted between the 2013 plot, the outside rangeland plot, and the 2009 plot. However, there was some variability in forage production and carrying capacity depending on the protection level of the site. These two parameters are higher in the 2013 plot than in the site accessible to livestock (Table 5).

Table 3. Forage balance by site in October of the last study year.

	<i>Df</i>	<i>Sum Sq</i>	<i>Mean Sq</i>	<i>F value</i>	<i>Pr(>F)</i>	<i>Significant impact</i>
<i>Date</i>	1	0.15567	0.15567	9.506	0.054	NS
<i>Zone</i>	2	0.02680	0.01340	0.818	0.521	NS
<i>Zone/Date</i>	2	0.03655	0.01828	1.116	0.434	NS
<i>Résiduels</i>	3	0.04913	0.01638			

Df = Degrees of freedom; *Sum Sq* = Sum of squares; *Mean Sq* = Mean of squares; *F value* = Fisher's coefficient; *Pr(>F)* = Risk of error; *NS* = Not significant.

Table 4. Forage balance by site in October of the last study year.

	<i>Net pastoral value Npv GQI</i>	<i>Herbaceous phytomass Hp</i>	<i>Quality forage Qf</i>	<i>Carrying capacity CC</i>
<i>Plot 2013</i>	83.21	3.69	3.07	0.61
<i>Plot 2009</i>	80.41	0.95	0.76	0.15
<i>Off plot</i>	83.97	1.08	0.91	0.18

Table 5. Analysis of variance (ANOVA) on forage productivity.

	<i>Df</i>	<i>Sum Sq</i>	<i>Mean Sq</i>	<i>F value</i>	<i>Pr(>F)</i>	<i>Significant impact</i>
<i>Test</i>	2	0.05429	0.027144	17.67	1.24e-05	***
<i>Résiduels</i>	27	0.04147	0.001536			

4. Discussion

This work aimed to determine the role of fencing in the production and pastoral quality of grasslands. Over the three years, the grassland flora recorded at Widou in October comprised 56 species divided into 40 genera belonging to 20 botanical families whose importance varies according to the year. This result matches that obtained by the reference [8] in terms of species number, who counted 45 taxa at the station in June and September 2010.

Variation in the grassland composition across sites indicates that semi-protection is more conducive to increasing the biodiversity of the herbaceous cover. The references [21] and [9] reported that pastures with low or moderate anthropogenic pressures record a greater floristic richness. The 34 species in the 2013 plot differ from that obtained by the author [9], who reported 66 species in the same plot. This difference can be explained by the survey method.

The prevalence of *Poaceae* at both ecological station and vegetation unit scales can be linked to the intrinsic nature of the herbaceous flora of Sudano-Sahelian savannas, which is dominated mainly by annual grasses [3]; [8]. Furthermore, the taxa in this family has a very high regrowth and tillering capacity [9]; [22].

The gross pastoral value varied from 66.77% to 84.7% at the different study sites across the three years of the study. This high value was observed due to the high composition and contribution of the species. Indeed, in both the plots and the communal rangelands, good pastorage value (*GPV*) and medium pastorage value (*MPV*) species exceeded 50% of the encountered species. It contrasts with [17] and [21] who reported a dominance of species with no pastoral value against those with good pastoral value in their studies. However, our result corroborates those of [3] and [18] who noted a prevalence of *GPV* and *MPV* species in the Ferlo Biosphere Reserve and in Dadaria in Niger, respectively. The reference [8] reported a gross pastoral value threshold of 65%, above which a pasture can be considered interesting. Therefore, our sites, which all show a gross pastoral value of more than 65% can be considered as good grazing areas. Multiplying the gross pastoral value by the overall vegetation cover gave the net pastoral value (*Npv*) or global quality index of grassland (*GQI*). As reported in the results, the *GQI* was lower in each site during the first year of survey, which could be explained by an earlier rainfall in May that year, followed by a break in rainfall before the onset of the rainy season. The early rainfall would trigger the germination of the fast-cycling seeds, leading to their decline in the pastures, and thus reducing their floristic composition. The net pastoral value over the last two years on each site shows that fencing does not significantly affect the grass quality. The authors [23] and [3] stipulated that the rainfall regime significantly affects the quality and quantity of herbaceous biomass, whatever the grazing regime.

From the outcome of their study, reference [3] stated that phytomass production in Sahelian rangelands significantly depends on their floristic composition, which co-determines the quantity and quality of the available forage. In the present study, the phytomass production amounted to 3.69 tons DM/ha in the 2013

plot, 0.95 tons DM/ha in the 2009 plot, and 1.08 tons DM/ha outside the plots. These results are close to those of author [8], which varied between 1.33 tons DM/ha and 2.10 tons DM/ha in the Widou station and those of [3] of 3.3 tons DM/ha at the Ferlo biosphere reserve. The higher forage production in 2013 plot, stipulates that fencing favors the development of grass cover. Reference [24] indicated that protection improves vegetation growth and significantly increases grass production. The ecological conditions of the area can also explain the results of rangeland production. According to reference [8], the annual production of herbaceous phytomass results from several ecological, zoo-anthropic, and climatic factors such as the soil, climate, and zoo-anthropic pressures. Fencing is also a significant factor since it allows the herbaceous stratum to develop without external pressure.

The theoretical annual carrying capacity (*CC*) varied across sites from 0.15 to 0.61 TLU/ha/yr. It was highest in the 2013 plot with 0.61 TLU/ha/yr and lowest in the 2009 plot with 0.15 TLU/ha/yr. This result is due to the fact that the carrying capacity is directly linked to the forage production; but also, to the protection status of plot 2013. The *CC* in the non-fenced area estimated to be 0.18 TLU/ha/yr is similar to that obtained by [8] in the same zone, which ranged from 0.14 to 0.18 TLU/ha/yr. Reference [3] found a *CC* of 0.41 TLU/ha/yr in the Ferlo Biosphere Reserve. This similarity could be explained by the fact that anthropogenic activities are reduced in reserve areas.

5. Conclusion

This study aimed to assess the role of fencing on the production and pastoral quality of Widou grasslands in northern Ferlo. It revealed that fencing has no significant effect on the pastoral value of the grass layer; however, it does have a significant effect on forage production and thus contributes to the acquisition of abundant quality forage, whereas the low level of protection or no protection seems to encourage the rapid depletion of the forage stock. In specific terms, full or partial protection would lead to a balance between Poaceae and Fabaceae, and other families such as Cyperaceae, Convolvulaceae, etc. In contrast, the absence of protection would favor the dominance of *Gramineae* over other taxa through grazing.

It would be interesting to continue this study under more rigorous scientific conditions in order to clearly bring out the effects of protection status on the dynamics of grass cover in Ferlo. In addition to the pastoral value, it would also be interesting to compare the nutritional value and digestibility of the various taxa identified according to the fencing level.

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Conflicts of Interest

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

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