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Effects of Grazing on Plant Productivity and Rain Use Efficiency in Sahelian Grasslands, (Northern Burkina Faso)

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In most arid and semi-arid zones primary production is restricted by water availability and intense human population pressure. The sahelian zone is marked by an irregular and persistent downwards rainfall trend. The vegetation has been severely overgrazed for several decades and is generally degraded. The investigation reported in this paper was part of a large study programme on the structure, productivity and dynamics of sahelian ecological systems (Oursi Pond watershed, Burkina Faso). The scope of the research was to measure the capacities for regeneration of native vegetation protected from human activities, mainly overgrazing by cattle , sheep and goats, under severe sahelian climatic conditions. In this paper the aboveground phytomass, productivity and rain use efficiency have been assessed.

The watershed around the pond of Oursi is situated in the northern of Burkina Faso, between the parallels 14°20' and 14°50' N, and in longitude from 0°10' to 0°40' W. The average annual rainfall (period 1976-1984) is 368 mm and is distributed over 39 rainy days ; nearly 90% of the rain occurs from june to september. The average annual PET (CHEVALLIER *et al.*,1985) is close to 8 times higher than the rainfall. This important deficit in the water budget places this location within the zones with marked arid characteristics. The location is even more drier as it has been under persistent drought conditions since 1968 (SNIJDERS 1986). The natural vegetation is a mixture of annual grasses and forbs (*Cenchrus biflorus* Roxb., *Aristida sp* , *Schoenefeldia gracilis* Kunth, *Panicum laetum* Kunth, *Zornia glochidiata* DC.) and trees and shrubs, most of them spiny (*Acacia sp*, *Ziziphus mauritiana* Lam., *Balanites aegyptiaca* (L.) Del.. These plants represent some 90% of the diet for livestock which number 13/14,000 cattle and 37,000 small ruminants. The major components of the economy are rain-fed crops (millet, sorghum) and livestock.

Six units of vegetation (tab.1) corresponding to different types of soil and landuses were entirely protected from domestic herbivores during 5 years. During the growing period, the 10-day variations in the plant biomass (alive material) and in the litter (dead material) were measured on each site from sample of 30 to 40 one square meter plots, according to the level of heterogeneity of the vegetation (LEVANG & GROUZIS 1980). The studied parameters are defined as follows :

- the potential productivity in the exclosures (g $DM.m^{-2}$) is the maximum difference between the total plant material *i.e* the phytomass (b+g) and the dead material (g) measured during the growth cycle ;
- the actual productivity in the disturbed plots is considered as the maximum phytomass which has been measured during the cycle ;

is nearly bare from january or february to june. This situation favours wind erosion during the dry season and water erosion during the violent storms at the onset of the wet season.

The graphs on figure 2 express the phytomass variations in the exclosures, as compared to the grazed areas, for those years when the exclosures remained undisturbed. The data describe the variation of both sets of plots from the beginning of the growing season to the maximum standing crop. The relation Phi= f(Phe) is highly significant to differentiate the plots which were grazed during the rainy season (phytomass in the exclosures 1.5 to 2.5 times higher than in the grazed area). The points which represent the grazed plots in drought season (Oursi and Kolel not shown on fig.2) indicate that no difference can be observed between the treatments in this case. The intercept of the regression line is an estimate of the phytomass left on the ground when the grazed plots have been completely denuded ; this value varies from 60 to 100 $g.m^{-2}$ for the various studied plant communities.

The plots which have been grazed during the growth period are well differentiated from the plots utilized during the dry season when considering water efficiency in the two treatments (figure 3). In the first group of plots (Gountoure, Kouni, Bas Kolel, Winde) the common regression line with 0.001 level of significance shows that water efficiency is about 2 times higher in the exclosures than in the grazed areas. In the second group (Oursi, Kolel) the location of the representative points indicates that no difference exits between the treaments.

- the average productivity (g $DM.m^{-2}.day^{-1}$) during the growth period is the average increase in plant material per unit area and time :

$$p = 1/n \sum (bi-bo)/(ti-to)$$

bi,bo : biomass at time ti and to (initial time) respectively.

- the rain use efficiency (RUE ,kg $DM.ha^{-1}.y^{-1}.mm^{-1}$) is the quotient of annual primary production or its estimation by annual rainfall ;
- the water use efficiency (WUE ,kg $DM.ha^{-1}.y^{-1}.mm^{-1}$ infiltrated water). The infiltrated water, measured as the difference between rainfall and rain-off is considered in this expression. These two last parameters, largely discussed by LE HOUEROU (1984) are very usefull to compare the production levels of different climatic zone ecosystems or various types of vegetation of the same area.

The seasonal variations of the phytomass of two vegetation communities respectively grazed in the dry season (Oursi) and in the rainy season (Winde) are shown in figure 1. For Oursi, net accumulation of plant mass (living and dead) during july through september was similar in grazed and ungrazed plots; the development in the grazed part shows the natural degradation and the impact of livestock (grazing, trampling). For Winde, the production curves reveal from the start of the rain the influence of livestock. This is further confirmed by the inter-annual comparison of productivity for both treatments (tab. 2): the only comparable values relate to Oursi (Ams) and Kolel (Cep) with dry season grazing.

Figure 1 also shows that the phytomass in the exclosures is always much higher than on the grazed plots, where the ground

This study on the results of plant protection in exclosures dealt with six ecological units typical of the sahelian zone and was intended to determine their capacity for regeneration. The protection creates an increase in plant cover and in the diversity of floristic composition through a manifestation of inter-specific competition (GROUZIS 1987). In terms of productivity, which was the subject of this paper, the protection favours plant growth and results in a noticeable increase in the productivity of the exclosures within the wetseason rangelands. This difference is equally valid for water efficiency.

These results illustrate the fragility of the equilibrium in the Sahelian ecosystems, their sensitivity to the interactions between production factors and their regeneration potential. The present vegetation differs from the potential vegetation as a consequence of the human influence. In spite of a rather unfavourable climatic environment, a good ability for the vegetation to regenerate has been demonstrated, together with the plants' vitality. Similar cases of natural rehabilitation have been quoted by (BOUDET 1977, NOBLE 1977, FLORET 1981). In the Sahelian zone, the potential for regeneration is due to the plasticity of the plants and of the vegetation structures in case of droughts, and to the variability of the soils and climatic conditions : dominance of annual species, drought-resistant plants, physiological adaptation (germinating characteristics of the seeds, high proportion of C4 species which need less water, vegetation pattern in mosaic, *etc.*

All these adaptative features could allow the plant communities to withstand the climatic risks, if the present and past pressure of men did not result in permanent stresses, aggravating the effects of the drought which has now lasted for 20 years.

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Table 1. Types of soil and landuses of the studied units.

SITE	ABBREVIATION	GEOMORPHOLOGY	LANDUSES
Oursi grazing	Ams	dune, sandy	drought season
Kolel grazing	Cep	piedmont, sandy	drought season
		more clayey in depth	area of cultivation
Goun-toure grazing	Ase	pediments, fine gravels	rainy season grazing drought season
			for lignous
Kouni	Sgl	glacis, loamy sand, glazed surface	rainy season grazing
Bas Kolel	Sgr	glacis, loamy sand	rainy season grazing
Winde	Spt	bottom lands sandy clay	early in the rainy season

Table 2. Interannual mean productivity (1977-1981) of ungrazed (U) and grazed (G) vegetation units (g $DM.m^{-2}.j^{-1}$)

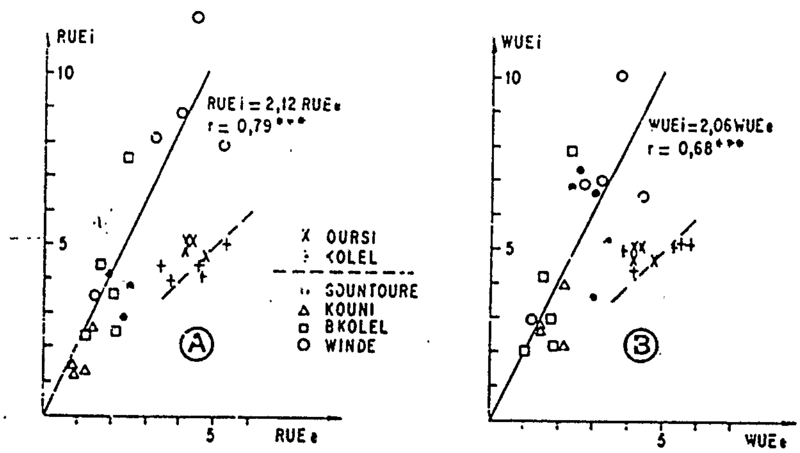
Units	Ams	Cep	Ase	Sgl	Sgr	Spt
Treatments	U : G	U : G	U :G	U :G	U: G	U :G
Productivity	2.7:2.9	3.1:3.2	2.3:1	1.6:1	2:1.5	4.9:2

LEGEND FOR FIGURES.

Figure 1. Seasonal variation of phytomass for the ungrazed and grazed units.

Figure 2. Interannual variations (1978-1981) of phytomass for the protected unit (Phi) versus grazed unit (Phe) in the three vegetation units differently used by man. Different symbols correspond to annual observations

Figure 3. Relation between rain use efficiency for ungrazed area (i) versus grazed area (e).
kg $DM.ha^{-1}.mm^{-1}$ of rain (A) and infiltrated rain (B)


RUEi
10
5
RUEi = 2,12 RUEe
r = 0,79***
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+ KOLEL
SOUNTOURE
△ KOUNI
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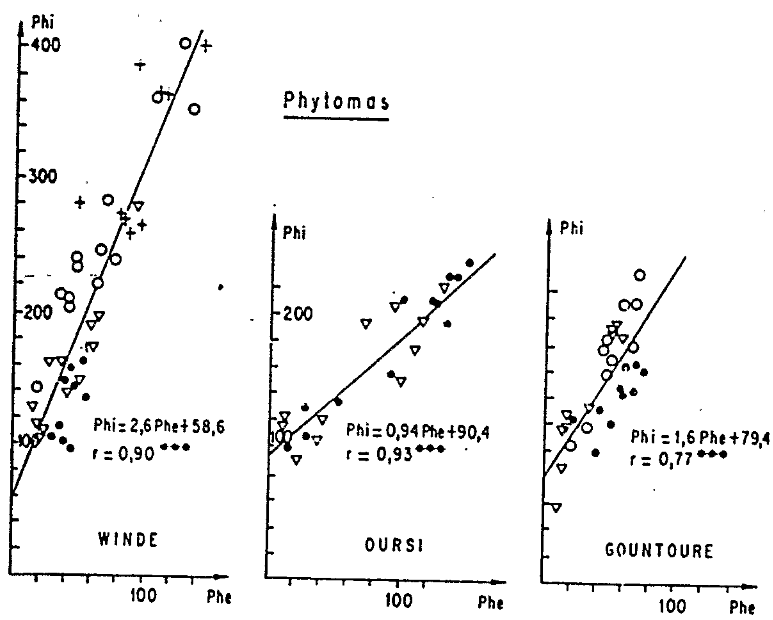
○ WINDE
A
RUEe
WUEi
WUEi=2,06WUEe
r = 0,68***
B
WUEe


Phytomas
Phi
400
300
200
100
Phi=2,6Phe+58,6
r = 0,90***
WINDE
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Phe
Phi
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Phi=0,94Phe+90,4
r = 0,93***
OURSI
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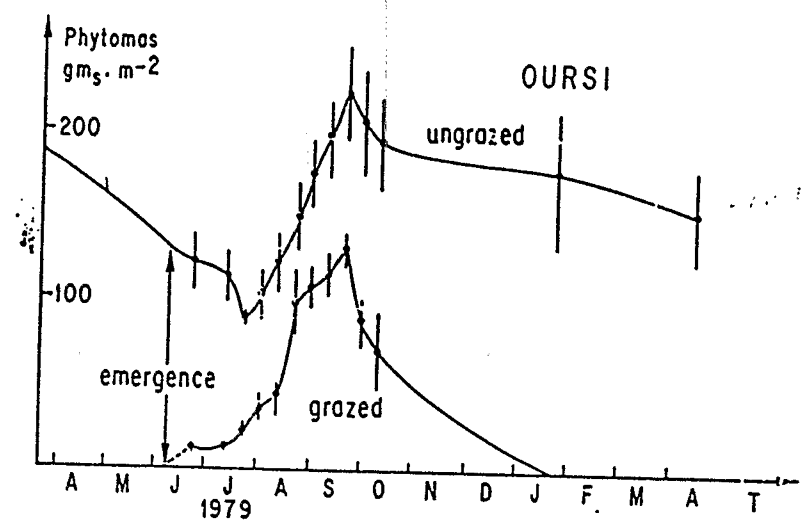
Phe
Phi
Phi = 1,6 Phe+79,4
r = 0,77***
GOUNTOURE
100
Phe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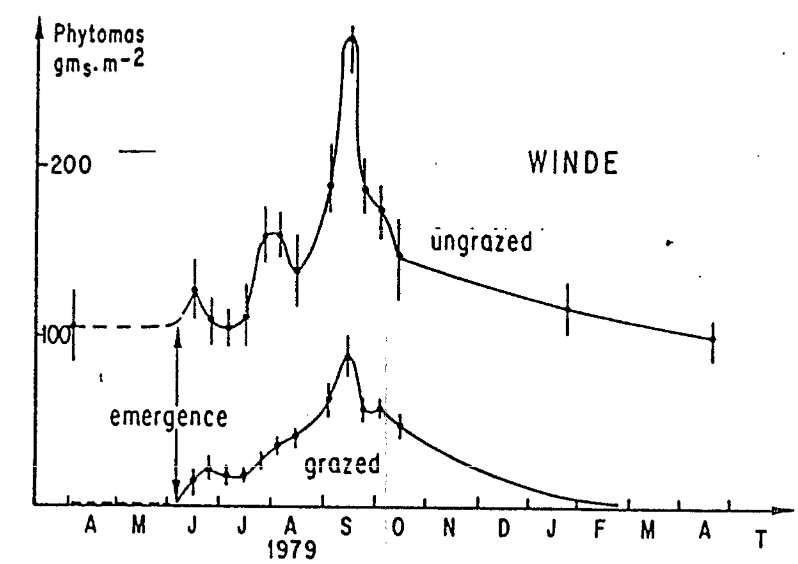
Phytomas
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