SPATIAL ANALYSIS OF LAND USE BY CATTLE HERDS IN A VILLAGE OF THE SUDANESE ZONE IN SENEGAL. APPLICATION FOR GRAZING SYSTEM IMPROVEMENT

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ABSTRACT
Spatial analysis of land use by cattle herds in the sub-humid area of Senegal is conducted through the utilisation of a Geographic Information System. This tool allows us to establish relationships between spatial practices, ruminant nutrition and performances. It gives leads to proposals for the improvement of the extensive ruminant feeding system.

KEYWORDS
Cattle feeding, diet, spatial behaviour, G.I.S, ruminant performances, Senegal

INTRODUCTION
Extensive ruminant feeding systems in the sub-humid area of Senegal (700-1200 mm annual rainfall from June to October) are developing in a heterogeneous environment (Guerin et al., 1986; Blanfort, 1991) which comprises rangelands, fallows, rainfed fields, rice fields and others, as in other parts of Africa (Bayer, 1996). The influence of seasons on the ruminant feeding system is important (Richard et al., 1991). As farmers have to work in the fields from June to December, ruminant diets rely on scarce forage resources of rangelands and forest during this period. Then, livestock returns to harvested fields where crop by-products are abundant. However, in our study zone, mid-Casamance, Kolda region, ruminant productions of sedentary pastoral systems remain low and differences in herd productions seem to bear, at least in part, some relation to herd spatial behaviour and management. In order to verify this hypothesis which may have important consequences in terms of herd management, land management and improvement, we decided to study spatial management and behaviour, feeding behaviour and production performances of cattle herds of a representative village during three years using a Geographic Information System as suggested by Meuret and Thinon (1993). This paper presents the first results of this study.

MATERIALS AND METHODS
Land composition around the village was designed from 1/12.000 aerial photographs and ground observations. Ten land types were defined : rainfed fields (Fi), house fields (HFi), young fallows (Fa), rice fields (Ri), ponds (Po), high forest (H= above 7m high), medium forest (M= 7 to 2m high), low forest (L= below 2m high) and herbaceous rangelands in forest (He) or in the palm zone (Hp). Each forest type was furthermore divided in four classes according to tree cover (class 1 for cover less than 20%; class 2 from 20 to 40%; class 3 from 40 to 70%; class 4 above 70%). In total, 19 different land types were defined. Spatial study of cattle herd management and feeding behaviour was carried out on three different herds (Diao, Mamadou, Mamoudou) which comprised respectively 32, 108 and 134 heads of N'Dama cattle. Over a period of three years, each herd was followed with a compass and a topometric thread for one whole day at two weeks intervals. Every five minutes, the position of the herds was thus noted. A recent version of Global Positioning System Navigator was also used during three courses to compare methods. At the same time, feeding behaviour was estimated through the instant percentage of grazing cattle. Fodder species that cattle fed on were registered using a hand plucking method every fifteen minutes. These observations were averaged throughout the day to calculate the average percentage of grazing cattle (PGC) and the average percentage of graminae, herbaceous legumes, forbs, crop residues and ligneous forage fed on (GRAM, LEG, FOR, CPR, LIG). This information was transferred onto the database of ATLAS-GIS[R] sofware together with the land-type map. Herd courses were plotted on maps either in line form (distances walked) or in point form (time spent) to compare results. With the same rhythm, herd diet quality (Organic Matter Digestibility:OMD and Digestible Nitrogen Matter content: DNM) was estimated from chemical analysis of faeces (Guerin et al., 1989). Average milk production of each herd was also calculated (MLK) but only from cows that calved during the rainy season (July to September). We added average daily milk yield with calves average daily weight gain converted into milk equivalent (Agyemang et al., 1993 :1 kg DWG = 9 liters of milk). Statistical analysis was carried out on 80 herd courses corresponding to three different herds, 19 land-type variables and 9 zootechnical variables.

RESULTS AND DISCUSSION
Land use. Comparisons of the different methods for herd course registration show that there is no significant difference between compass/thread versus GPS methods in terms of land use estimates. When we compare line versus point course registration methods on 28 courses, we find that results were highly correlated (r = 0,62 to 0,97) except for the two land types (H2;H4) which correspond to zones where cattle walk a lot along tracks. The GPS method may then be recommended as easier to apply. Distance and time measurements for land use are both valuable but time seems preferable. For this first set of data, we used distance measurements. When plotted on a map, courses show that the three herds use quite different zones around the village during the year. Whereas all three herds use rainfed fields and rice fields during the dry season, the small herd (Diao) can stay in the near forest during the rainy season while the two big herds have to use an adjoining forest to find enough water and forage. Over the year, we calculated a frequentation index dividing the average percentage of a land type in herd courses by the land type representation on ground. Figure 1 shows that some land types are quite well exploited (Ri;M4;M3;Hp;H4) whereas others are deserted (L1;L4; He;H1;M1). Analysis of variances confirm that for land types (L1; H1; H3; H4; M1; M4; Po) herders' practices are significantly different on a yearly basis ($p<0,05$) whereas it is not for others. Analysis on seasonal effect on a monthly basis shows that for almost all land types (except L2; H1; H4; M1; Po), seasonal effect is significant ($p<0,05$). This is due to cultivating constraints which force herders to alternate forest and field use. At this stage, we can already state that some land types are useless for cattle feeding (L4, M1) and might be improved by soil work and forage species planting.

Zootechnical variables. All variables are significantly affected by the seasonal effect except DNM content of diets and percentage of grazing cattle (PGC) which might be interpreted as a result of low variations and a small number of observations per month. Herd effect is significant only for MLK (respectively 1145, 746 and 1358 ml/cow/day for Diao, Mama and Mamo) and PGC (respectively 72.8; 66.9 and 66.6 %), whereas it is not for botanical composition and quality of diets except for ligneous forage ingestion (respectively 8.4; 6.9 and 12.5 %).

Relationship between land use, nutrition and performances. In order to analyse whether different herders' practices bear any relation to animal nutrition and production, we conducted a principal component analysis (PCA) on the first 80 different herd courses registered during our study. To minimize seasonal effect, we carried out PCA after division of our data in four sets, namely rainy season in forest (RSF), beginning of dry season in forest (DSF), dry season on crop residues (DSR), end of dry season (EDS). This analysis shows that (Table 1) :

- during RSF season, CPR are related to Fi and Ri, and other forage type to forest land type frequentation. Forbes intake is related to MLK and OMD.
- during EDS season, FOR is related to many land types and to MAD. MAD is related to MLK and OMD. During this period, Graminae intake is related to Fallows and PGC.

These partial results show relationships between herders' practices, land-type use and seasons, as mentioned by Richard et al. (1991), but furthermore with ruminant diet characteristics and productions. It suggests the role of land-types to be different according to seasons (ex : Fallows related to GRA or to LIG) and gives leads to feeding system improvement techniques such as land-type management and improvement, forage crop implementation and ruminant supplementation. Other tools are being used (Balent, 1993) to confirm these statements.

CONCLUSION

Firstly, results of this study prove how GIS can be used as a relevant tool with which to investigate extensive ruminant feeding systems. It requires information on natural resources to feed it and can be combined with zootechnical parameters to understand relationships between ruminant spatial land-use and production. Moreover, throughout this research programme, we are searching for other key parameters which could make the diagnosis easier, faster and cheaper to allow appropriate intervention on extensive ruminant feeding systems.

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Figure 1
Map representing land types around the village of Sare Yero Bana in the Kolda region (Senegal) and the three herd courses for the first eighteen months of the study.

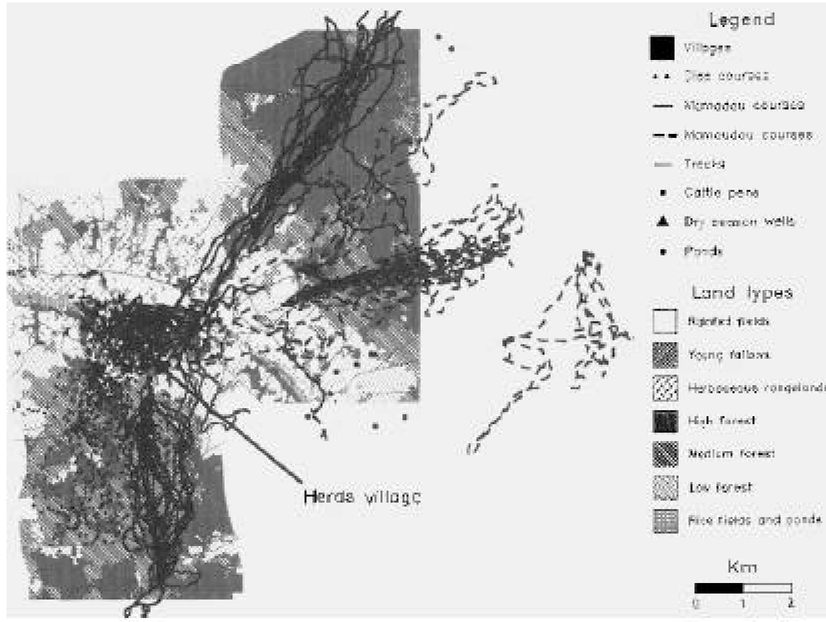

Figure 2
Land types representation and herd annual average frequentation index

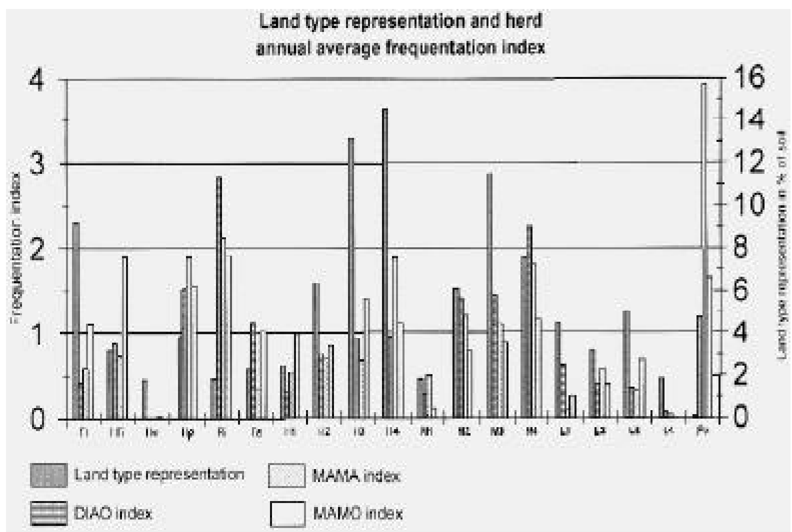

Table 1
Relationship between seasonal land use by herds and nutritional and production variables.

SEASONS	Rainy season (RSF)						Early dry season (DSF)	Middle dry season (DSR)						End of dry season (EDS)					
DATE	1 July to 15 Sept.						15 Sept. to 15 Nov.	15 Nov. to 15 March						15 March to 1 July					
Nb of courses	19						27	21						15					
Main Land Types	Forest						Forest	Fields						All types					
Land Type	L1	M3	M4	H2	H4	Fa	L2	Fi	Ri	H2	H3	H4	M4	Ri	Fa	L2	L3	M3	H3
Land type related variables	Gram	Gram	Gram	Forb	Forb	Lign	Legum	Crop res.	Crop res.	Legum Lign	Legum Lign	Legum Lign	Forb	Forb MLK	Gram PGC	Forb	Forb	Forb	Forb
Other related variables	DNM/Lign						Legum/PGC, Gram/OMD	Forb./MLK, Forb./OMD, MLK/OMD						Forb./DNM, DNM/OMD DNM/MLK, Gram/PGC					