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RESEARCH ARTICLE

Predicting the amount of biomass produced grassland depending on the rainfall recorded in the Sahelian area of North – Senegal in West Africa

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Abstract

Predicting the amount of biomass produced grassland depending on the rainfall recorded in the Sahelian area of North – Senegal in West Africa

This study is the logical continuation of the first article, which has established strong correlations between the amount of rainfall and herbaceous biomass produced in the Sahel region, for different winters followed. It took place in Unit Pastoral Malandou, located in the north of Senegal, located in the administrative region of Matam between latitudes 15 ° and 16 ° 30 North and longitudes 13 ° 30 and 16 ° West, thus occupying part of the pastoral zone of Senegal. The work relates to the period 1994 - 2010, on the basis of (i) collection of rainfall data, (ii) direct measurements of the herbaceous production and (iii) interviews and surveys of farmers. All data and information stored, were subject to a treatment that has shown that the variability of production of course is closely linked to that of rainfall, which the experimental verification of these links have corroborated, Now, this is, to rely on the amount of rainfall each year, based on the production of biomass measured in the surveys of selected sites on the courses, to develop a simple estimation tool grassland productivity of the study area. Satisfactory correlations obtained on three ground control sites installed in the Pastoral Unity($r \approx 0.90$ to 0.93), helped develop a comprehensive prediction equation of type « $Y = ax^n$ », summarizing the results achieved. This equation yielded reliable estimates of quantities produced on a grassy pasture lands within the area of study but can be extrapolated to other areas that are similar to it in the Senegalese Sahel.

INTRODUCTION

This study is interested in herbaceous biomass rangeland which represents the bulk of the diet of livestock in the Senegalese Sahel. It derives its importance from the fact that herbaceous vegetation of tropical savannah provides between 75 and 90% of the total biomass of ecosystems (Garnier and Dajoz, 2001)

It is also known that in the Sahel in general and in the Senegalese Ferlo especially pastoralism is an important part of economic activity and is based on transhumant pastoralism that gets most of the livestock feed , natural pastures

whose disposable feed consists essentially of this herbaceous vegetation. The rather precarious climatic conditions prevalent in the area will determine a relatively low grass cover provided which requires a rational, sustainable and ensuring the preservation and sustainability of the environment.
To do this, the most appropriate strategies to perfect management of space, require the anticipation based on the availability of effective tool at any time to have some assessment of the pastoral value natural course of the study area.

The Pastoral Unit (UP) of Malandou home this study builds an experience of over twenty years in the pastoral space management, initiated in the context of Integrated Ecosystem Management Project Sahel (PGIES). Due to its geographical position, this zone embodies the typical Sahel both the climatic point of view and in terms of farming systems applied thereto.

By referring to the work already published, several authors have shown that the productivity of a course is influenced by several factors including: soil quality, rainfall, level of attendance... It was also noted that arid environment, abundant rainfall is the main factor that determines the quality of a pasture (PSSP, 2009). In the same vein, the authors Grouzis, Cattin, Barral (1976; 1980) have also proved that "biomass production potential is highly dependent on rainfall."

Also, it will be within the framework of this study to rely on the quantities of rain fell and biomass production measured in the surveys of sites selected on the courses, to develop a simple estimation tool the productivity of grasslands of the study area.

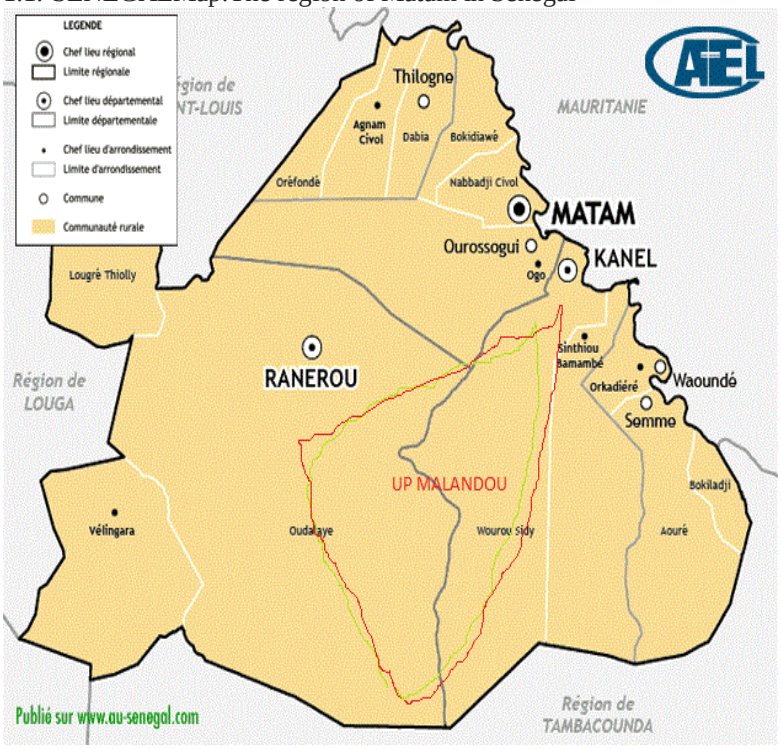
Indeed, under the management of Pastoral Units (UP), it is customary to determine the carrying capacity of pastoral space control allows better exploitation perimeters. Thus some authors have sought to establish their equations to predict the pastoral potential expressed in FU / ha, easily transformable in stocking unit (Senn 1991). We will try in the case of the Pastoral Unit investigated, to register the same logic as to design appropriate equations for a reliable prediction of the amount of grass produced on a given pastoral space within the study area or other spaces that are similar to it.

I-- MATERIALS AND METHODS

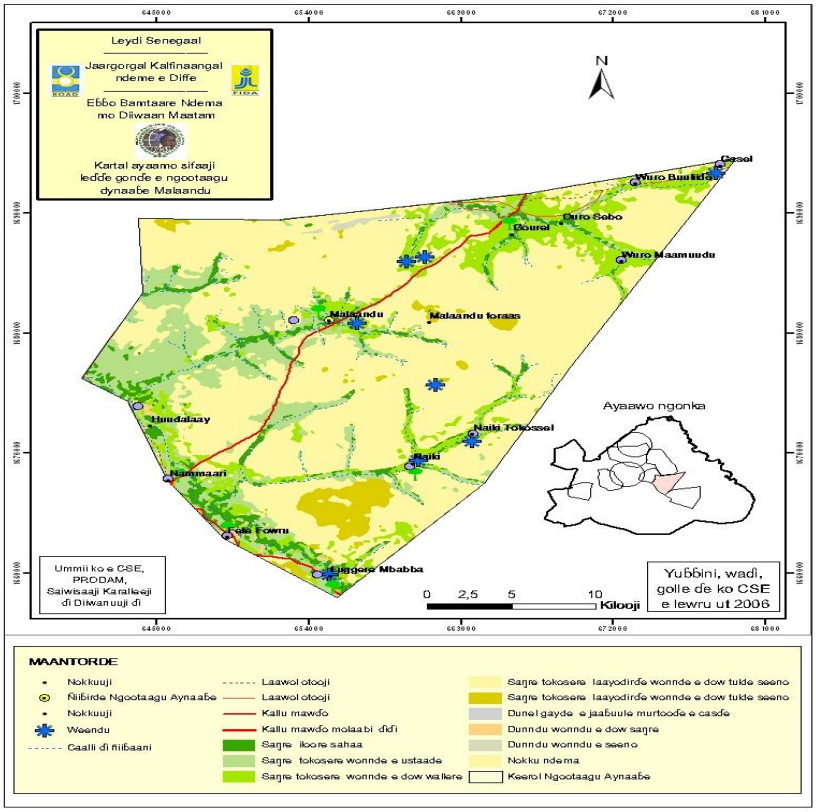
1.1. Presentation of the study area

This study was conducted as part of a collaboration with the Centre for Ecological Monitoring (CSE) in Dakar, the Development Project in Matam (PRODAM) and Integrated Ecosystem Management Project Sahel (PGIES). They are all called to contribute to achieving the main objective focused on the development and sustainable management of Natural Resources in the region.
The pastoral unit that houses Malandou our study lies within the areas of intervention and such projects straddles areas covering both agro ecological areas that are: (i) the "Ferlo" which is located south and has a pastoral vocation; (ii) the "Dieri" in northern Senegal, corresponding to the principle highway of the Region It is marked by its business activities and intermediation;
The U.P. Malandou is located in the administrative region of Matam between latitudes 15 ° and 16 ° 30 North and longitudes 13 ° 30 and 16 ° West, on a vast plateau of 116.4 km perimeter and an area of 7.282 million hectares.

1.1.-SENEGALMap:The region of Matam in Senegal



1.2. Area Map: Malandou position in MATAM Region



1.3.-Card of Pastoral Unit of Malandou

Malandou is at isohyet 200; however, its recorded average rainfall is 400 mm / year (National Meteorology). Inter - annual rainfall is very fluctuating. Climatic variations are recognized but they are an inherent characteristic of Sahelian perimeter and do not represent an exceptional situation.

Because of its location, the area is under the influence of a Sahelian climate with two distinct seasons: a dry season that lasts eight (8) months, namely from November to June and a wet season four (4) months, from July to October. It is located at isohyet between 300 and 500 mm. The area is subject to many natural, animal and human constraints that shape the facies of the vegetation of the area. The vegetation is characterized by a predominance of Acacia nilotica (Gonakier) in the Walo on soils "hollaldé" desert date (Soump) and Acacia senegalensis on "founded" soils sometimes a shrub layer consists of Acacia seyal (Surur), Boscia senegalensis, Ziziphus mauritiana (jujube) etc. Water resources are limited and consist mainly of very deep groundwater and surface water during the rainy season. Forage resources are dominated by annual species

1.2. Methods

1.2.1- Equipment used

to make this work, the following material was used:

- Floristic survey sheets of woody and herbaceous, for identifying the various species;
- GPS (Global Positioning System) to locate plots;
- milestones to delimit plots and to allow the targeted;
- computer and appropriate software
- etc.

1.2.2 Method study

- **General information:**

The productivity study was performed by means of measurement units for the production of biomass, consisting of circular permanent plots of 16 m radius. The data gathered in this context, consist of geographical landmarks, rainfall records, biomass measurements, bromatological values .

They are exposed in three stages.

- First, the data used are presented.
- Second, the techniques of spatial and statistical analysis are grouped
- The last part brings together the interpretations and conclusions.

The data flow processing plant production of maps based on satellite data processing, supplemented by ground surveys.

For the study of biomass, it has focused on ground control sites (SCS) three in number, namely: Malandou 1, 2 and 3.

- **Direct measurement of grass production**

Data were collected from measurements of the area, on the occasion of visits scheduled in 4-6 months a year, and divided into several targeted periodic stays. Grass production was measured according to the method of the laminated sampling line. It consists, from a transect 1 km long, effecting stratification according to different production levels of the herb layer. For each of them, the determination of the dry matter (DM) examined nine samples corresponding to three samples in all three production levels (1, 2 and 3).

On the line transect, green is sampled plots of one square meter, cut at random.

This freshly harvested herbaceous biomass, is weighed and then homogenized. Part of the mixture was weighed and then brought to the laboratory for evaluation in an oven, the dry matter content (DM). By a calculation incorporating productions per square meter (expressed as dry matter) and the reference surface is obtained in the available kilograms of dry matter per hectare (kg DM / ha). On the ground, the grassland production measurements are made by sampling and by cutting by using the method called "destructive" of cutting grass with shears or a sickle, inside a square of 1 meter square.

- **Rainfall Statements**

Rainfall data were collected at Meteorological stations of Matam and Ranérou-Ferlo with support from the National Geographic Service. The amounts and the number of days recorded in the village of Malandou rain were obtained from surveys conducted regularly after each rain, however small it.
These data were supplemented and confirmed by the information and data collected from populations of all the villages of the pastoral unit

- **Operating Data**

Assuming that variability in production route seems strongly linked to rainfall, it is proposed to experimentally verify these links and then wonder about the spatial relationships between (i) drought, (ii) plant production and (iii) breeding. The study of biomass, covered the ground control sites (MCS) which, in the case of the pastoral unit Malandou are three in number, including: Malandou 1, 2 and 3.
This model consists of measures taken annual quantity of dry matter, at the herbaceous layer on these 3 sites identified:

- Malandou 1: is located 2 km west of the village, going towards the hamlets of Naiki and Tokossel. Its UTM coordinates: X = 6556880, Y = 1679687
- Malandou 2 is 7 km to the north, going towards the village of Oudalaye, with UTM coordinates: X = 649122 Y = 1677980
- Malandou 3 is 12 km north of Malandou by going to the village of Dendoudi and for UTM coordinates: X = 664091 Y = 1688328

The data used in this study represent the averages calculated from the results obtained in the three sites.

II-RESULTS

Fig.1 -Presentation of the geographical area of study

2.1. Rainfall

The amount of rainfall recorded in the Malandou zone between1980 and 2010 are shown in Figure2 below

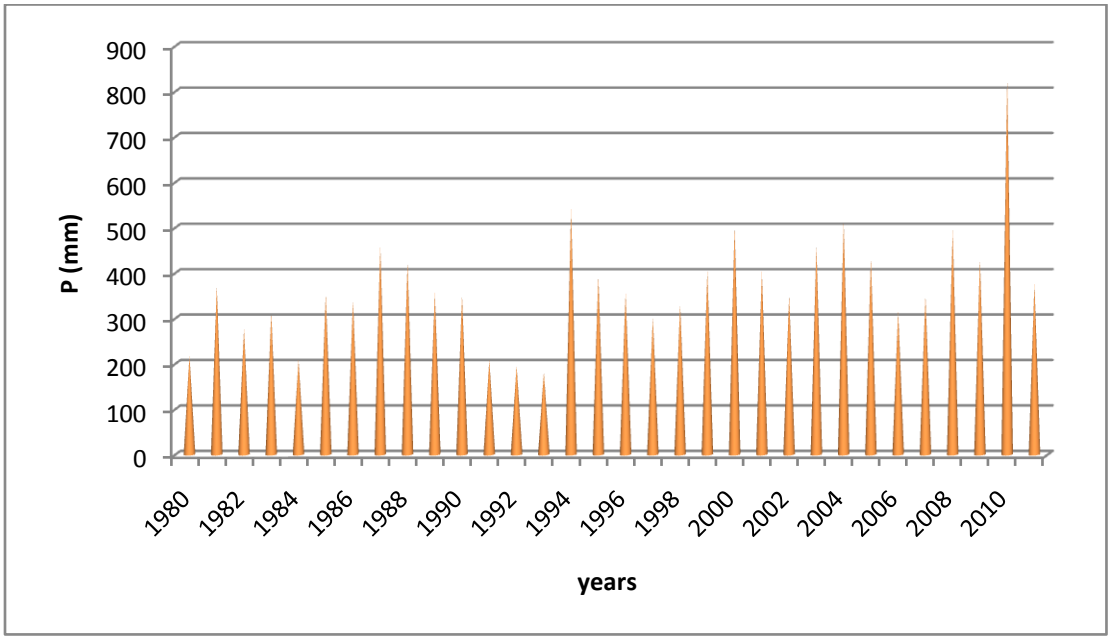


Figure 2: annual rainfall recorded between1980-2010 (31 years)

Inter – annual climate variations are an inherent characteristic of Sahelian perimeter and do not represent an exceptional situation in the case of UP Malandou.

Figure 2, shows a very fluctuating inter annual rainfall in the area covered by the Pastoral Unit, with an annual average of less than500 mm except that of 2010 (810mm).

To better illustrate the rainfall variability, a classification of years according to the recorded precipitation was performed. Table 1-below, shows the distribution of the 31years studied, according to the different available classes.

Table1: Classification year's rainfall in Pastoral Unit of Malandou
(On the basis of the combination of rainfall classes defined by the CSE)

Classes	Deficit Years P < 200 mm	**Normal years** 200 < P < 500 mm	**Excess years** P > 500 mm
YEARS	1992 1993	1980 ; 1981 ; 1982 1983 ; 1984 ; 1985 1986 ;1987 ; 1988 1989 ; 1990 ; 1991 1995 ; 1996 ; 1997 1998 ; 1999 ; 2001 2002 ; 2003; 2005 2006 ; 2007 ; 2008 2009	1994 2000 2004 2010
% number of years	**2/31 = 6%**	**25/31= 81 %**	**4 /31 = 13%**

Rainfall is relatively satisfactory in the area, for 21 years on the 31 followed and 25 years , corresponding to, 81% of rainfall years, are normal or in excess. Changes in rainfall, resulted in relatively large differences between years and amounts of rainfall recorded, that ranged from a minimum of 180 mm (1993) and a maximum of 829 mm (2010). The average rainfall is around 376 mm / year, with a standard deviation of 128 mm,
This result obtained in the last 31 years studied in the P.U of Malandou , confirms, if need be, the 400 mm average rainfall attributed to this zone of the Senegalese Sahel.

2.2. Production of grassland

The table N° 2 below, gives the quantities of herbaceous biomass (kg DM / ha) measured on different sites (MCS) of the pastoral unit Malandou that are:

- Prod M1: is the production on the site of Malandou1;
- Prod M2: representing the production site of Malandou 2
- Prod M3: equivalent to the production obtained on the site of Malandou 3.

Table N° 2: Grassland Production and rainfall measured on the 3 sites (M1, M2, M3)

Years	1994	1995	1996	1997	1998	1999	2000	2005	2006	2007	2008	2009	2010
Prod M1	1169,00	1192,00	1036,00	499,00	713,00	1793,00	1717,00	776,98	185,92	519,99	393,69	968,00	939,21
Prod M2	1798,00	1849,00	735,00	481,00	683,00	1422,00	1891,00	1419,59	394,69	520,67	602,29	1035,00	1635,9
Prod M3	1949,00	1927,00	1029,00	341,00	478,00	1373,00	2110,00	478,32	412,61	1094,63	747,27	1101,00	1795,2
Average biomass production (kg DM / ha)	1638,67	1656,00	933,33	440,33	624,67	1529,33	1906,00	891,63	331,07	711,76	581,08	1034,67	1456,7
Deviation – Type (kg DM / ha)	413,69	403,72	171,80	86,49	127,90	229,65	196,92	480,99	126,02	331,57	177,74	66,50	455,26
Rainfall(mm)	541,18	393,90	356,30	301,10	330,20	404,60	503,00	432,60	314,50	349,20	495,50	429 ,4	828,80
Biomas Prod./rainfall (in kg DM/mm rain)	3,02	4,20	2,62	1,46	1,89	3,78	3,79	2,06	1,05	2,04	1,17	2,41	1,76

Average biomass production /rainfall: $\frac{3,02 + 4,20 + \ldots\ldots\ldots\ldots + 2,41 + 1,76}{13}$ = 2,40 kg DM/ mm of rainfall

Average; Prod M1; Prod M2; Prod M3 = Biomass Production M 1, 2, 3

Prod M1; Prod M2; Prod M3 are expressed in kg DM / ha

III - THE PREDICTION MODELS

They are based on a statistical approach that allows to connect simultaneously, the data from plots demarcated in Pastoral Unity with all the rainfall records, to estimate annually, biomass production that corresponds to the amount of rainfall fallen during the rainy season

This study builds on the results in Table N°. 2 page 389, which shows the average of grassland biomass production and gives reports that link the amounts of fallen rain with the biomass produced for each of the years studied.
Our commitment to develop predictive models of herbage biomass produced, according to rainfall, was inspired by the work of several authors, including:

- **TOUTAIN and LHOSTE**, which in 1978 already showed the existence of a correlation between the amount of rain and grass production but were limited to noting that the relationship was not simple. Following them,

- **BREMAN and KRUL** (1982) confirmed this correlation by specifying that where rainfall was limiting for biomass (<500 mm), it established a direct relationship between rainfall and pasture productivity. As part of the same logic,

- Some authors such, **HUTCHINSON (1996); KEYA (1998)** estimate that the biotic factors are more decisive than the abiotic factors in the change in herbaceous biomass

- Other authors **LEPART, (1997); MARAGE, (2004)** have shown that natural processes such as climate, rainfall and the nature of the edaphic substrate, play a decisive role in the functioning and dynamics of ecological systems

- **SINSIN and al. (1989); AGONYISSA and SINSIN, (1998); Houinato and al. (2003); Cardinale and al. (2004); Orthmann, I. and B. TOKO SINSIN (2005); TOKO and SINSIN, (2008),** found that the change in biomass following the topography, is primarily related to the physicochemical characteristics and the soil water availability.

- **ELLIS and SWIFT (1988); LEJOLY and SINSIN, (1993); Houinato and al (2003); Sawadogo and al., 2005),** adding that the soil water availability, depends not only on the amount of rain but mainly its good distribution, which influences in fact, the variation of herbaceous biomass. However,

In the final report on the production of biomass in Ferlo, it was noted that the year of 1984 although it was more rainy, than 1983, had produced less herbaceous biomass, due to a poor distribution of rain. Also, between 1986 and 1987, this same phenomenon could be observed, not without specifying that the differences caused by the disparities between these years, are not significant.
In the same vein,

- The Sahelian Pastoralists unanimously, recognize the strong dependence of the biomass produced on rainfall. They note in particular, that: "Water is the first limiting factor for pasture productivity, at the isohyet 400 mm, while at higher rainfalls, it is the soil quality that becomes the constraint major "(SPP 2009).

- If the results recorded in our study (Table N° 1 Page 387), showing 81% of the years studied with rainfall not exceeding the limit of 400 mm, in addition, the results of the Pearson study on correlation between biomass production and rainfall that shows a highly positive correlation, it can be validly admitted that the annual total rainfall is clearly positively related to the production of herbaceous biomass.

Based on these considerations, P.P.S. has already provided quite complex estimation formulas that take into account (i) the rainfall per decade, (ii) the water balance, (iii) the availability of nitrogen and (iv) the soil phosphorus contain, etc.

By entering the same logic, this study connects, biomass production and rainfall, leading to all possible deductions and seek ways of predicting the amount of biomass produced in that part of the Sahel area.
To do this, we came to the idea of working to design prediction models that incorporate the annual total rainfall, with the production of herbaceous biomass.
Models based on the development of a simplified relationship and the design of an equation, so, are proposed.

3.1 Simplified Prediction Model

Based on the sample consisting of measures quantities of biomass produced during the years of study and the amount of rainfall recorded corresponding year, we tried to establish a relationship between the two variables involved.
The idea is that we can have a simple way to calculate the estimators of the parameters "biomass" from the data of the other parameter "rainfall"
By referring to the data in the table on it, we found by calculations, that hectare of biomass production per millimeter (mm) of rainfall, varied from 1.05 kg DM. to 4.20 kg DM. These results, reported to all the Pastoral Unit, calculated production, is on average 2.40 kg DM ha^{-1} / mm of rain recorded.
It is observed on the 3 ground control sites studied, as:

- The minimum of 1.05 kg DM per millimeter of rain was recorded in 2005, with a rainfall of 314.5 mm
- The maximum is 4.20 kg DM / mm of rain. It was obtained in 1995, with a total rainfall of 394 mm

More exhaustively, we can note that:

• the least rainy year (1997 with 301.10 mm) has an average production per hectare of 1.46 kg DM / mm of rain, while
• the highest rainfall years (2010 and 1994 mm with 829 mm with 541) recorded respectively 1.76 and 3.02 kg DM / mm of rain, therefore, higher than the corresponding ratios of less rainy years.
• The lower production of biomass per hectare (1.05 kg DM / mm rainfall) was obtained in 2006 with a rainfall of 314.5 mm
• the largest production of biomass per hectare (4.20 kg DM / mm rainfall) was recorded in 1995,when rainfall is 393.90 mm (≈ 400 mm).

We observe, then, that years to above 400 mm of rainfall, namely:

o 1994, with 541 mm of rain (3.02 kg DM / mm of rain)
o 2000 with 503 mm of rain (3.79 kg DM / mm of rain)
o 2008, with 495 mm of rain (1.17 kg DM / mm rain) and even the year
o 2010 with 829 mm of rain (1.76 kg DM / mm of rain),

have all, their production of biomass per unit rain, lower than years whose rainfall is around 400 mm That is the case of 1995 and 1999, respectively, which recorded rainfall of 394 and 405 mm, corresponding to production of biomass per hectare of 4.20 and 3,80DM kg / mm of rain

These results recorded in the framework of this study and for the overall production of herbaceous phytomass per mm of rain incident (see Table No. 2 page 389), we found that each millimeter (mm) of rainfall, corresponds on average production per hectare of 2.40 kg DM. This result is quite comparable to those obtained by other authors who have worked in the same Sahelian zone, namely:

• 2.20 kg DM ha^{-1}. mm^{-1} Grouzis (1989);
• 2.40 kg DM ha^{-1}. mm^{-1} : DIARRA, BREMAN (1975)
• 2.58 kg DM ha^{-1}. mm^{-1} : THE HOUEROU and Hoste (1977)
• 3.30 kg DM ha^{-1}. mm^{-1} : Cornet (1981)
• 2.60 kg DM ha^{-1}. mm^{-1} : BREMAN and AL. (1975)
• 3, 0 kg DM ha^{-1}. mm^{-1} BALL (1975 and 1977 b)
• 2.16 kg DM ha^{-1}. mm^{-1} Grouzis and SICOT (1981)

These results recorded under other authors work at different times, reveal several facts:

- The amount of biomass produced per mm of rain, range from 2, 16 to 3,30 kg DM $ha.^{-1}..mm^{-1}$
- The average calculated from 7 results available is 2.60 kg DM ha^{-1}. mm^{-1} so the same result as Breman and al (1975) and substantially equal to 2,60 kg DM $ha.^{-1}.mm^{-1}$resulting from our work

The research that has been conducted the same year, took the results that were different or identical:

- Grouzis and Sicot (1981) and Cone (1981) found: 2, 16 and 3,30 kg DM ha^{-1}. ; However
- Breman and al (1975) and Diarra (1975), had close results: 2,40 and 2,60 kg DM ha^{-1}. mm^{-1}

These results seem to be well in line with those from our work. Also agreeing with Grouzis (1981), "that semi-arid area, crop production and therefore, pastoral potential, is closely linked to rainfall variability," we can consider the

rain as the most important factor in herbaceous biomass production. It is for this reason, and considering the authors' conclusions above - mentioned, we appear possible to estimate the potential of grassland production by applying the following formula, drawn from the results above: **BP = 2.40 x P.** with:

- BP = Biomass produced in kg DM / ha
- 2.40 = Coefficient lined with UP average biomass production in kg DM / ha / mm of rainfall
- P = Rainfall (mm / year)

Naturally, to consider the limitations and other uncertainties related to the proposed direct relationship, it appears that the reliability of this relationship, accommodates with an application to scale well controlled. It means that areas must be well circumscribed, like than our targeted Pastoral Unit.
Applying this relationship, should, in the main, to have right out of the rainy season, guidance on the situation in most pastures in the area and in turn an idea on capacity estimated load under normal conditions.

3.2. Prediction equations

To predict equations, the available data were processed by the SAS System software and then analyzed and interpreted. For this purpose, all the rainfall data were crossed with the amounts of biomass produced.
The variance analyzes have also incorporated the annual rainfall with:

1- The statements of each of the three ground control sites (Malandou1, Malandou2 and Malandou3), treated by individual way and

2- The results of the synthesis details for three sites obtained from averages of calculated output determining herbaceous biomass production throughout the entire Pastoral .Unit.

Studies have resulted in the design of a predictive equation of the biomass produced (BP) depending on the annually fallen water level.
The objective is to develop a simple tool for decision support as part of pasture management and organization of the movements of cattle in connection with the ongoing research needs of food for livestock.

3.2.1. Basic principle:

Under the previous study we had to conduct our first separate analysis of each of the 3 sites had already achieved very significant results which augur reliable data that can be used in the design of the prediction equation sought. Indeed, the regressions calculated from the rainfall integrated biomass production measured on the 3 sites, each site had given a satisfactory correlation, namely:

- (i) $r \approx 0.90$ for Malandou 1;
- (ii) $r \approx 0.93$ Malandou 2 and
- (iii) $r \approx 0.92$. on Malandou 3.

The determination coefficients resulting on these correlations were respectively of: R^2 = (i) 0.8361, (ii) 0.8518; (iii) 0.8712 and (iv) 0.8159. This had enabled satisfactory correlation, from the raised equations, to establish highly reliable forecasts.

The analyzes from these results, had helped to design an equation that shows the correlation between rainfall and biomass production.
The equation is of the type $\mathbf{Y = ax^n}$ and can be written in the form: $\mathbf{BP = a.\ p^n}$, with:

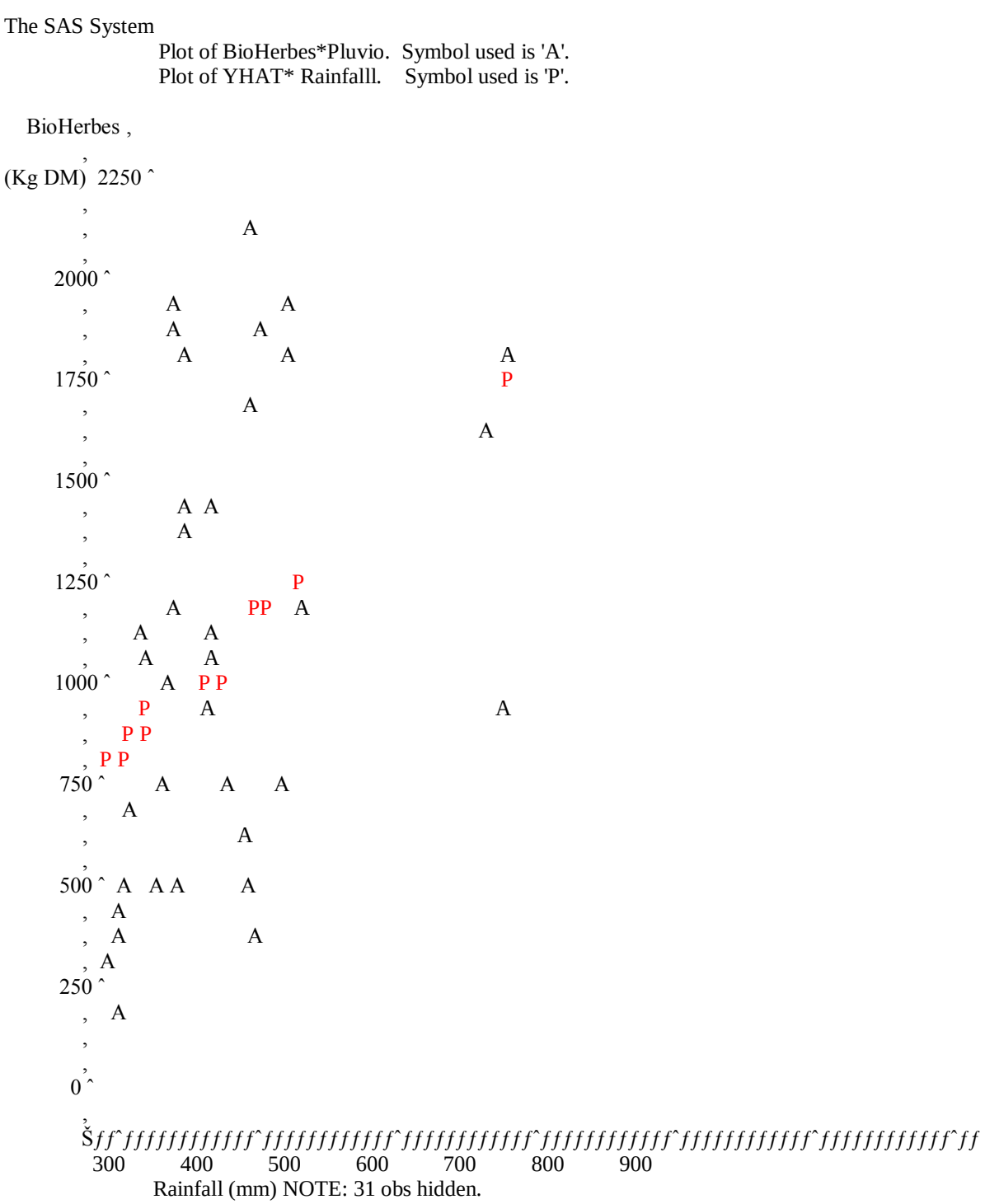
- **BP** = the amount of biomass produced per hectare in kg DM
- **a** = the coefficient
- **P** = rainfall in mm

This equation was calculated for each site, in a first time and then the 3 sites were integrated. The result derived from the synthesis of all of the data appeared to us more representative of the entire Pastoral Unit, and therefore the area in question.
It will, thus, be regarded as the reference.

3.2.2. Synthesis of the three ground Control Sites (average Malandou 1, 2, 3)

By integrating the 3 sites, regression calculated between integrated rainfall and biomass production measured in the field, gave a satisfactory coefficient of correlation ($r = 0.91$).
The equation of the line that results is designed as illustrated in the figure above -after:

Fig. N° 3



Graphique N° 3: Data Synthesis of 3 sites of Malandou

The overall equation resulting from the synthesis of the three sites, is as follows:
B.P. = 8.98 * P ^{0,79} ; (with R^2 = 0.8361) =

Produced biomass (BP) = 8,98 * Rainfall ^{0,79} , with R^2 = 0,8361

This equation summarizes the surveys on well sites and 3 can be applied to the full extent of the Pastoral Unit or, in the entire Sahelian zone with similar characteristics. As can be seen, this relationship is not linear.

From statistical analyzes based on the different results obtained, the following prediction equation was developed and proposed, to allow users to be able to make herbaceous biomass production forecasts based on rainfall data recorded on the Pastoral entire unit or in all Sahelian zones that are similar in terms rainfall data recorded him.
MICHEL Grouzis (1989) also conducted a study that shows that the production of the herbaceous layer is significantly related to effective precipitation by a relation of the type:

y = ax + b, In other words; **$y = a.Pe + b.$**

The resulting equations are as follows:

- **Y = 0, 40. Pe - 34,6**, if considering the actual run off coefficient and,
- **Y = 0,36.Pe - 14,2**, , if the conventional hydrological coefficient is used

This is the result of the work of SICOT- Grouzis (1981). In this relationship:

- **Y:** expresses the amount of biomass produced in g DM/ m²,
- **Pe:** represents the effective amount of rainfall in mm infiltrated water.

The reliability of these results appears to us well founded if we admit, with the Sahelian Pastoralists (PPS) that "water is the main limiting factor of the herbaceous production where annual rainfall does not exceed 400mm." Now, referring to the 31 years over which focused our study, we observe that only 6 years or fewer than 20% have a rainfall higher than 400 mm.

CONCLUSION

This study took place in a Pastoral Unit located at North -Senegal in the Sahel. It was based on the results registered in terms of rainfall and pasture biomass production over several years monitoring. The analyzes and interpretations that resulted, helped to develop prediction herbaceous biomass production tools, from the quantities of rains in the Pastoral Unit (UP). This is to help decision makers, through better management of pastoral areas, to anticipate the design of a program to use natural pastures of the area by the end of the rainy season, based on their estimated load capacity. Rainfall has proved to be a factor in very good connection with the production of grassland biomass, correlation coefficients being at least $r \approx 0.90$ for each of the three ground control sites, the reliability of forecasting tools resulting, can be logically accepted.
The prediction equation (**$B.P. = 8.98 * P^{0.79}$**) combined with the average quantity of biomass produced per millimeter of rainfall (**2.40 kg DM / mm**), represent an alternative to the difficulties and delays that policymakers have always met for the information and data on pastoral resources needed to ensure proper organization of the herd.

This equation should thus be put to use to help better plan and schedule the use of space but also the organization of transhumance and animal movements throughout the Malandou Pastoral Unit. It also, could be extrapolated in other areas of the Sahelian space which are similar to it.
Naturally, our study presents some limitations and it is thus recommended to its deepening, to consolidate some evolutionary trends of natural pastures in the Senegalese pastoral farming area for excellence.

Bibliography

AGONYISSA D SINSIN B. 1998. Productivity and carrying capacity of natural grassland in Benin. Elev Review. Med. Vet. Countries too, 51 (3):. 239-246.

BARRAL H., 1977. - The nomads Oudalan and pastoral space. Trav. Doc. ORSTOM, Paris, 120 p. 8 h.t. cards

BARRAL H., 1982. - "The Ferlo boreholes": past and present pastoral land management; study of human geography, ORSTOM Dakar.

BALL, J. C. 1975 - Measurement of prod uction herbaceous zone sah ed ian African tropical pastures 3-8 March 1975 BAMAKO 4 p. Mimeo.

BALL, JC 1977a - Study of the net primary production of a Sahelian ecosystem. Trav- Doc. O RSTOM, Paris 65: 82 p.

BALL, J. C. 1977b - Vegetation and productivity Sahelian 5 sites in Senegal - Technical Document 'of the Division of' Science and Technology for the Environment and Plant Production, ILCA-ILCA, Addis Ababa, 25 p. Mimeo.

BREMAN, H. L. DIARA, M. I. CISSE, and Mr. TOGOLA 1975 - Tropical pastures africains- Bamako, 3-8 March 1 9 7 5, Adhique International Livestock Centre for Africa (ILCA-ILCA) p. 195-213 French version).

Breiman H., 1975. - The maximum load capacity of Malian pastures. Proceedings of the Conference of Bamako (Mali): Inventory and mapping of tropical pastures
Africa, 3-8 March, 1975, 249-256.

Benoit-Cattin M. Methodological proposals for the analysis of production systems - 1975 to 1910

Benoit-Cattin: Multi-Economic Analysis of a group of square followed: experimental units from 1969 to 1975. Methodology and main results - 1976

BREMAN and KRUL (1982): "The rainfall and forage production on natural pastures" in FWT De Vries Djiteye and MA (eds). The productivity of Sahelian pastures A study of soils, vegetation and operation of this natural resource, pp. 304-319. Agric. Res. Rep. 918. Pudoc, Wageningen

Cardinale BJ, IVES AR, P. 2004. Effects Inchausti of species diversity on the primary productivity of ecosystems: Extending our space and temporal scales of Inference. Oikos, 104: 437-450.

Cornet, A. 1981b. - Biomass measurement and determination of aboveground net production of herbaceous plant communities in three of the Sahelian zone in Senegal - Acts OEcologica, OECOL. PLUVLZ., 2 (16), 251-266.

ENVIRONMENTAL MONITORING CENTER (ESC):. Crop production. Dakar: CSE, from 1987 to 1996; 8 cards at 1/2 500 000.
CSE: DEC - 2008: STUDY in SSC Annual Bulletin, No. 17

L. Diarra BREMAN ~ H; 1975. - Influence of rainfall on pasture production. Proceedings of the Symposium of Banako (Mali), Inventory and Mapping of African tropical pastures, ~ 3-8 March 1975 171-174.

ELLIS JE, SWIFT DM. 1988. Stability of African pastoral ecosystems, alternate paradigms and implications for development. J. Range Manage, 41 (6):. 450-459.

GARNIER LKM, Dajoz I. 2001. The effect of fire on the demography of a dominant grass species of West African savannas, Hyparrhenia diplandra. J. Ecol. Oxford, 89 (2): 200-208.

Grouzis M., 1979: Structure, floristic composition and dynamics of dry matter production of Sahelian vegetation. (Mare Oursi, Upper Volta). A.C.C. Fight against aridity in Oudalan DGRST ORSTOM, rep. multigr., Ouagadougou, 56 p.

Grouzis 1981 - Methodological study and application to the production estimate
frequency watershed pond Oursi highly volta

Grouzis SICOT M and M, 1981 - Production of Sahelian rainfall and natural pastures. A.C.C. Fight against aridity in I'OUDALAN, DGRST-ORSTOMR
providing multi graphy, 33 p.

Grouzis M., J. Albergel, 1989.- From climate risk to ecological constraints: the impact of drought on crop production and environment in Burkina Faso. In "The risk in agriculture", Mr. Eldin, P. Milleville Edition Collection through fields, ORSTOM, Paris, p 243-254.

Grouzis M, J & CARBONNEL Albergel JP 1989.- climatic deterioration in Burkina Faso: water resources and effects on crop production: 165-178, in "The men face drought, North East Brazil, African Sahel", B. Bret (coord.), IS IHEAL: 422 p.

Houinato million KAGONE H, SINSIN B. 2003. Seasonal cycle of herbaceous plant phytomass of Kouffé Mountains Region in Benin. In Proceedings of the VIIth International Rangelands Congress. Durban, South Africa; 1399-1402.

HUTCHINSON CF. 1996. The Sahelian desertification debate: a view from the American south-west. Journal of Arid Environments, 33 (4): 519-524.

KEYA GA. Herbaceous layer 1998. Production and utilization by herbivores under different ecological circumstances in arid savanna of Kenya annually. Agric. Ecosyst. About. 69 (1): 55-67.

THE HOUEROU HN, HOSTE C ~ H, 1977. -. Rangeland Production and annual rainfall relationships Meditcrranean Basin and in the Sahelo-Sudanian in African area. Journal of Range Management, 30, (3) ~ 181 - 189.

LEJOLY J, B. 1993. SINSIN China grass (Pennisetum polystachion (L.) Shult) pasture in northern Benin: Fodder species composition, productivity, feed value and grazing value. In XVII International Procceeding of the Grassland Congress; 257-259.

Lepart J. 1997. The environmental crisis and theories of ecology in balance. The environmental crisis in 80 Larrere C Larrere R (Eds). INRA Paris; 131-144.

MARAGE D. 2004. Determinism, dynamic and spatial modeling of plant diversity in a context of pastoral abandonment. Application to the sustainable management of mountain areas in doctoral méditerranéenne.Thèse influence Cemagref / INRA France236 p.

Orthmann B. 2005. Vegetation ecology of a woodland-savanna mosaic in central Benin (West Africa): Ecosystem analysis with a focus on the impact of selective logging. PhD thesis, University of Rostock, Rostock, p.148

P.P.S. "Productivity Project Sahelian pastures." Dutch-Mali project located in Mali, under the supervision of the University of Wageningen and the Institute of Rural Economy of Mali.- Annual Report 2009

PSW: Securing Project Pastoral Systems, Mission Support to pastoral resources management component; Support for pastoral wells management strategy IRAM - October 2008, André Marty, Noudjia Kaigama Kiari 56 p;

SAWADOGO L, D Tiveau, NYGARD R. 2005. Influence of selective tree cutting, livestock and prescribed fire on herbaceous biomass in the savannah woodlands of Burkina Faso, West Africa

SENN 1991 their equations to predict the pastoral potential expressed in FU / ha, easily transformable unity stocking. Impact of sheep grazing on the vegetation and fertilized Closed in Southern Alps

SINSIN B, OLOULOTAN S, M. 1989. OUMOROU dry season grazing in the Sudanese region of northeastern Benin. Rev. Elev. Med. Vet. Country too, 42 (2). 283- 288.

SICOT Grouzis M.-M. (1981): Rainfall and production of natural pastures Sahel: methodological study and application to the estimation of the frequency output of the catchment area of the pond Oursi Upper Volta ORSTOM, 1981, 45 p. multigr.

TOKO I, B. 2008. SINSIN erosion and natural soil collapse (dongas) of the W National Park and their impact on the productivity of pastures. Drought, 19 (3): 193-200

TOUTAIN B & LHOSTE Ph 1978. Estimation test the coefficient of use of the herbaceous biomass by livestock in a Sahelian area. Rev. Elev. Med. Vet. Too Country 31 (1) pp. 95-10