



## Structure and phenology of herbaceous forage plants in the Sahelian rangelands of Senegal during the rainy season

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### Abstract

This study describes the structure and phenology of Sahelian rangelands during the rainy season. It was undertaken in thorny steppe on a grazed plot and a nearby fenced plot with otherwise similar site characteristics. Measurements were taken every 10 days over two rainy seasons between July and October 2022 and between August and October 2023. The measurements included the phenological stage, the vegetative and flowering height, the foliage cover, and the phytomass. The results showed that phytomass did not systematically differ between grazed and fenced plots. Flowering started as early as mid-July, but most of the plants flowered in early October. Flowering and fruiting occurred earlier (based on the number of days after the first rain) in the late rainy season (2023) than in the early one (2022). These stages reached their peak in October; senescence began in October. Vegetative height, reproductive height, and coverage were similar between the two years. Height peaks were similar, but they were reached earlier (based on the number of days after the first rain) in the late rainy season than in the early one. Coverage peaks were similar (59.8% in the early rainy season vs. 65.8% in the late one). Vegetative height (around 30 cm), reproductive height (around 36 cm), and coverage (around 60%) reached their maximum in October, but reproductive height was greater than vegetative height. These parameters were lower at the grazed, and flowering started earlier at the grazed site. Grazing reduced cover and height, and delayed flowering. Structure and phenology were more sensitive to changes in rainfall between years. Knowing phenology helps determine the best time to harvest the phytomass, because the nutritional quality of the forage is known to decrease after fruiting.

### Introduction

In the Sahelian rangelands, the main economic activity is pastoral livestock farming, which is mainly based on ephemeral vegetation. These rangelands comprises a stratum of annual herbaceous plants, mainly grasses, and a stratum of scattered woody plants dominated by the genus *Acacia* (Diawara et al., 2018). In the Sahel, the quantity of grass produced is largely determined by rainfall, which varies between years. Low rainfall caused low biomass which leads to pastoral crises.

It is therefore important to know the dynamics of the herbaceous stratum so as to adapt pastoral livestock farming to climatic constraints. However, most studies on phytomass production in the herbaceous stratum have mainly focused on variations between years and between zones, with sampling often taking place at the end of the rainy season; few studies have looked at dynamics during the season, and herbaceous plants grow very quickly during the rainy season (from June or July to October) due to the availability of soil moisture (due to rainfall) and nutrients and the impact of grazing (Habibou et al., 2018). Most studies have focused solely on biomass. However, studying other vegetation parameters over the entire life cycle of plants can provide a great deal of useful information for understanding vegetation dynamics, especially in relation to animal production.

The goal of this study was to measure the structure and phenology of the herbaceous stratum over a rainy season and to examine whether grazing had any effect on the measured parameters. Thus, phytomass, vegetative height and phenology were monitored at ten-day intervals during the rainy season, for two years, in thorny steppe at a grazed site and nearby a fenced site. These sites had otherwise similar site characteristics. The grazed site was grazed by cattle, horses, donkeys, sheep and goats at high intensity. The fenced sites excluded all herbivores from grazing. This study is innovative in that it measures parameters that are not always measured (height of inflorescences) and that were measured much more frequently than usual.

## Materials and Methods

### Study area

The study was conducted in the Sahelian part of Senegal named Ferlo (Fig. 1). The Ferlo, also known as the sylvopastoral zone, is the largest of Senegal's six agroecological zones. It is located between 15°21' north and 15°28' west. It covers an area of 54,380 km<sup>2</sup> or 27.6% of the national territory. The physiognomy of the vegetation in Ferlo has changed from a wooded savannah to a shrubby savannah in the 1960s to a thorny steppe today (Habibou et al., 2018).

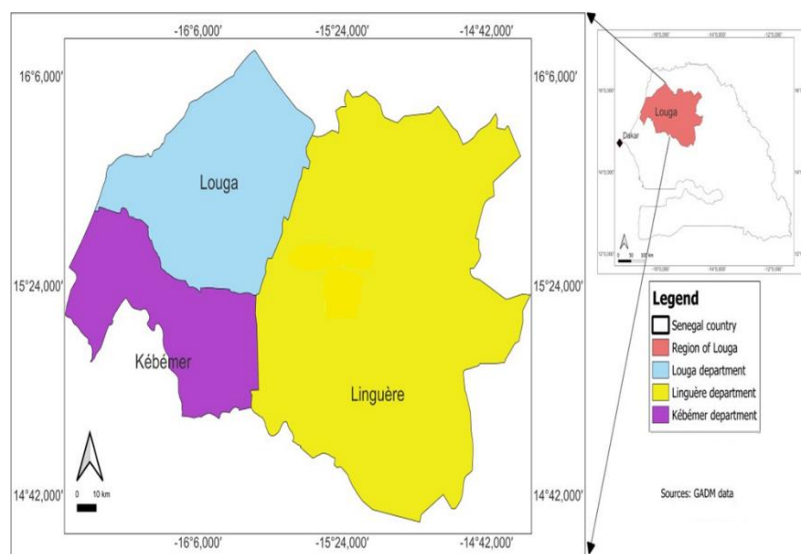


Figure 1: Study site

### Data collection

Similar measurements were taken at a grazed site (g) and a fenced site (f) in the rainy season for two years to see if there were any differences between the rainy seasons and whether grazing had any effect on the

parameters monitored. The measurements were carried out between July and October 2022 and between August and October 2023. Annual rainfall was 356 mm accumulated over 21 different events in 2022 and 336 mm over 20 different rainfall events in 2023. The 2022 rainy season was about 30 days earlier but was marked by long dry spells at the beginning of the season. Measurements started ten days after the first rainfall of at least 0.1 mm and were taken every ten days up to the end of the rainy season. Twenty-eight points were measured on each measurement date at each site. At each collection point, the following parameters were measured:

- Herbaceous phytomass, harvested at ground level on an area of 1 m<sup>2</sup> was weighed fresh and placed in an oven at 65 °C until a constant weight was obtained before being weighed again to obtain the dry weight.
- Phenological stages: leafing, flowering, fruiting, and senescence. When a stage was present in the quadrat, the percentage of plants at that stage was estimated visually.
- Vegetative height was measured from the soil to the highest leaf.

### Statistical Analysis

Student's test was used to compare parameter values across sites on each measurement date and between monitoring years.

## Results

### Phytomass

In contrast to 2022, where there was little variation in production between the two sites, overall phytomass production was lower at the grazed site in 2023. Maximum phytomass was reached on the same date (early October), but the peak at the grazed site (1800 kg·ha<sup>-1</sup>) was less than that of the fenced site (2357 kg·ha<sup>-1</sup>).

### Vegetative Height

In 2018, vegetative height was equal at both sites at the beginning of the rainy season, i.e., 40 days after the first rainfall (up to early August) (Fig. 2). For the rest of the rainy season (mid-August to the end of October), it remained lower at the grazed site. This height reached a maximum of 42 cm at the fenced site and 31.3 cm at the grazed site. However, the maximums were reached on the same date, i.e., in mid-October (the 110th day after the first rainfall). In 2023, vegetative height was lower at the grazed site during the rainy season. This height reached its maximum of 48.09 cm at the fenced site slightly earlier than at the grazed site (27.4 cm) in August. This maximum height was therefore lower at the grazed site.

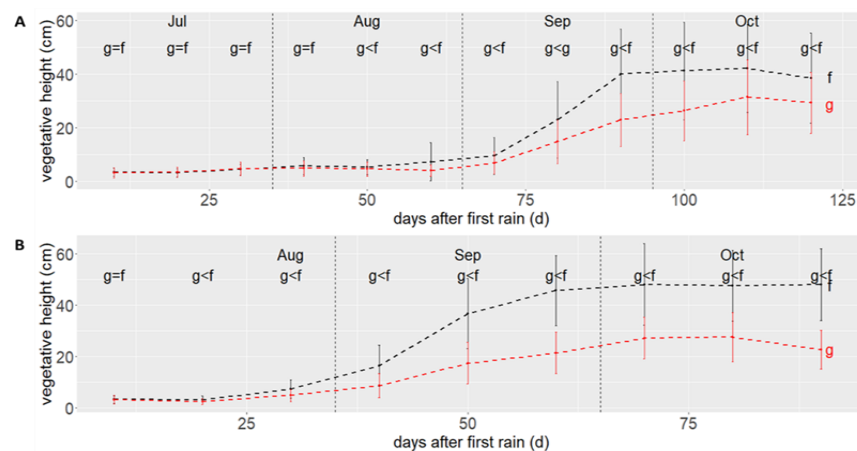


Figure 2: Vegetative height of grazed (g, red) and fenced (f, black) sites in 2022 (A) and 2023 (B).

### Phenology

In 2022, the difference in phenology between the fenced site and the grazed site concerned the date flowering first appeared (Fig. 3). It occurred on the 20th day after the first rain (second ten days of July) at the grazed site and on the 30th day after the first rain (third ten days of July) at the fenced site. In 2023, flowering began 10 days after the first rain at the grazed site and 20 days after the first rain at the fenced site. In contrast, fruiting occurred earlier (40 days after the first rain) at the fenced site compared to the grazed site (50 days after the first rain). Senescence started at both sites on the same date, i.e., 80 days after the first rainfall (August). Each of the different phenological stages appeared in the same month at both sites and both years.

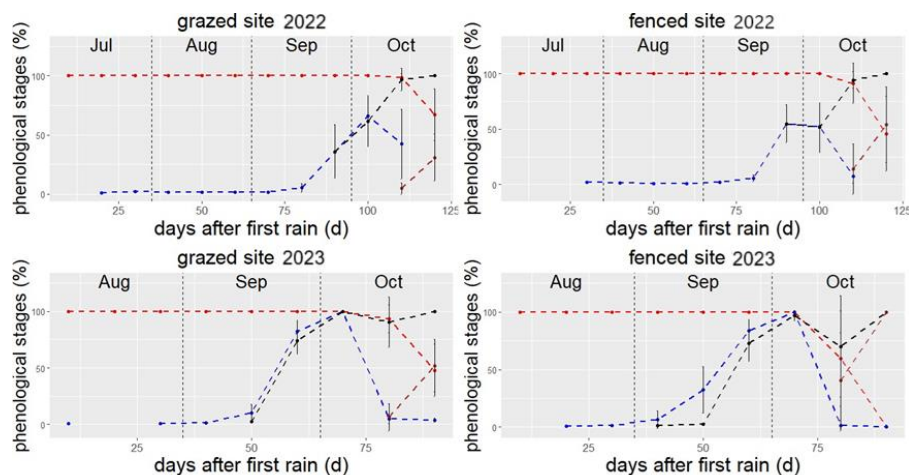


Figure 3: Phenology of grazed and fenced sites in 2022 and 2023. Red: leafing; blue: flowering; black: fruiting; brown: senescence

### Discussion

The amount of phytomass was lower at the grazed site than at the fenced site, though the differences were small in 2022 throughout the season. Nevertheless, this result supports the hypothesis that grazing decreases phytomass production, which is similar to previous results in a steppe formation, even in a savanna (Diatta et al., 2023).

Animal husbandry can cause overgrazing that reduces productivity. On the other hand, trials testing protection from cultivation, forest removal, fire, and grazing carried out in Niger (Sadoré reserve), Burkina Faso, and Senegal resulted in slightly lower herbaceous production than in the grazed control, mainly because of the greater relative importance of broadleaf weeds (Diawara et al., 2018).

Flowering and fruiting occurred earlier in a late rainy season year compared to an early rainy season year. These two stages reached their peak in October, while foliage cover started to drop. Seeding began in October for both years. The onset of flowering in mid-July indicates the existence of early-flowering species at the site. Earlier flowering was noted on pastures in Burkina Faso (Sanou et al., 2021).

Peaks in vegetative height (31 cm) and reproductive height (36 cm) were reached in October, but the reproductive height was slightly higher than the vegetative height. These figures ranged from 0.5 to 1 m (Pontanier et al., 2003) for the height at maximum vegetation and from 40 to 60 cm (Ngom, 2013) for

the Ferlo area. These ranges align with other evidence that the herbaceous stratum in the typical Sahel can reach 50 cm in height on sandy dunes (Diatta et al., 2023). It is explained that even though some species continue a vegetative growth after flowering, the majority of grasses stop doing so. Grasses were the major family of the pastures studied, but most annual grasses, under the influence of the photoperiod, flower between the end of August and the beginning of September. This means that almost all species reach their maximum size and stop growing at that time.

### Conclusions and Implications

The vegetative height, reproductive height, and flowering of herbaceous plants were sensitive to grazing.

The presence of early-flowering species in the area is consistent with species adaptation to the Sahelian climatic conditions, in particular to the short duration of the rainy season.

The dates of appearance of the phenological stages and the height of the herbaceous layer do not seem to depend on the date of the start of the rainy season.

When measuring the height of the canopy in grassy rangelands, it is best to measure reproductive height so as not to underestimate it.

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