INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 13, No. 5, p. 122-135, 2018
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Effect of the water reserve on the regeneration of herbaceous species in the Sudano-Guinean zone in Benin

Koudjodé Simon Abahi*[1], Alassan S. Assani[1], Pierre B. Akponikpe[2], Jonas A. Djenontin[3], Hilaire S. S. Worogo[1], Yaya Idrissou[1]

[1]*Laboratory of Ecology, Health and Animal Productions, Faculty of Agronomy, University of Parakou, Benin*

[2]*Hydraulic and Environmental Modeling Laboratory (HydroMod E-Lab), Faculty of Agronomy, University of Parakou, Benin*

[3]*Ecology and Productions Systems, Faculty of Agronomy, University of Parakou, Benin*

Article published on November 15, 2018

Key words: Pastures, Fires, Plant-available water, Productivity, Benin.

Abstract

In Benin, wildfires are lit for various purposes: hunting, agriculture, livestock farming and many other reasons. However, the recommended period for these fires is often vague and does not take into account the water-determining factors of soils favoring the resumption of vegetation. This study aims to assess the effect of the water reservoir on the resumption of the vegetation of rangelands subjected to various fires in the Sudano-Guinean zone in Benin. The experimental design is a two-way split-plot, the main one type of pasture and the secondary is the date of fires. The evaluation of the photomaps is carried out by the clear-cutting method 30 days after the fires. The gravimetric method was used to assess the available water supplies for plants. In addition, the simple linear model allowed to model the productivity of the regrowth and the water reserve. The results of this study revealed that the phytomass yields obtained after the fires were significantly different ($P < 0.001$). The third fire lit during the dry season induced lower biomasses than the first fire lit at the end of the rainy season. The water reserve available for plants is gradually dwindling according to dates. Thus, when the third fire is lit, the water reserve is zero. Linear regression shows that the water reserve has a significant effect on pasture productivity after fire.

***Corresponding Author:** Koudjodé Simon Abahi ✉ abassabahi@yahoo.fr

Introduction

In Benin, the use of vegetation fires is a common and ancient practice widely used in agriculture, as these fires are a cultural practice related to the substance of economy (da Matha Sant'anna, 1998) . Wildfires in savannah appear as an important component in the ecological dynamics of grazed ecosystems (Preece *et al.*, 1991) and roam these savannas annually.

The availability of regrowth for livestock is enormously improved after the passage of fire (Sinsin and Saidou, 1998) . For example, wildfires participate in the dynamics of ecosystems and influence their structure and production (Houinato *et al.*, 2001).

However, to enhance the availability of fodder resources for rangelands, it is necessary to control the use of fires as a means of natural rangeland management (Preece *et al.*, 1991; Sinsin and Saidou, 1998).

In addition, fire control as a means of development requires knowledge of the appropriate ignition dates in relation to the rainfall regime (Sinsin and Saidou, 1998) and especially the water determinants of the soil favoring the resumption of vegetation.

While the fire ignition period is vaguely indicated, it is intimately linked to the availability of sufficient water in the soil that would favor the resumption of vegetation.

For this purpose, experiments have been conducted to determine the indicative periods of ignition of wildfires (Sinsin and Saidou, 1998). Others measured the effect of fire intensity or regularity on vegetation in grazed ecosystems (Afelu *et al.*, 2016) . But no study has focused on the soil water reserve, which favors the resumption of vegetation after fires.

Thus, the present study investigates the effect of the soil water reserve on the resumption of vegetation of rangelands subjected to various fires in the Sudano-Guinean zone in northern Benin.

Material and methods

Study area

The experiment was conducted at the Okpara Breeding Farm in Tchaourou town, Borgou Department, North-East Benin.

The Okpara breeding farm is located in the municipality of Tchaourou, 15 km from the city of Parakou. It was created in 1952 and covers an area of 33,000 hectares. The farm is located 325 meters above sea level, 09°18'295' 'Latitude North and 02°43'902'' Longitude East. It is bounded on the north by the Okpara polyculture farm, the Okpara river, the villages of Kika1, Kika2 and Kokobè , on the south by Wona , on the east by the Sui river and the Kpari village on the east side (**Error! Reference source not found.**), in the west by the Monou backwater and north-east by the Parakou-Okpara service road. The vegetation grown as fodder for cattle and small ruminants on the farm consists of *Panicum maximum* Jacq. and *Urochloa ruziziensis (R.Germ.* & *CM Evrard).* On the other hand, the natural vegetation developed in places to serve as natural pastures consists of wooded savannas, shrub savannas and grassy savannas. The dominant woody plants are *Isoberlinia doka* Craig & Stapf., *Daniella oliveri* (Rolfe) Hutch & Dalz, *Vitellaria paradoxa* C. F. Gaertn. and *Terminalia avicennioides* Guill. & Perr. while the low grass stratum is dominated by Brachiaria spp and the tall one by Hyparrhenia spp and Andropogon spp.

The study area is influenced by the Sudan-type climate, characterized by a long dry season (November to May) followed by a wet period (May to October). The average rainfall recorded between the periods of 1956 to 2002 is 1126.42 mm of rain with a maximum height during the months of August and September.

The average annual evapotranspiration (ET_o) calculated for the region is 1575.19 mm. In the study area, the harmattan (northeast wind) is the prevailing wind. It blows from November to March. Monthly averages of relative humidity range from 18.08 % in January to 96.02 %. in September.

From December to February, the average relative humidity is less than 50%, the evaporating power of the air is then strong while from March to November, the average relative humidity is greater than 50%. The duration of maximum insolation is observed during the months of November, December, January and the minimum is observed in July, August, and September. The average temperature is around 27.09°C and the average sunshine duration is 2502.08 hours in the year. During the study period, no precipitation was recorded after November.

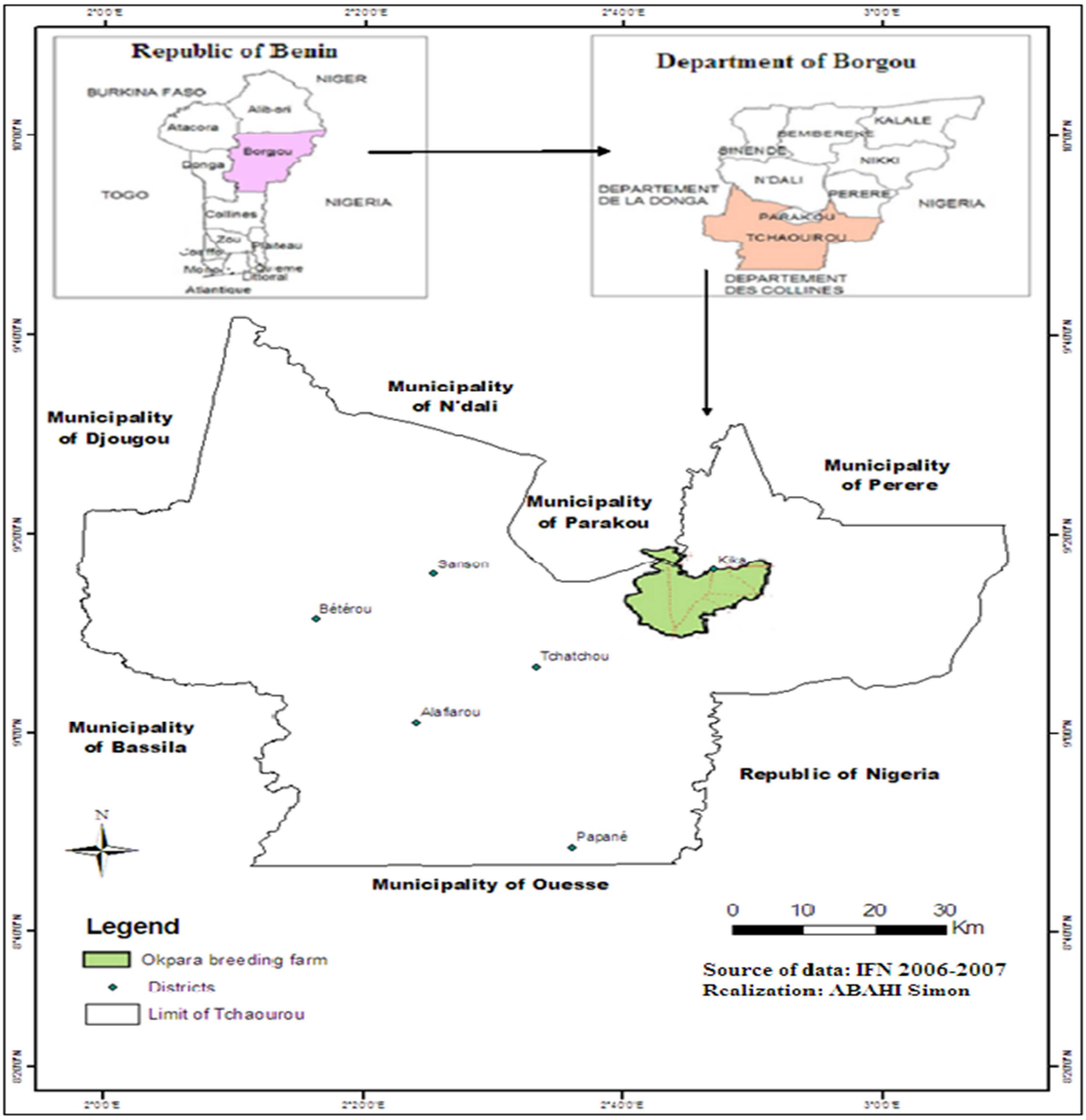


Fig. 1. Location of the study area in Benin.

Experimental design

The experimental set-up is a split-plot with two types of pastures as main factors (*Panicum maximum* and *Urochloa ruzizienzis* grassland and the natural pastures of *Brachiaria falcifera and Isoberlinea doka*) and as secondary factors the dates of burning successively in November (at the end of the rainy season), December (beginning of the dry season) and January (full dry season) (

Fig.). The elementary plots, 20 m x 20 m in size, have been installed and protected. Within each plot, moisture lanes (10 m x 10 m) were installed to determine phytomass and periodic soil moisture under each type of pasture before and after the fire.

Phytosociological inventory

The phytosociological survey is carried out following the method of Braun-Blanquet (1932) used in Sudan and Sudano-Guinean zones (Sinsin, 1993 ; Houinato, 2001) and in the plots installed for study before and after the fire . A total of 24 surveys were carried out, including 12 in *Panicum maximum* and *Urochloa ruzizienzis* grassland and 12 in the shrub savanna at *Brachiaria falcifera and Isoberlinea doka*.

The sample areas used have taken into account in each zone the homogeneity of the floristic and structural in relation to the homogeneity of the environmental conditions. During each survey, the species are identified and coefficients of abundance-dominance are assigned to them. The abundance-dominance scale of Braun-Blanquet (1932) has been used is that. The floristic lists obtained were used to calculate the gross and weighted biological spectra and the biological types used are: phanerophytes (Ph), chamephytes (Ch), hemi cryptophytes (He), geophytes (Ge) and therophytes (Th) (Raunkiaer, 1934).

Evaluation pasture productivity and carrying capacity

The method of clear-cutting with gardening shears is used to estimate the phytomass. After the application of fire, in the plots assigned to the different fire treatments the cutting rate is 30 days (Agonyissa and Sinsin, 1998) . On each productivity plot, 7 cuts of one (01) m^2 were made diagonally. The cut plant material is sorted into two lots: grasses and other species. Fresh weights are taken in the field using a digital weigh scale (accuracy = 0.01g).

A sample of 150 g of fresh plant material from each lot is collected at each plot, in productivity bags for the determination of dry matter in an oven at 105°C at the Multidisciplinary Laboratory of the Faculty of Agronomy of the University of Parakou. Consumptive phytomass data are used to calculate carrying capacity over a period of (05) five months (dry season period of the area) of each pasture (Boudet, 1991).

Assessment of the water reserve under pasture

In order to determine the water reserve under the pastures, samples of soil samples are taken to a depth of 60cm. and passed to the oven at 105°C for 48 hours (gravimetric method). Samples are taken weekly and regularly over the entire trial period.

Statistical analysis

The statistical treatment of the results was realized thanks to the software R 3.4.4 (R Core Team, 2017). The analysis of variance was performed on productivity data, load capacity and reserve of soil water at the 5% level. The Newman- Keuls test at 0.05 was used to separate the homogeneous groups. In addition, the relationship between water supply and regrowth productivity was in simple linear regression.

Results

Characterization of different pastures

Physiognomy of the grassland at Panicum maximum and Urochloa ruziziensis This pasture free of trees and shrubs consists of: *Panicum maximum* C_1, *Urochloa ruziziensis,* of *Aeschynomene indica L., Stylosanthes sp.* and *Andropogon* sp., which are the most dominant species.

Table 1. Analysis of variance of soil water reserve.

Source of variation	Df	Sum Sq	Mean Sq	F value	Pr (> F)
Blocks	3	31	10,333		
pastures	1	0.7	0.67	0005	0.95
Fires	2	72116	36058	730.4975	2.92e-13 ***
Fires : Pastures	2	225	113	2282	0145
Residuals	12	592	49		

Meaning. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1.

Table 2. Analysis of variance of biomass productivity after fires.

Source of variation	Df	Sum Sq	Mean Sq	F value	Pr (> F)
Blocks	3	379.9	126.6		
pastures	1	28621	28621	146.4	0, 00122 **
Fires	2	29493	14747	141.33	4,561 ***
Fires : Pastures	2	6403	3202	30.68	1,914 ***
Residuals	12	1252	104		

Meaning. Codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 '' 1.

The physionomic study is made from a matrix of 12 phytosociological records and 41 species. These species belong to 15 botanical families the most abundant of which are Leguminosae (3 8%) and Poaceae (27%) (Fig.). This grassland is dominated by Poaceae (89%) and Leguminosae (6%) (Fig. **1**).

Table 3. The amount of regrowth and the carrying capacity of pastures according to the fires.

Pastures	*Panicum maximum*			*Brachiaria falcifera*		
Fires	F1	F2	F3	F1	F2	F3
Productivity (kg.DM.ha⁻¹)	165 ± 19.15[a]	115 ± 17.32[a]	40 ± 0.0 [b]	57.75 ± 5.2[a]	42 ± 5 [a]	12.55 ±4.6 [b]
Carrying capacity (LTU/ ha / 5 months)	1.76 ± 0.20 [a]	3 1,2 ± 0,18[a]	0.43 ± 0 [b]	0.6 2 ± 0.05[a]	0.4 6 ±0.05 [a]	0.1 4 ± 0.05[b]

Values followed by the same letter are not significantly different at the 5 % threshold.

All life forms are shown in the meadow. Hemi cryptophytes are the dominant form of life (83.8%), followed by therophytes (12.2%). While therophytes being the form of the most abundant life (52.5%) of this pasture followed by phanerophytes and hemi cryptophytes (17.5%) (Fig. 2).

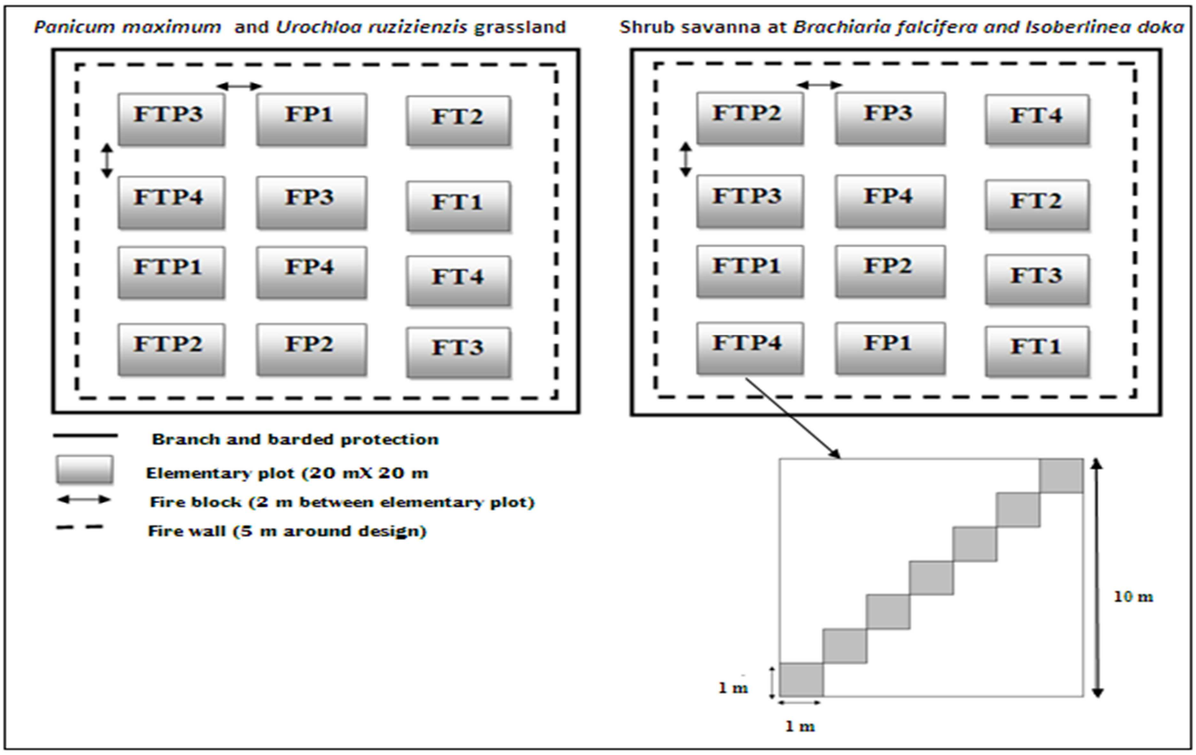


Fig. 2. Experimental device (FTP =1st fire, FP =2nd fire FT =3rd fire).

Physiognomy of the shrub savanna at Brachiaria falcifera and Isoberlinia doka

This natural pasture is located in a shrub savanna dominated by shrubby species such as *Isoberlinia doka, Vitellaria paradoxa, Monotes kerstingii* Gilg and *Strychnos spinosa* Lam. and a dominant herbaceous species : *Brachiaria falcifera* (Trin.) Stapf. This pasture shelters a community of 102 species distributed in 33 families and the most abundant are Poaceae (19 %) and Leguminosae (28%) (

Fig.). Poaceae (6 3%) dominate this specific community followed Leguminosae (16%) and Rubiaceae (5%) (

Fig.). On shrub savanna, therophytes (41.1%) are the most abundant life form followed by phanerophytes (31.6%). Hemicryptophytes (59.9%) dominate the path followed by phanerophytes (25%) (Fig.).

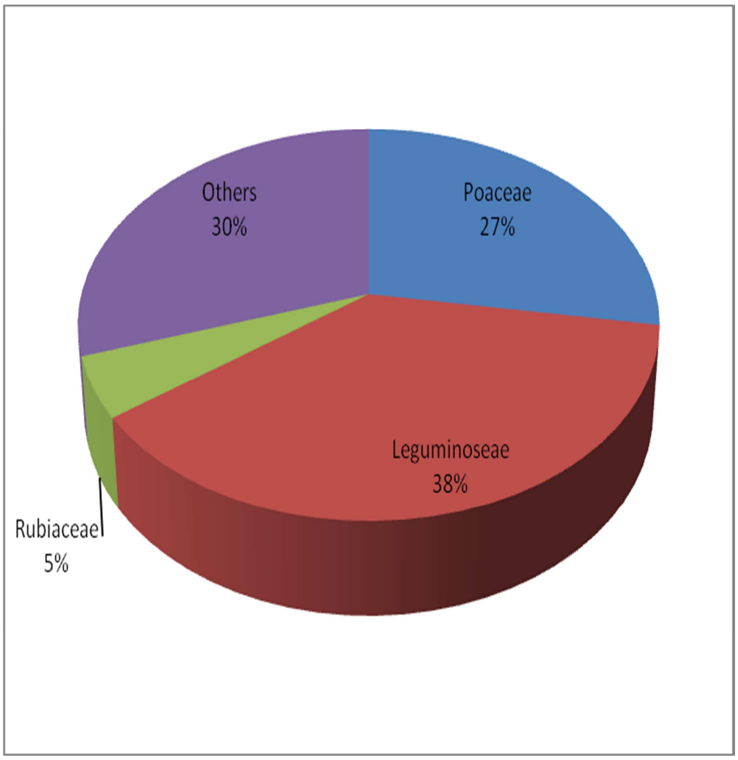


Fig. 3. Crude spectrum of grassland families.

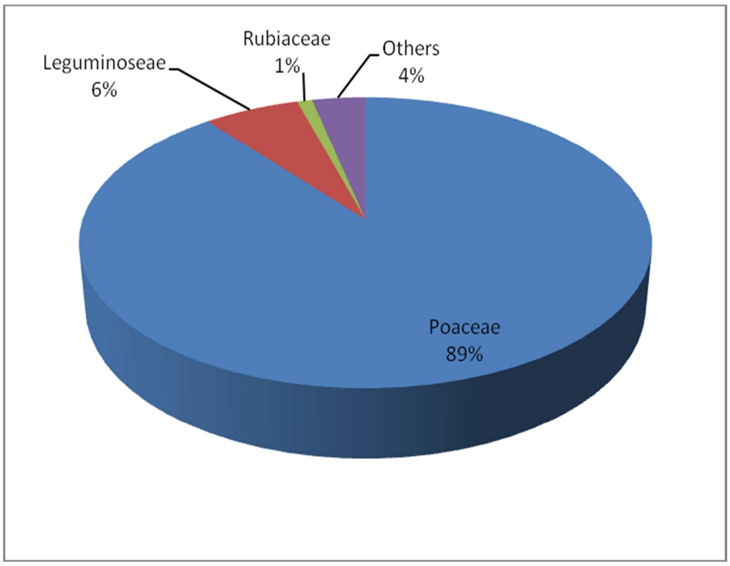
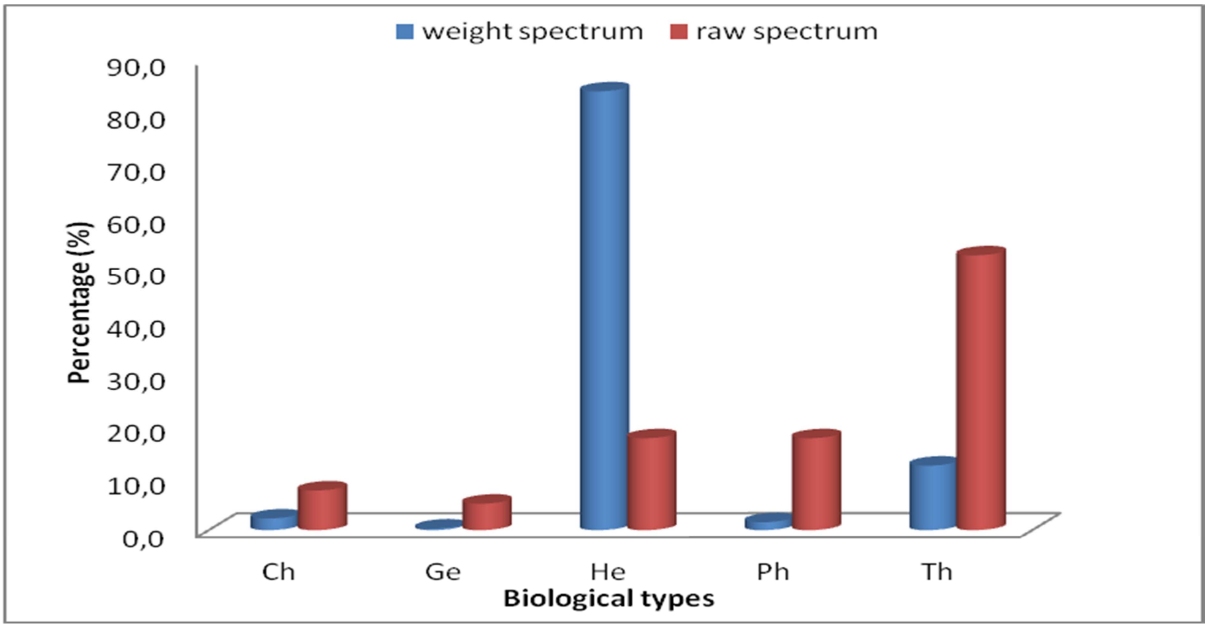


Fig. 1. Weighted spectrum of grassland families.

The soil water reserve under pasture between 0-60 cm at the start of fires

The analysis of variance of the water reserve between the fires reveals as significant difference ($p < 0.001$) (Table 1). Moreover, between the pastures, the water reserve is not significant ($P=0.95$). In addition, the interaction Fires* pasture was not significant ($P = 0,145$).



Ch = Chamephytes; Ge = Geophytes; He = hemi cryptophytes; Ph = phanerophytes; Th = Therophytes

Fig. 2. Biological specter of grassland species.

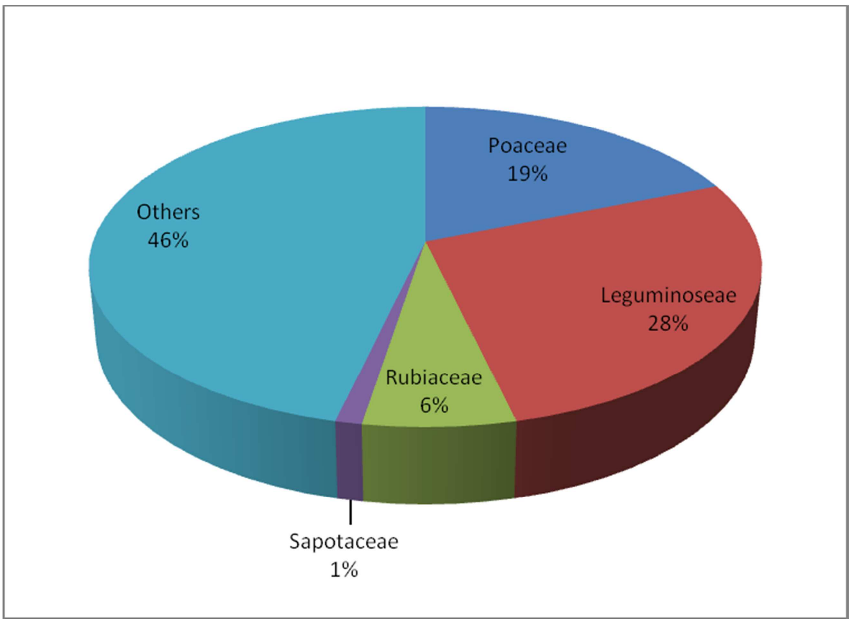


Fig. 6. Crude spectrum of shrub savanna families.

The Student- Newman- Keuls pairwise comparison test indicates that the water reserve at the time of ignition of the first light greatly exceeds that of the second and third fire. Indeed, when fires start, the average available water reserve for the plants is respectively: 123.75; 16.755 and 0.00 mm for the first fire, the second fire and the third fire on both pastures (Fig. 3).Thus, the available water reserve for the plants decreases gradually according to the dates of fire.

Biomass productivity after fires and carrying capacity

The biomass productivities obtained on the different plots are presented in Table 3.

Whatever the type of fires, the highest productivity is obtained on the grassland of *Panicum maximum and Urochloa ruziziensis*. Analysis of variance revealed between the obtained productivities a very significant difference (P < 0.001) between pastures, fires and interaction fires × pastures (Table 2).

The comparison of the two-to-two performance of the different fires shows that the third fire (26.3 ± 7.49) kg.DM.ha^{-1} induced lower biomasses than the first and second fire; which are similar with an average yield of (95.1 ± 49.7) kg.DM.ha^{-1} (Fig.). These results show the positive impact of the first fire (lit just at the end of the rainy season) on the biomass productivity available to herbivores during the dry season.

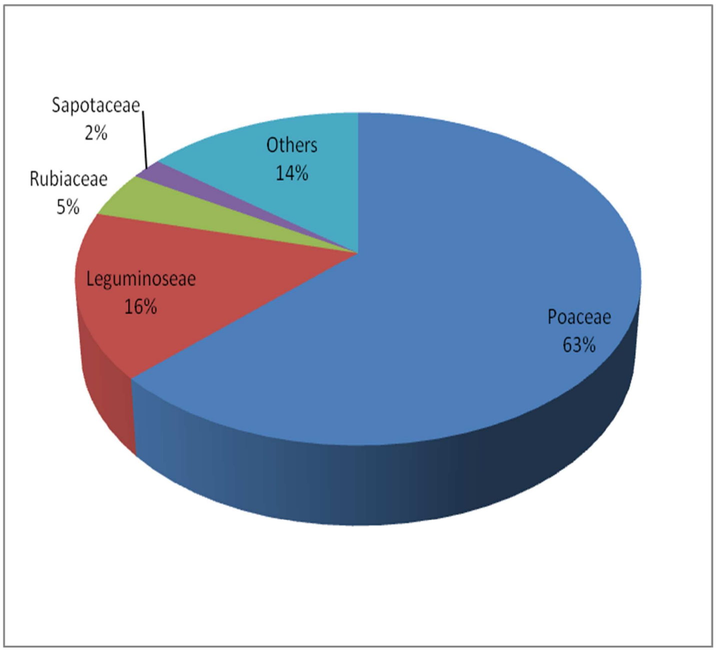


Fig. 7. Weighted spectrum of shrubby Savanna families.

Regarding the carrying capacity, whatever the date of the fire, the highest carrying capacity (0.43 to 1.76) (P < 0.001) are recorded on the grassland of Panicum < maximum and Urochloa ruzizienzis. For each pasture, the carrying capacity decreases with the delay of the fires. Thus, the carrying capacity of the first and second fire is higher than that of the third fire (Table 3).Therefore, a good water supply is essential in increasing forage productivity in the dry season and is a determining factor in improving the carrying capacity of the Sudano-Guinean zone.

Regression of biomass productivity and soil water reserve

Variations in soil under pasture water reserve explain respectively to 70.85% and 64.48% changes in the productivity of the grassland and the shrub savanna (P < 0.001) (Fig. 11 and Fig. 12).

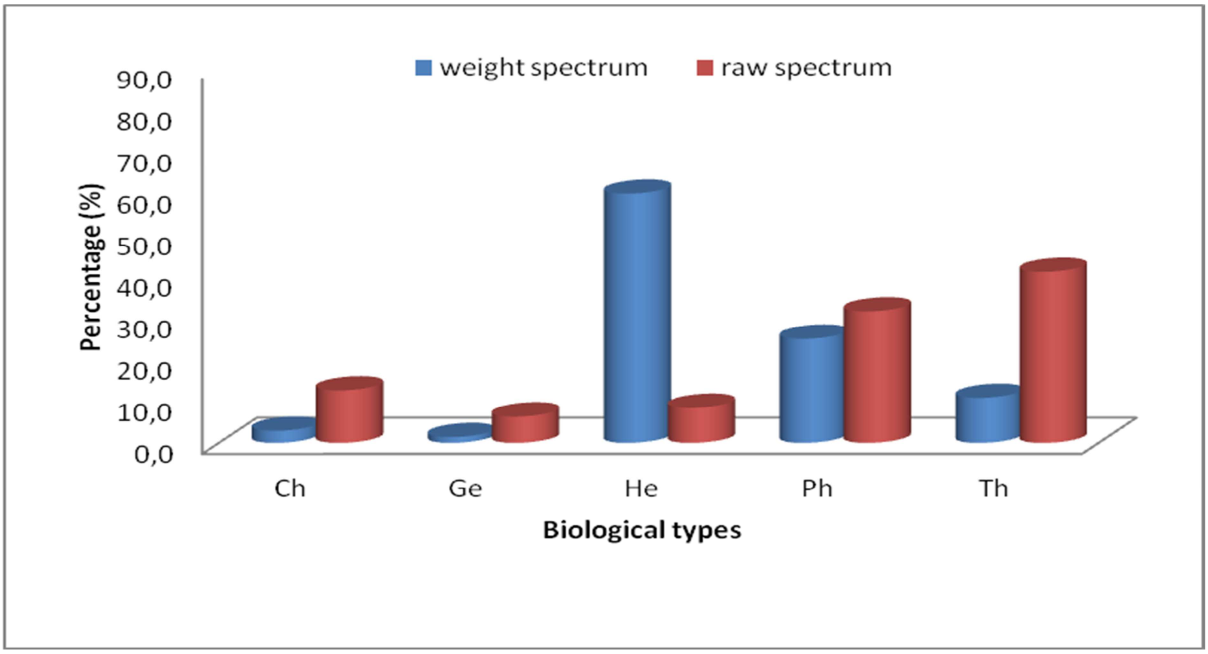
Thus, the importance of the soil water reserve is very essential for the increase of the productivity of the regrowths in the dry season. Because the pair (productivity, water reserve) studied at the pasture level is quite well correlated with coefficients of determination greater than 60 %.

Discussion

Characterization of different pastures

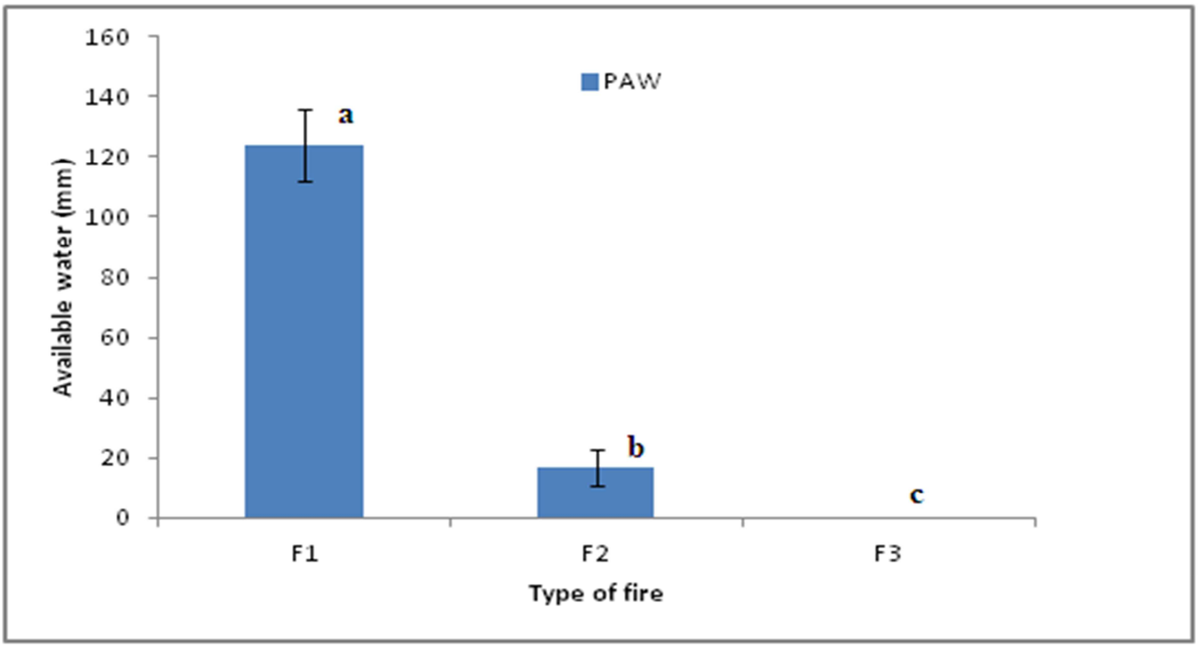
The overall floristic analysis revealed the dominance of Poaceae and Leguminosae. The dominance of the Poaceae and Leguminosae families observed globally on all the pastures confirm those obtained by Djenontin (2010) and with the same areas of surveys. Furthermore, Sinsin (2001) and Orthmann (2005) in their study in the Sudanian region found that the species of the Poaceae family were the most numerous, followed by those of the Leguminosae.

From the analysis of the adaptive behavior of the species, the notable dominance of the hemi cryptophytes was noted (more than 50%). This could be explained by the fact that these pastures are subject to annual wildfires and permanent pastures. These results are in agreement with the conclusions of Sinsin (1993) and Houinato *et al.* (2001) who worked in the Sudan region.



Ch = Chamephytes; Ge = Geophytes; He = hémi cryptophytes; Ph=phanerophytes; Th = Therophytes

Fig. 8. Biological spectra of shrubby savanna.

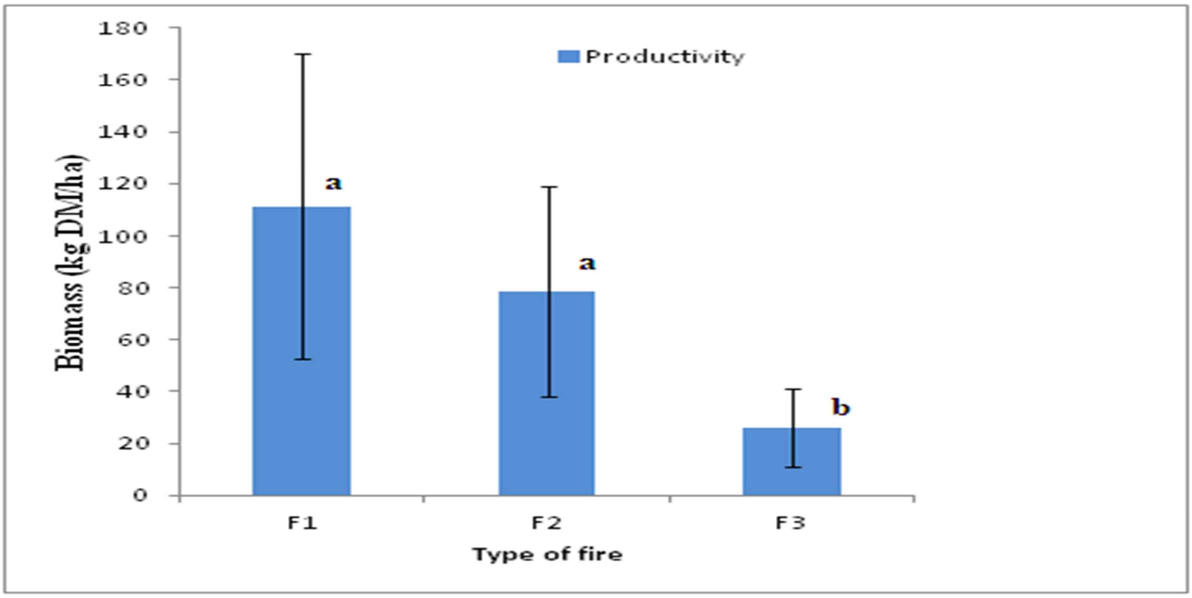


F1 = 1st fire; F2 = 2nd light; F3 = 3rd light. Paw is the reserve e to the illumination of lights. The bars represent the standard deviation of the average of the water reserve. The averages followed by the same letter are not significantly different at the threshold of 5 %

Fig. 3. Water reserve (mm) between 0 - 60 cm when lighting fires.

Biomass productivity after fires and carrying capacity

The day after the fire, a few small green leaves point at the base of tufts of grass. They grow over time of the order of a few centimeters. A week to two weeks after the passing of the fire, scattered pastures were growing green again. These observations are similar to observations made by Zoungrana (1991) . In the Sudanian regions in general, the regrowth are very small, very scattered and of low height (Sinsin *et al.*, 1989 ; Zoungrana, 1991). In addition, Lejoly and Sinsin (1991) observed post-fire early regrowth from the tillering trays of hemi cryptophytes, which are dominated by the Sudanese pastures studied.



F1 = 1st fire; F2 = 2nd light; F3 = 3rd light. The bars represent the standard deviation of the average yield per type of fire. The averages followed by the same letter are not significantly different at the 5 % level.

Fig. 10. Livestock biomass productivity after fires.

The productivities obtained on the experimental site vary between 165 and 12.55 kg.DM.ha^{-1} with load capacities between 1.76 and 0.14 LTU/ha/5 months.

The observations made are comparable to those obtained by Rippstein *et al.* (2000) who observed mean regrowth production values of 134.4 kg.DM.ha^{-1} for the same period (28 days after fires).

Moreover, Zoungrana (1991) observed in Burkina Faso in the Dinderesso and Toumousséni regions for the same period similar productivity values.

Regarding the regrowths, in most cases, they vary from one fire to another and even weak; play an important role well known breeders. Thus, in the various pastures the first fire (on just the end of rainy season) which appears as early fires induced the highest biomass. They improved the productivity of regrowth on each pasture. Our observations are comparable to those obtained on Bétécoucou and Samiondji by Yaoïtcha (2004). Similarly, Ahouangan *et al.* (2010) observed the same trends in the W Biosphere Tran boundary Reserve.

Soil water reserve under pasture at the start of fires

In pastures, soil water reserves are gradually being depleted during the dry season. This observation is similar to that made in Brazil's cerrado ecosystems by Oliveira *et al.* (2005). They say that the high values of the water reserve are generally obtained after the rainy season and the lowest values are generally recorded at the end of the dry season. In fact, the amount of regrowth per fire decreases, and all the more so as the water reserve of the plants turn down. This is the basis of the small amount of biomass observed at the third fire.

The high yields are recorded when the soil water reserves and their availability for the plants are important. This situation of low deliverability observed in the dry season explains the importance and the need of a large reserve in water. So, we will remember for these vegetation's: the use of early fires and frequent irrigations in the dry season in order to maintain an adequate supply of water in the upper layers of the soil and to increase the amount of regrowth during this period. These same observations are made by Ahouangan *et al.* (2010), who have shown that in the Sudano-Sahelian region, the supply of water has a favorable influence on the development of hemi cryptophytes during the dry period.

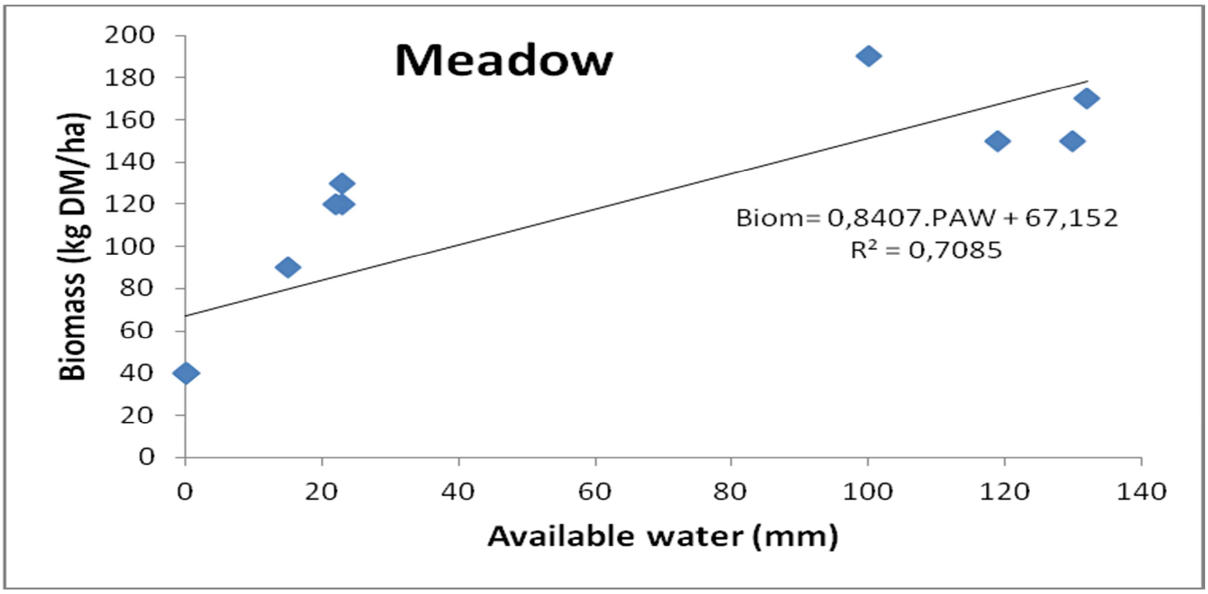


Fig. 11. Regression of grassland productivity based on soil water reserve.

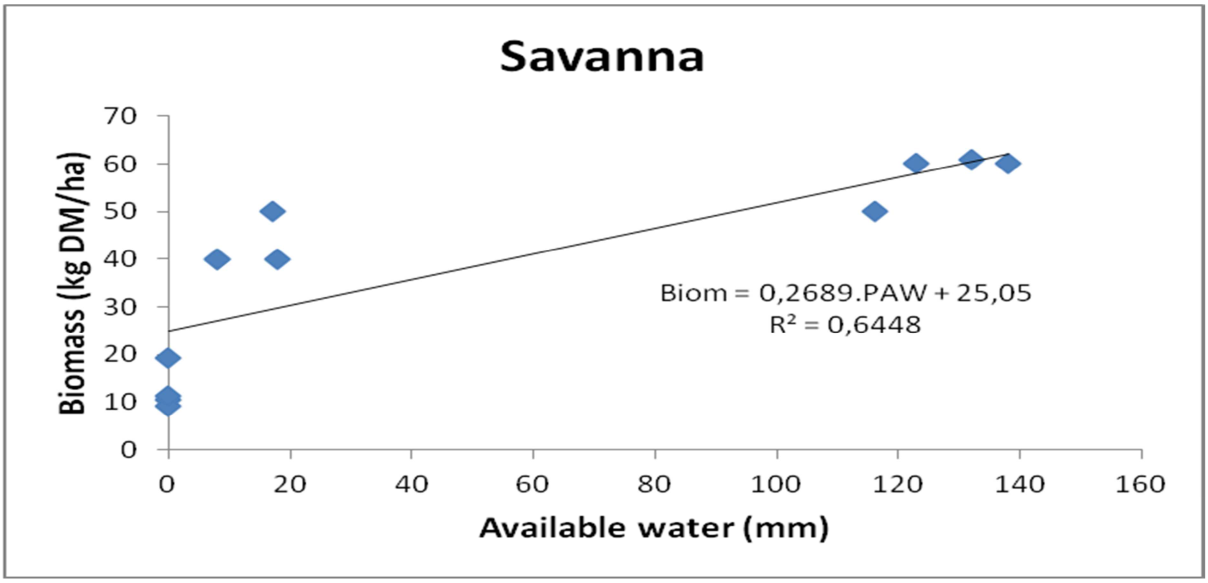


Fig. 12. Regression of shrub savanna productivity according to the soil water reserve.

Regression of biomass productivity and soil water reserve

On the two pastures, the coefficients of determination of the couple (productivity, water reserve) studied vary between 64.48% and 70.85%. This pair is quite well correlated. These coefficients are lower than those found by Sinsin (1991) and Ahouangan *et al.* (2010), which are respectively 99% and 87%.

Conclusion

After this study, it appeared that the different pastures exploited in the Sudano-Guinean zone are dominated by Poaceae and Leguminosae. The ecology of the species shows the dominance of hemi cryptophytes, which is the expression of the disturbance of the different vegetation by the annual vegetation fires and the permanent pastures of the study area. In addition, the available water reserves for plants are gradually depleted according to dates. Achieving a remarkable growth in phytomass at the level of the plot of the first fire lit at the end of the rainy season compared to that of the plot of the third fire lit in the dry season, reflects the importance and necessity from the application of fire right at the end of the rainy season. Thus, the water reserve has a favorable influence on the regrowth of the vegetation in the dry season. In addition, the significant difference in regrowth observed on the plot of the first fire demonstrates the importance of a good water reserve for the increase of the amount of regrowth at the pasture level.

References

Afelu B, Fontodji K, Kokou K. 2016. Impact des feux sur la biomasse dans les savanes guinéo-soudaniennes du Togo. VertigO Revue électronique en sciences de l'environnement **16(1).**

Agonyissa D, Sinsin BA. 1998. Productivité et capacité de charge des pâturages naturels au Bénin. Revue d'élevage et de médecine vétérinaire des pays tropicaux **51(3),** 239–246.

Ahouangan B, Houinato M, Ahamide B, Agbossou E, Sinsin B. 2010. Etude comparative de la productivité de repousses et de la capacité de charge des hémicryptophytes soumises aux feux de végétation dans les parcelles irriguée et non irriguées dans la Réserve Transfrontalière de Biosphère (RTB) du W-Benin. International Journal of Biological and Chemical Sciences **4(2)**.

Boudet G. 1991. Pâturages Tropicaux et Cultures Fourragères. Collection des Manuels et Précis d'Elevage **4**, Institut d'Elevage et de Médecine Vétérinaire des Pays Tropicaux. Ministère de la Coopération; 266.

Braun-Blanquet J. 1932. Plant sociology. The study of plant communities. Plant sociology. The study of plant communities. First edition. https://trove.nla.gov.au/version/21795887

Da Matha Sant'anna MA. 1998. Les feux de brousse en attendant mieux ... Syfia **113**, 43–44.

Djenontin JA. 2010. Dynamique des stratégies et des pratiques d'utilisation des parcours naturels pour l'alimentation des troupeaux bovins au Nord-Est du Bénin. Thèse de Doctorat, Université d'Abomey-Calavi, p 274.

Houinato M, Sinsin B, Lejoly J. 2001. Impact des feux de brousse sur la dynamique des communautés végétales dans la forêt de Bassila (Bénin). Acta Botanica Gallica **148(3),** 237–251.

Houinato MRB. 2001. Phytosociologie, écologie, production et capacité de charge des formations végétales pâturées dans la région des Monts Kouffé (Bénin). Thèse de doctorat, Université Libre de Bruxelles, Belgique, p 255.

Lejoly J, Sinsin AB. 1991. Structure et valeur pastorale des pâturages soudaniens des bas-fonds dans le Nord-Bénin. Périmètre Nikki- Kalalé, p 554-557.

Oliveira RS, Bezerra L, Davidson EA, Pinto F, Klink CA, Nepstad DC, Moreira A. 2005. Deep root function in soil water dynamics in cerrado savannas of central Brazil. Functional Ecology **19**, 574–581. https://doi.org/10.1111/j.1365-2435.2005.01003.x

Orthmann B. 2005. Vegetation Ecology of a Woodland-savanna Mosaic in Central Benin (West Afrika): Ecosystem Analysis with a Focus on the Impact of Selective Logging (PhD Thesis). Doctor thesis University of Rostock, 148 p.

Preece ND, Allan GE, Baker LM. 1991. Two approaches to fire management in central Australia: implication for rangeland management and policy. Montpellier, France, p 854–856.

R Core Team, 2017. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. www.R-project.org

Raunkiaer C. 1934. The Life Forms of Plants and Statistical Plants Geography. Clarendron Press: Oxford. https://archive.org/details/in.ernet.dli.2015.271790

Sinsin AB. 1993. Phytosociologie, écologie, valeur pastorale, production et capacité de charge des pâturages naturels du périmètre Nikki-Kalalé au Nord-Bénin. Thèse de doctorat, Université Libre de Bruxelles, Belgique, 350 p.

Sinsin B. 2001. Formes de vie et diversité spécifique des associations de forêts claires du nord du Bénin. Systematics and Geography of Plants **71(2)**, 873–888.

Sinsin B, Saidou A. 1998. Impact des feux contrôles sur la productivité des pâturages naturels des savanes soudano-guinéennes du ranch de l'Okpara au Bénin. Annales des Sciences Agronomiques du Bénin **1**, 11–30.

Sinsin BA, Oloulotan S, Oumorou M. 1989. Les pâturages de saison sèche de la zone soudanienne du Nord-Est du Bénin. Revue d'élevage et de médecine vétérinaire des pays tropicaux **42**, 283–288.

Yaoïtcha AS. 2004. Dynamique des pâturages naturels suivis de 2000 à 2004 sur les fermes d'élevage de Bétécoucou et de Samiondji et l'exploitation pastorale des alentours par les éleveurs bovins riverains. Thèse d'Ingénieur Agronome. FSA/UAC. Abomey-Calavi, Bénin, p. 111.

Zoungrana I. 1991. Recherches sur les aires pâturées du Burkina Faso (PhD Thesis). Thèse de doctorat, Université de Bordeaux **3,** p 371.