ILCA
SYSTEMS STUDY 5

SYSTEMS RESEARCH IN THE ARID ZONES OF MALI

INITIAL RESULTS

PUBLISHED BY
INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA 1981
P.O. BOX 5689, ADDIS ABABA, ETHIOPIA

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Acknowledgements:

ILCA research staff in Mali are indebted to Mr. J. Durkin and Mr. R. Sayers for data analysis and advice on their interpretation: without their help the studies on livestock production (3.3 and 4.4) would not have been written in their present form. Acknowledgement is also made to Mrs C. de Stoop for painstaking efforts and continued endurance in editing; for art work in Bamako to Mr. J. Marie, Miss J. Harmsworth and Mrs Tessandrier and in Addis Ababa to Mr Admassu Wondafrash, Mr Abdulhakeem, Miss Bezunesh Tamiru, Miss Martha Getaneh and Mrs Yeshi Tekabe; for typing in Bamako to Mrs Sangare Toure and Mrs A. Camara and in Addis Ababa to Mrs Salome Gerima and Miss Bethlehem Terrefe.

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PREFACE

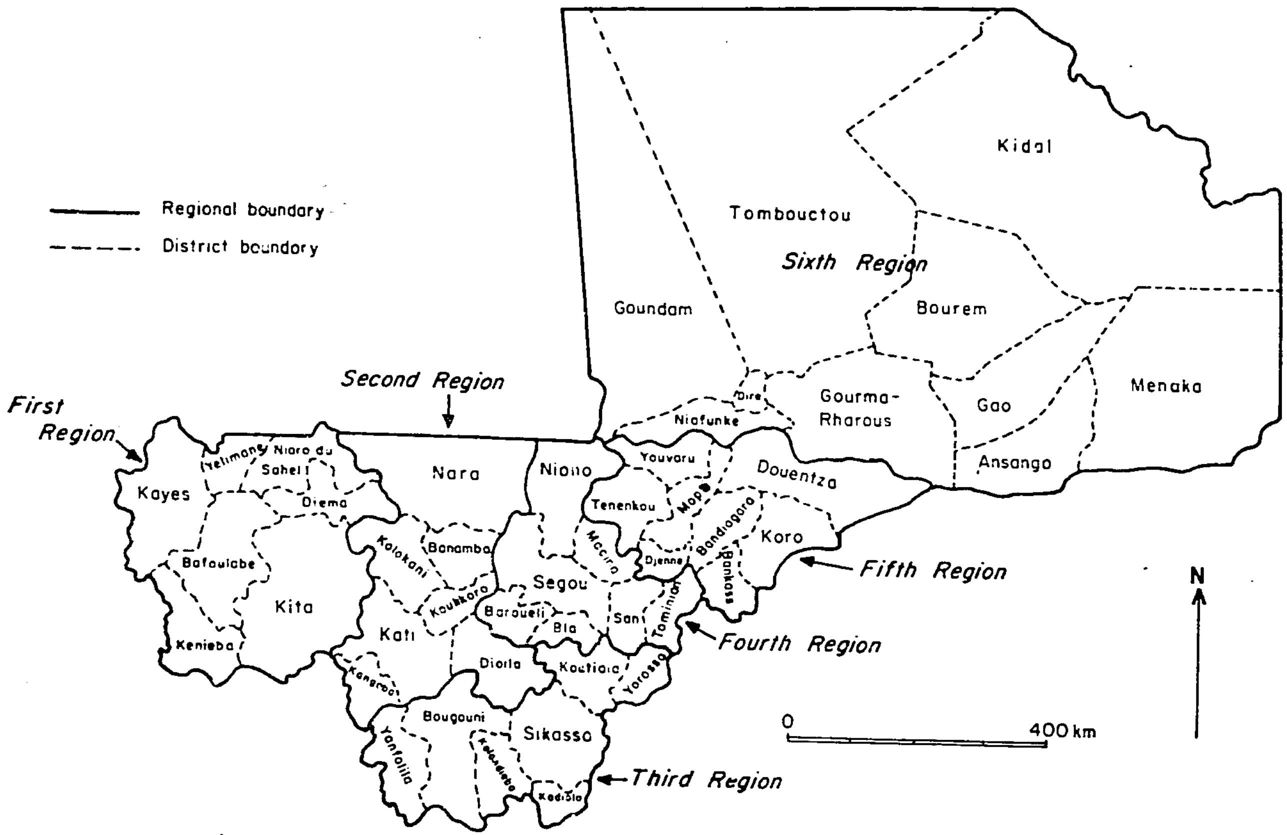
This is the first edited draft of a systems study intended for publication by ILCA in the near future. It deals with 5 years of research on two livestock production systems in the arid zones of central Mali. The work carried out over this period, using the systems approach adopted by ILCA, has covered a wide range of interrelated topics. The activities of the ILCA/Mali programme have therefore been complex as well as varied, but inevitably research has developed further in some fields than in others, with the result that for some of these activities the results reported here are more detailed than for others.

The wide range of activities in Mali is amply borne out by the number of different contirbutors to this report and the wealth and complexity of the material they submitted for inclusion. On the editorial side these factors have created certain problems, and inevitably, in the interests of overall coherence and unity, some of the material submitted has had to be sacrficed or adapted to suit a specific context. In addition , the overall form of the report, in terms of presenting information in a rational sequence, still leaves much room for improvement. Using a single chapter for the presentation of an entire production system, for example, has meant that a logical ordering of sections has become almost impossible owing to the many different topics discussed, the interrelated nature of these topics adding further difficulties in some cases. Lastly, the speed at which writing, translating, editing and production have had to take place means that many inconsistencies remain to be ironed out, that some editorial decisions had to be taken rather arbitrarily, and that mistakes in presentation may have occured.

This draft is intended for discussion and comment, and all suggestions for its improvement would be gratefully received.

Simon Chater
Editor/translator
ILCA, August 1981

An administrative map of Mali



CONTENTS

SYSTEMS RESEARCH IN THE ARID ZONES OF MALI: INITIAL RESULTS

1. INTRODUCTION

1.1 BACKGROUND

This study summarizes 4 years of research carried out by the International Livestock Centre for Africa (ILCA) on livestock production systems in the arid zones of Mali. The ILCA research programme was launched in 1976, when a cooperative agreement was signed with the Institut d'Economie Rurale (IER) in Mali, by which ILCA was granted access to the facilities of the Station du Sahel in Niono and, in collaboration with IER, began to study the production systems in the area surrounded the station, the Fourth Region of Mali. Activities were later extended into the Fifth Region.

A major appraisal at the end of 1977 led to the start of an intensive phase with the object of a better description of the systems. The results of this phase are reported in ILCA (1978), which formed the basis for the research programme in the subsequent years.

The present report first sketches the importance of livestock and livestock production in the Sahel, and then briefly describes the prevailing livestock production systems in Mali. It goes on to give a short environmental description of the area in which ILCA is working, to provide a framework for the understanding of ILCA's work on specific production systems, which forms the main body of the report. A final chapter gives some general conclusions and outlines the direction of future research.

It should be made clear at the outset that the systems under study are complex, have evolved over centuries, and are in a very delicate state of balance in relation to their environment. Indeed, they seem to utilize the available resources reasonably well, given their present levels of technology and the constraints inherent in traditional system. Interventions in such systems could well have negative effects, as the rather disappointing results with development projects in the arid zones over the last 20 years have shown. In addition, any intervention will have only a gradual impact and, in the prevailing environment, no dramatic breakthrough in terms of increased productivity can be expected. ILCA has therefore devoted considerable time to the determination of biological and socio-economic parameters within the systems, in order to identify specific constraints and formulate interventions which may be effective over the longer term. It should also be noted that research has progressed further in some disciplines than in others, due in the early stages to staffing and administrative problems and, later, to budgetary restrictions.

Livestock productivity receives the main emphasis in this report, since by the terms of its mandate this is ILCA's major concern. However, a consistent attempt has also been made to place livestock production within the context of the social and biological environments in which it takes place, so that possible interventions can be assessed within the systems as a whole, under which they will be implemented.

1.2 LIVESTOCK PRODUCTION IN THE WEST AFRICAN SAHEL

As shown in Table 1, the Sahel proper (including Sudan) has a total estimated livestock population of over 33 million tropical livestock units (TLU). It contains over a quarter of the livestock population of tropical Africa (ILCA, 1981a), and is therefore an important region in terms of animal production. Over the last decade the Sahel, previously neglected, has been a focus of world attention, as the 1971-73 drought brought home the vulnerability of this area, and the pressing need to solve its many rural development problems. In many parts of the Sahel livestock are the only means of subsistence, since the extreme variability of the rainfall makes cropping very risky. Combining crop with animal production improves food security, and in some areas of the Sahel cropping would not be possible were it not for the presence of livestock, which cushion the periodic grain deficits caused by poor rainfall. Livestock in the Sahel therefore play a part which goes well beyond their mere numerical significance.

Table 1. *Distribution of ruminant livestock by species in the Sahel countries ('000).*

Species:	Camels		Cattle		Sheep		Goats		Total TLU
	Head	(TLU)[a/]	Head	(TLU)	Head	(TLU)	Head	(TLU)	
Country									
Senegal	4	(4)	2,806	(1,964)	1,884	(188)	1,000	(100)	(2,256)
Mali	208	(208)	4,459	(3,121)	6,067	(607)	5,757	(576)	(4,512)
Upper Volta	87	(87)	2,700	(1,890)	1,800	(180)	2,700	(270)	(2,427)
Niger	330	(330)	2,995	(2,096)	2,500	(250)	6,400	(640)	(3,316)
Chad	410	(410)	4,070	(2,849)	2,278	(228)	2,278	(228)	(3,715)
Sudan	2,500	(2,500)	17,300	(12,110)	17,200	(1,720)	12,200	(1,220)	(17,550)
Total head	3,539		34,330		31,729		30,335		(33,776)

[a/] TLUs calculated on the following basis: one camel = 1.0 TLU; one head of cattle = 0.7 TLU; one sheep or goat = 0.1 TLU.

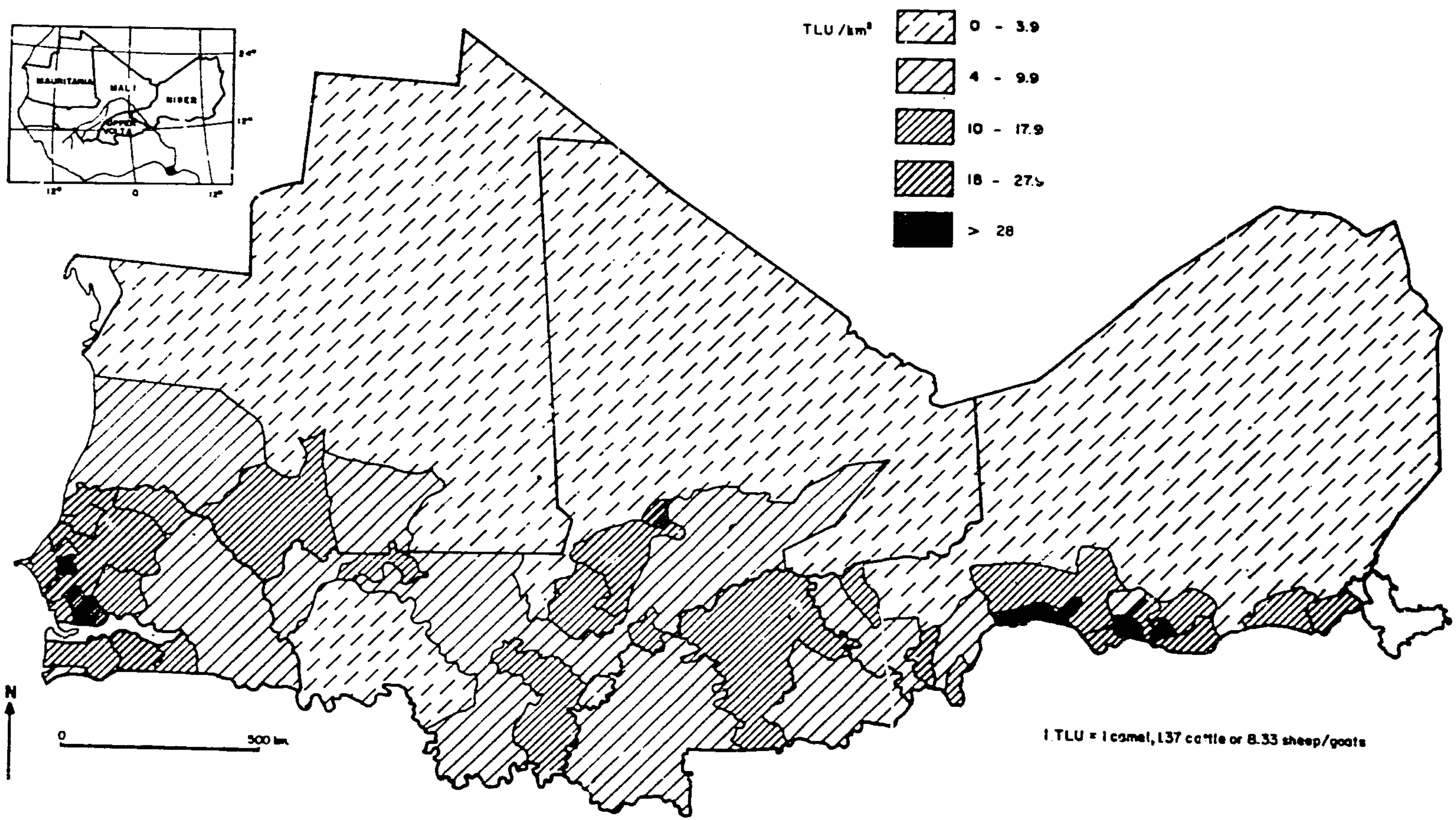
Source: FAO (1979) and ILCA (1981a).

Livestock distribution[1] in the West African Sahel shows a high degree of diversity. In some areas a clear correlation can be seen between areas of medium to high density of livestock and areas of high population density (Figures 1 and 2). This is the case in western and central Senegal and even more markedly in the intensive agricultural zone of southern Niger, where intense land pressure and shortage of fallow forces animals to move north during the cultivation season. However, this correlation does not occur in Mali and Upper Volta, where there is a relatively high density of animals in the western part of the delta, but low densities on the Dogon and Mossi plateaux, where farmers are too poor to invest in animals and do not use cattle for traction. A map of livestock per rural inhabitant (Figure 3) suggests the extent to which the rural population is dependent on pastoral activities, clearly indicating the importance of livestock in the north of the region, while the south generally has lower ratios, except in southern Niger and southern Senegal.

The important pastoral areas in Mali are found in the central and northern areas of the country, especially in the two administrative divisions of Nioro du Sahel and Nara, where pastures along the Mauritanian border are used by Moors, the northwest part of the Niger delta, where Fulani animals are grazed, and the Gourma-Rharous, Gao and Menaka divisions, which are part of the Tuareg pastoral zone. Other important pastoral areas are found in Niger, notably the Wodabe and Tuareg areas in the west and centre, and in the Dori region of northern Upper Volta, where both Fulani and Tuareg herds are found. The varying degrees of dependence on livestock throughout the West African Sahel made any choice of a production system or systems for detailed study difficult and, to some extent, arbitrary. In the end ILCA selected Mali for its Sahel programme because of its diversity of production systems, with their different degrees of dependence on livestock, and the relative availability of infrastructure. The following section provides an overview of livestock production and land use in Mali in greater detail.

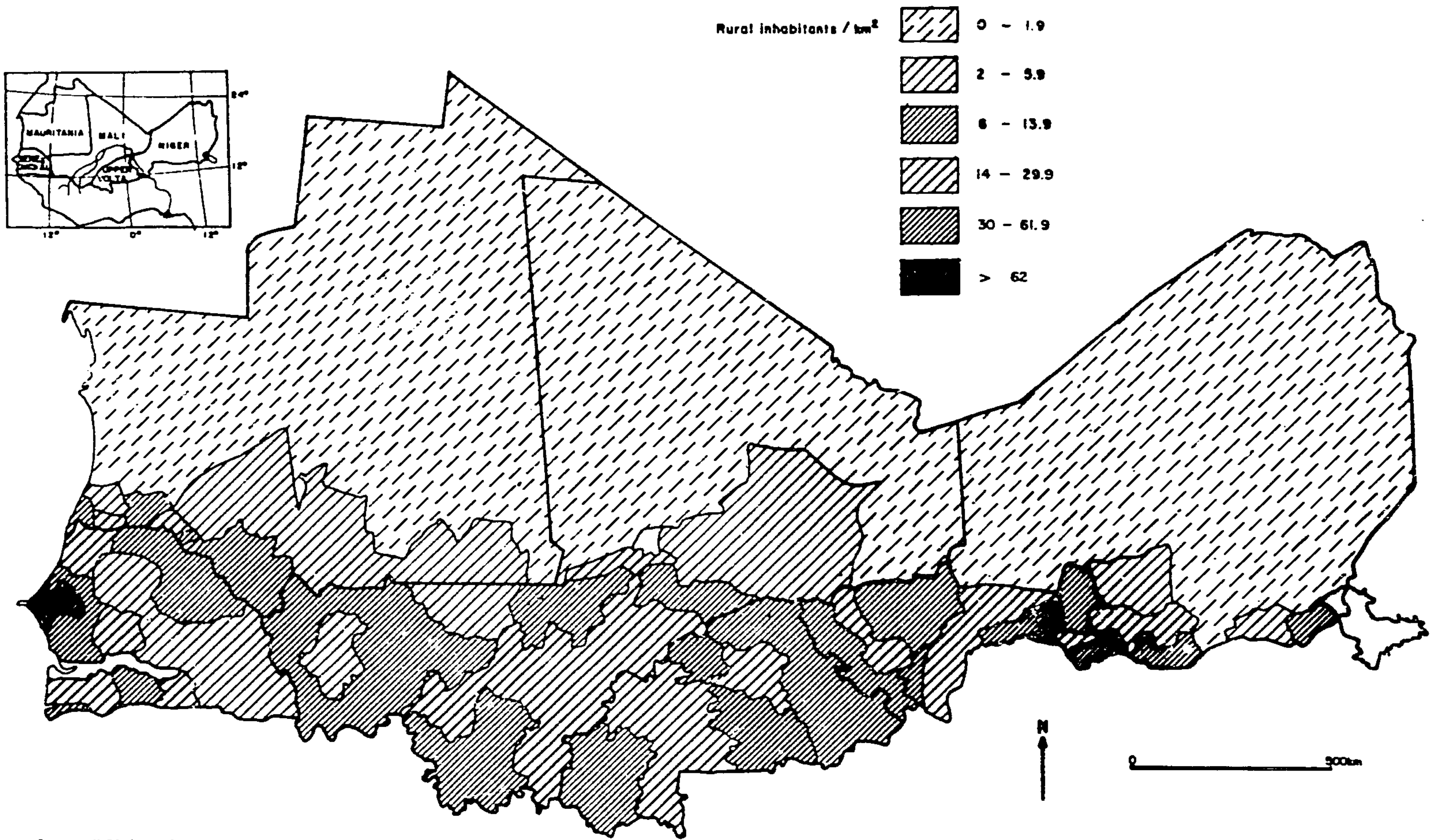
[1] This section is based on ILCA (1981b).

Figure 1. Livestock density in West African Sahel



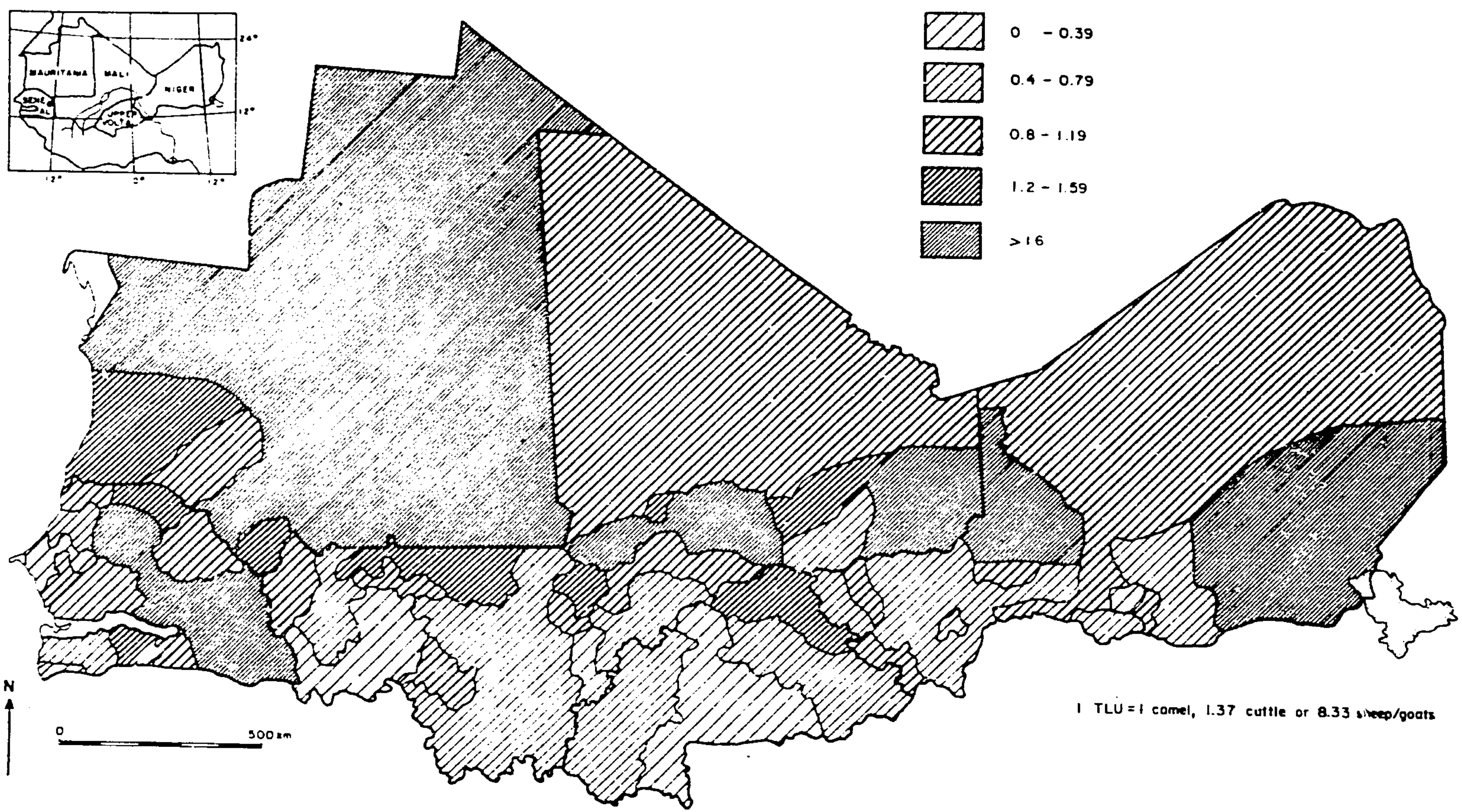
Source : ILCA (1981 b)

Figure 2. Rural population density in the West African Sahel



Source : ILCA (1981 b)

Figure 3 Tropical livestock units per rural inhabitant in the West African Sahel



Source: ILCA (1981 a)

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1.3 LIVESTOCK PRODUCTION IN MALI

1.3.1 Ecological zones

Crop and animal production systems in Mali are primarily influenced by rainfall[2/]. The mean annual rainfall isohyets for Mali and the main ecological zones delineated by them are shown in Figure 4. However, the area flooded annually by the Niger has its own characteristic vegetation and land use. On the basis of rainfall and annual flooding it is therefore possible to define four broad ecological zones:

The arid zone, associated with pastoral production, includes all land receiving less than 600 mm annual rainfall (400 mm with 80% probability), excluding the inner delta of the Niger. This zone includes two major belts. The first belt consists of those areas receiving less than 200 mm where cropping is not possible, while north of the 100 mm rainfall line, the vegetation becomes typically Saharan. In the second belt, often termed the Northern Sahel, where rainfall is usually between 200 and 400 mm, some rainfed agriculture is practised but is extremely risky, since the coefficient of rainfall variation is 25 to 35[3/]. Thus defined, the arid zone accounts for well over half the surface area of Mali.

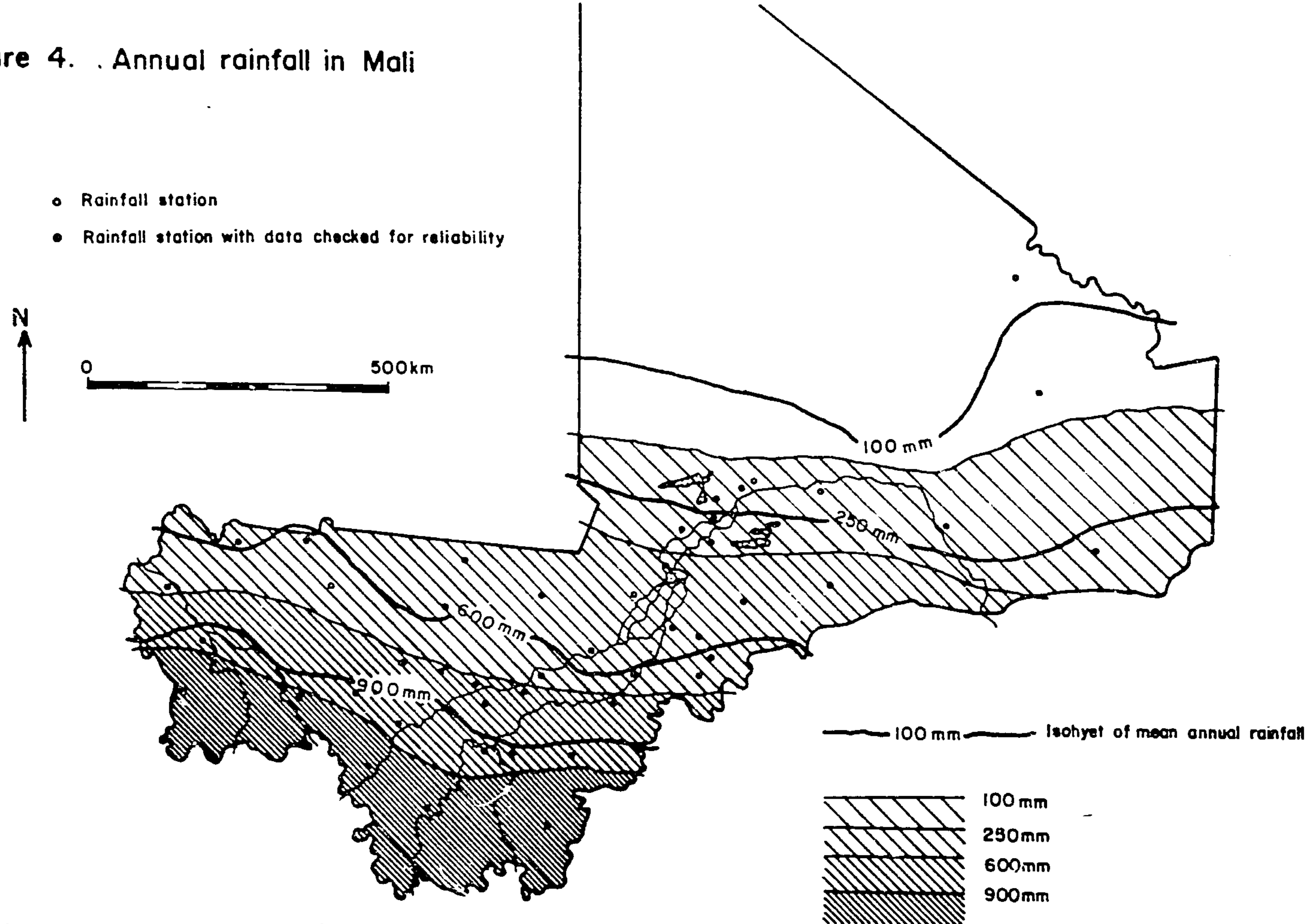
The semi-arid zone, associated with pastoral and low-potential rainfed crop production, is approximately located between the 600 and 1000 mm isohyets. It includes the southern Sahel and northern Sudanian vegetation zones, extending in a relatively narrow belt accross the southern half of the country. Rainfed millet is the main crop, being replaced by sorghum, groundnuts and cotton towards the South. The coefficient of rainfall variation is 20 to 25%.

The subhumid zone, associated with high-potential rainfed crop production, lies south of the 1000 mm rainfall isohyet, covering only the southern fringes of Mali.

2/ Details of climate associated with mean annual rainfall are described in Chapter 2.1.

3/ The coefficient of variation is the standard deviation divided by mean annual rainfall. Rainfall with 80% probability is that quantity of rain equalled or exceeded in 8 years out of 10.

Figure 4. . Annual rainfall in Mali



<u>Source</u>: Cartographie des Pays du Sahel, République Française, Ministère de la Coopération, (1976) (à partir des fichiers de l'ORSTOM)

This zone includes the central and southern Sudanian vegetation belts. The higher and more reliable rainfall permits rainfed cultivation of cotton, while sorghum and to lesser extent maize are the dominant food crops.

The inner delta of the Niger, associated with floodplain grasslands and some farming, forms a fourth zone where vegetation is strongly influenced by the annual flooding of the Niger. It includes the rich grasslands grazed by Fulani pastoralists, areas of traditional cropping, and also areas of rice cultivation under controlled irrigation by the Office du Niger.

1.3.2 Distribution of people and animals

Rural population densities in Mali were shown in Figure 2. The pattern shows three main areas. The first is a large area of very sparse settlement (under 6 people/km^2), roughly equivalent to the pastoral zone with its predominantly livestock-based economy (the "pure" pastoral production system described later), but also including the hilly area in the southwest of the country, which is heavily infested with tsetse fly. The second area has medium to dense settlement (over 14 people/km^2) and includes the Dogon Plateau and adjacent areas, Dire, a small, central district with an extensive irrigation potential resulting from the nearby course of the Niger, all the remaining irrigable areas of the inner Niger delta and the Office du Niger, and the intensive rainfed agricultural areas of southeast Mali together with the area around Bamako. The remainder of the country constitutes the third area, which has moderate settlement (6 to 14 people/km^2).

Figure 1 showed the density of livestock per km^2 in tropical livestock units (TLU). For Mali the pattern in this case indicates two main areas. The first has low animal density and lies in the two different parts of the country: a pastoral zone, where large tracts of land are unusable due to lack of water, and southwest Mali, where tsetse fly severely restricts livestock production: both parts correspond with areas of low human settlement (see above). The second area is one of high density found in the inner Niger delta, corresponding closely with the production system in which pastoralism is associated with irrigated cultivation (described later), and to a lesser extent in the intensive rainfed agricultural areas of southeast Mali.

Figure 3 showed the number of TLU per rural inhabitant, giving an impression of the dependence on livestock or livestock-based wealth in different parts of the West African Sahel. In the case of Mali the two highest density categories (i.e. more than 1.2 TLU/rural inhabitant) correspond closely with the northern pastoral zone and the inner delta of the Niger, in other words with the pure and floodplain-associated pastoral production systems. The area with the highest ratio is the Gourma-Rharous district in central Mali, with 4.4 TLU/rural inhabitant. Outside the northern pastoral and delta zones livestock numbers per rural inhabitant are much lower, especially in the sparsely inhabited southwestern areas.

If human and livestock densities are compared, it appears that the areas of high numbers of livestock per rural inhabitant are principally in the north and east of the country, whereas those with a high human population are mainly in the southeast. The two zones scarcely overlap at all, indicating the extent to which agriculture and pastoralism are still separate activities. The exceptions to this situation are the central Malian districts of Mopti, Macina, Dire and Nianfunke, all of which are in or near the Niger floodplain area and contain both agricultural and pastoral systems.

If livestock holdings per rural inhabitant for cattle and smallstock are considered separately, it emerges that the areas of high cattle density (Figure 5), containing an average of more than one head of cattle per rural inhabitant, occur in a belt along the southern edge of the pastoral zone: in the Nioro du Sahel and Nara districts along the Mauritanian border, in the inner Niger delta, in the Gourma-Rharous district south and in the Menaka district in the east. This pattern corresponds with the production systems in which pastoralism is associated with either dryland or floodplain cultivation, as well as with the southern fringe of the "pure" pastoral system.

The distribution of sheep and goats per rural inhabitant (Figure 6) is somewhat different. The three highest density categories, containing more than 2.2 sheep/goats per rural inhabitant, form a belt corresponding roughly with the pastoral zone and the "pure" pastoral production system. Sheep and goats have a more northerly and easterly distribution than cattle, with the highest densities lying in the Gourma-Rharous, Gao, Bourem and Menaka districts. They are much less important in the rest of Mali, especially in the south. With the exception of Macina wool sheep small ruminants are less numerous in most of the inner Niger delta, which is first and foremost a cattle zone.

Figure 5. Cattle per rural inhabitant in Mali

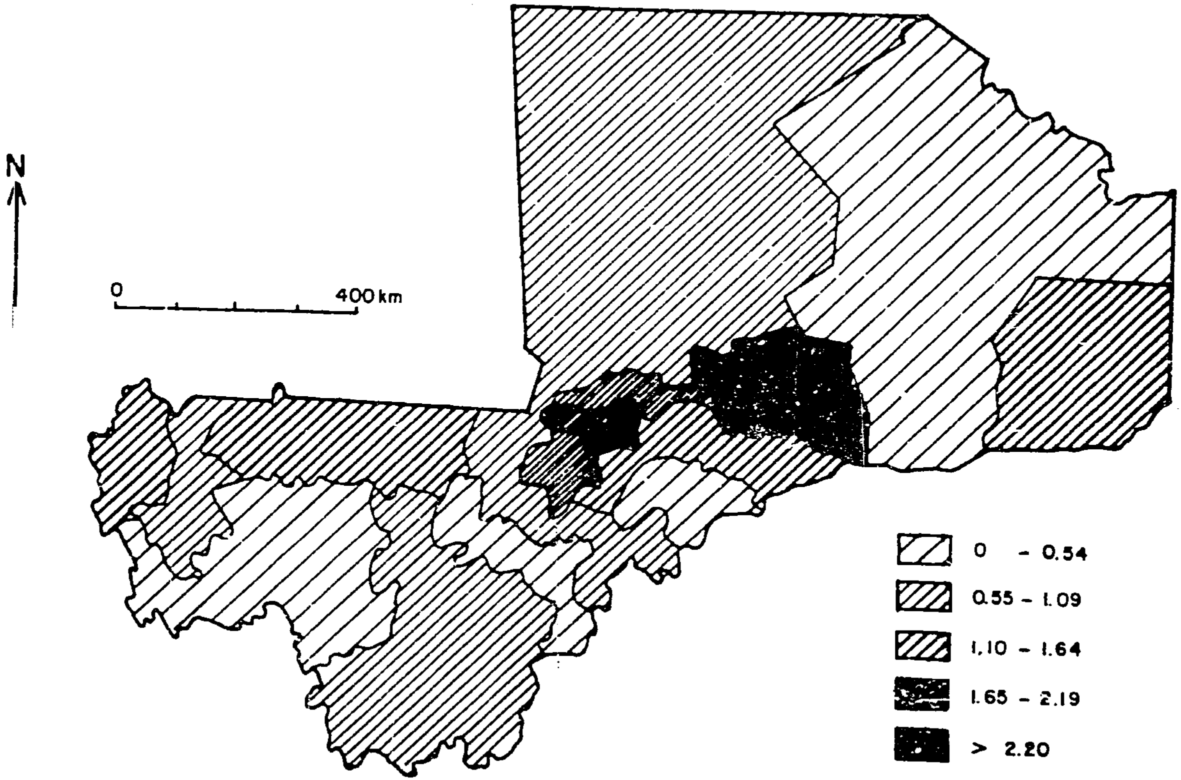


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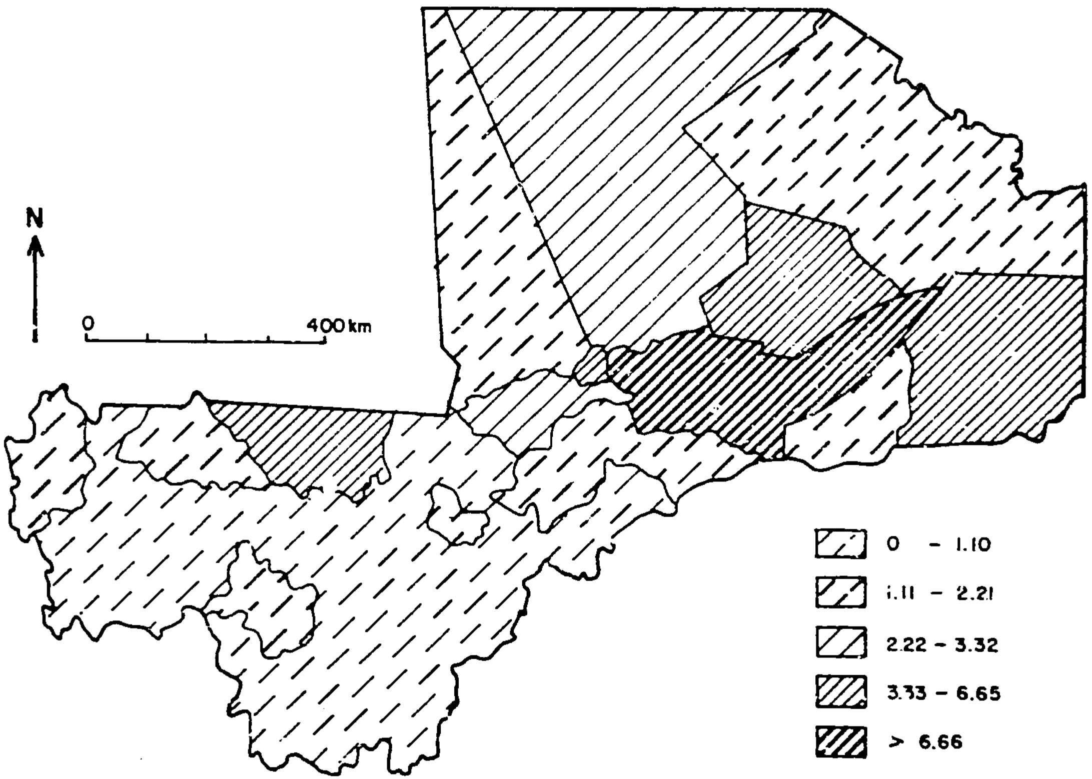
Figure 6. Sheep and goats per rural inhabitant in Mali



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These data make it possible to estimate the distribution of livestock by ecological zone in Mali. To do this, the administrative districts for which livestock census data were available were linked with one of the ecological zones delineated in Figure 4, and estimates were made on outstanding fractions belonging to another zone. Estimated in this way, the distribution of people and livestock by ecological zone in Mali is shown in Table 2.

Table 2. *Distribution of people and animals by ecological zone in Mali.*

	Area km^2	(%)	Rural population '000	(%)	Camels '000	(%)	Cattle '000	(%)	Sheep and goats '000	(%)	TLU[a/] '000	(%)
Arid zone	856	(70)	815	(15)	164	(91)	939	(21)	3596	(43)	1277	(28)
Semi-arid zone	191	(16)	2355	(43)	15	(8)	1468	(32)	2418	(25)	1380	(31)
Subhumid zone	129	(10)	1514	(27)	-		1009	(22)	790	(10)	832	(19)
Inner Niger delta	54	(4)	840	(15)	1	(1)	1114	(25)	1439	(18)	993	(22)
Total	1230	(100)	5522	(100)	180	(100)	4530	(100)	8293	(100)	4482	(100)

a/ 1 camel = 1.0 TLU; one head of cattle = 0.73 TLU; one goat or sheep = 0.1 2 TLU.

Mali's rural population is mainly concentrated in the semi-arid zone which, although it covers only 16% of the country, contains 43% of its inhabitants. The subhumid zone to the south contains just over one quarter of Mali's rural population, with the arid zone and the inner Niger delta containing another 15% each.

The arid or pastoral zone contains over 90% of Mali's camels and 43% of its sheep and goats, but only 21% of its cattle. However, it should be remembered that the cattle, sheep and goats from the inner delta of the Niger also use the rangeland of the pastoral zone for 6 months of the year, as do many cattle from the extensive rainfed agricultural areas further south. Conversely, animals from the pastoral zone use pastures and crop residues in agricultural areas after the harvest and until the following rainy season.

Table 2 highlights the importance of the semi-arid zone, which contains a third of Mali's cattle and nearly a third of its total TLU although it is far smaller in area than the arid zone.

1.3.3 Animal production systems

Two main criteria were used to define the animal production systems of Mali: the first was the degree of dependence on pastoral products for the gross revenue or food supply of the household or production units; the second was the various modes of agriculture associated with the livestock system.

Other criteria would also have been possible, one common one being the duration and distance of livestock movement. Although this may be an important aspect of an animal production system it is a contingent one, often having the effect of diverting attention away from the main factor, which is the degree of dependence on the animals raised.

Somewhat arbitrary limits were set when degree of dependence on livestock products was classified. A system in which more than 50% of gross revenue (the value of subsistence plus marketed production) or more than 20% of household food energy was directly derived from livestock or livestock-related activities was classified as a pastoral system. One which derived between 10 and 50% of gross revenue from livestock, in other words 50% or more from agriculture, was classed as an agropastoral system. A third system, in which less than 10% of revenue was derived from livestock, might have been classified as "agricultural", but lay outside the scope of this study. It should also be pointed out that the concept of gross revenue includes the theoretical value of camels or other species as transport animals, and the value of cattle for traction and manure production. An indication of the degree of dependence on livestock in different production systems in Mali and the West African Sahel given in Table 3.

The two main criteria thus gave rise to two major production systems, pastoral and agropastoral, each with a number of subsystems. These subsystems are shown in Table 4, in which the main characteristics of each are listed. Three pastoral subsystems were identified. The first was a 'pure', mainly camel-based system in the northern arid zone, with high mobility and almost no links with agriculture. The second, found in the northern central and northwestern semi-arid areas, was one in which animal production is associated with dryland cropping, with some cultivation and the exchange of manure for stubble grazing. Cattle, goats and sheep are the main species raised. In the third subsystem, specific to the inner delta of the Niger and its hinterland, animal production is linked with floodplain grazing and farming. Cropping is more important and cattle are the main

Table 3. *Dependence on livestock in different Sahelian production systems.*

	Percentage of gross revenue from livestock	Percentage of household food consumption (total kcals)			
		Milk	Meat	Cereals	Source and date
Pure pastoralism:					
Mali: NE Tuareg	99	68	8	24	(1) 1971
Niger: Tuareg	80	51	3	47	(1) 1963
Fulani	96	39	2	58	(1) 1963
Chad: Annakaza	-	48	-	24	(1) 1950
Pastoralism/rainfed cropping					
Upper Volta: Fulani	78	12	3	85	(2) 1977
Niger: Fulani	-	24	2	74	(4) 1963
Tuareg	-	33	2	65	(4) 1963
Tuareg	-	17	3	80	(3) 1976/7
Pastoralism/floodplain farming system					
Mali: Niger delta Fulani	57	25	-	75	(5) 1958
Agropastoralism					
Mali: SE of Segou	10	0,5[a]	0,8	95	(6) 1974/5
Upper Volta: Mossi	10				(2)

[a] Probably underestimated.

Sources: (1) Swift (1979a and b); (2) Delgado (1978); (3) Eddy (1979) but kcal values recalculated using 850 kcal/kg for milk and 1450 kcal/kg for meat; (4) Swift (1979a); (5) Swift (1979a) from Gallais (1967); (6) IER (1975).

species raised. Under agropastoralism a further three subsystems were again identified, in which mobility was very low, cropping was the major component, and the main species raised was cattle often used for draught. In the first of these, found in the central semi-arid regions, animal production is associated with the rainfed cropping of millet, mostly for subsistence. In the second, found in the dead delta of the Niger, livestock are raised by producers under contract with the Office du Niger irrigation scheme, and the main crop grown is rice. In the third subsystem, located in the southern subhumid zones, animal production is a minor component associated with both cash and subsistence cropping, millet, sorghum and groundnuts being the main crops.

A first approximation of the distribution of livestock over the different systems is also given in Table 4. It suggests that 30% of livestock in the semi-arid zone belong to the agropastoral system, with the remaining 70% belonging to the pastoral system associated with rainfed cropping. In the arid zone, 50% of the cattle and 70% of the small ruminants are raised under the pure pastoral system, while the remainder are associated with the rainfed millet system.

The relative importance of the domestic species found within the systems and subsystems varies considerably, the only exception being that of camels, which are confined almost exclusively to the pure pastoral subsystem in the arid zones, with only a few occurring in the pastoral/dry and cropping subsystem. However, even in the pastoral system, camels are numerically unimportant compared with cattle or sheep and goats. Because of their size and cash value, cattle are probably the most important animals in all the systems[4/], irrespective of whether their role is primarily milk production, as in the pastoral systems, draught power, as in the agropastoral systems, or a combination of these two roles plus meat production where systems boundaries are not clear cut. As Table 2 has shown already, in terms of TLU cattle dominate the livestock sector in Mali, although the numbers of both sheep and goats are probably considerably and consistently underestimated. Sheep are extremely important in the pastoral system, especially in the northern and delta areas, containing the pure and floodplain subsystems. In the latter, the wooled Macina variety dominates. In the agropastoral system, goats are much more important than sheep, at least at the level of the individual production unit. This fact is seldom acknowledged in statistics or development plans, and should therefore not be overlooked.

In the agropastoral system, and especially in the irrigation and cashcrop subsystems, work oxen are an extremely important element in the total livestock holding. Donkeys also play a large, if usually unpublicized, part in providing transport for agricultural produce and fuelwood. Horses are of minor importance in all systems, perhaps vested with the only remaining traces of the prestige once attributed to livestock owners.

[4/] Although, were an "urban" system to be added, donkeys might well replace cattle, to be followed closely by goats.

Table 4. *Major characteristics of livestock production systems in Mali.*

Characteristics	Pastoral: Pure	Pastoral: Associated with dryland cropping	Pastoral: Associated with floodplain grazing and farming	Agropastoral: Associated with rainfed millet cropping (mainly subsistence)	Agropastoral: Associated with irrigation	Agropastoral: Associated with rainfed cash/subsistence cropping
Contribution of pastoral production to gross revenue (%)	95	90	60	25	15	10
Location and ecological zone	Northern arid/semi-arid	Northern central and northwestern semi-arid	Niger floodplain and Senegal basin	Central semi-arid	Dead delta (central semi-arid)	Southern central semi-arid and southern subhumid
Rainfall (mm)	< 400	300-600	200 - (floodplain)	400-800	500 - (irrigation)	700-1400
Importance of agriculture	Nil to negligible	Low	Can be quite important	Considerable	Very important	Paramount
Linkages with agriculture	Very weak	Some cultivation, manure exchanged for stubble grazing	Cultivate or arrange for cultivation of own crops	Cultivate own crops; work oxen are important and consume crop residues		
Current densities (no./km^2)						
Human	0-1.9	2-5.9	14-29.9 (30-61.9)	2-13.9	14-29.9	6-29.9
TLU	0-3.9	4-17.9	10-27.9	4-9.9	10-17.9	4-17.9
Current carrying capacity						
Human	Very low	Low/medium	High/very high	Medium	High	Medium/high
Livestock	Low	Low/medium	Medium/high	Low/medium	Medium/high	Medium/high
Current TLU/rural inhabitant	0.8 - 1.6	0.4 - 1.59	1.2 - 1.59	0.461 - 19	(0.4 - 1.19)	0.4 - 0.79
Production unit	Nuclear family (often grouped in camps)	Nuclear or extended family	Nuclear or extended family (important non-agnetic ties)	Extended family		
Ethnic groups	Bella, Tuareg, Moor	Harratin, Bella, Tuareg, Moor	Delta Fulani Seno Fulani	Bambara, etc	Various, inclu ng former immigrants	Bambara, etc.
Hired labour	Very occasional	Fairly common	Common	Seasonally frequent, occasionally longer term		
Land tenure system	Tribal rights, often associated with access to water		Traditional rights; *leydi* in delta	Usufruct (often shifting cultivation)	Contract with Office du Niger	Usufruct (permanent or shifting cultivation)
Mobility	High, often irregular with no fixed base	High, usually more or less permanent with fixed base	High in wet season; precedence rights on stock routes and in delta; fixed base	Low, short distances during crop growing period permanent base		
Marketed production	Low (40%): barter of milk (and salt) for grains	Medium/high (50 or 60%): sale of purchase	Medium (45 or 50%): sale of animals and grain	Very low/medium (10/50%)	High (60%): rice	High (60%): cash crops
Importance in Mali (% of animals)						
Cattle	10	33	25		32	
Sheep and Goats	30	33	18		19	
Camels	92	8	-		6	
Importance in other Sahel countries						
Mauritania	High	Low	Low/medium	Low	Nil	Nil
Niger	High	High	Nil	Medium	Nil	High
Senegal	Low	Low	Low/medium	High	Low	Medium
Upper Volta	Low	Medium	Nil	High	Low	Medium/high

Source : Compiled by authors

Herds are built up by a variety of processes including inheritance, gifts, loan arrangements and natural increase. In the pure pastoral subsystem some animals may be purchased with the proceeds of caravan trading or with cash from wage labour, often earned outside Mali. In the pastoral/dryland cropping subsystem some agricultural profits may be re-invested in livestock, as they also are in the delta floodplain subsystem. In both the latter women can own considerable numbers of animals acquired by dowry and from the proceeds of milk sales. In the agropastoral system animals, particularly work oxen, are often acquired through credit facilities arranged with the relevant organization (Office du Niger).

Livestock also play a role in savings, the returns from agriculture being diverted to this end in the absence of alternative forms of investment. In fact there is considerable evidence that rapid changes in ownership are taking place, and not only among farmers. The new owners include civil servants, service personnel and merchants as well as agriculturalists, who are investing large amounts of cash in livestock. This tendency brings with it a rapid increase in the use of salaried herdsmen and the growing acquisition of grazing rights by non-pastoralists, a trend which may well be undesirable from the point of view of an equitable distribution of the country's resources. Integration within the market economy is also increasing, in some cases rapidly, although there is still a wide range of market involvement, from almost wholly subsistence-based production to cropping for cash alone.

1.4 THE ILCA FOCUS

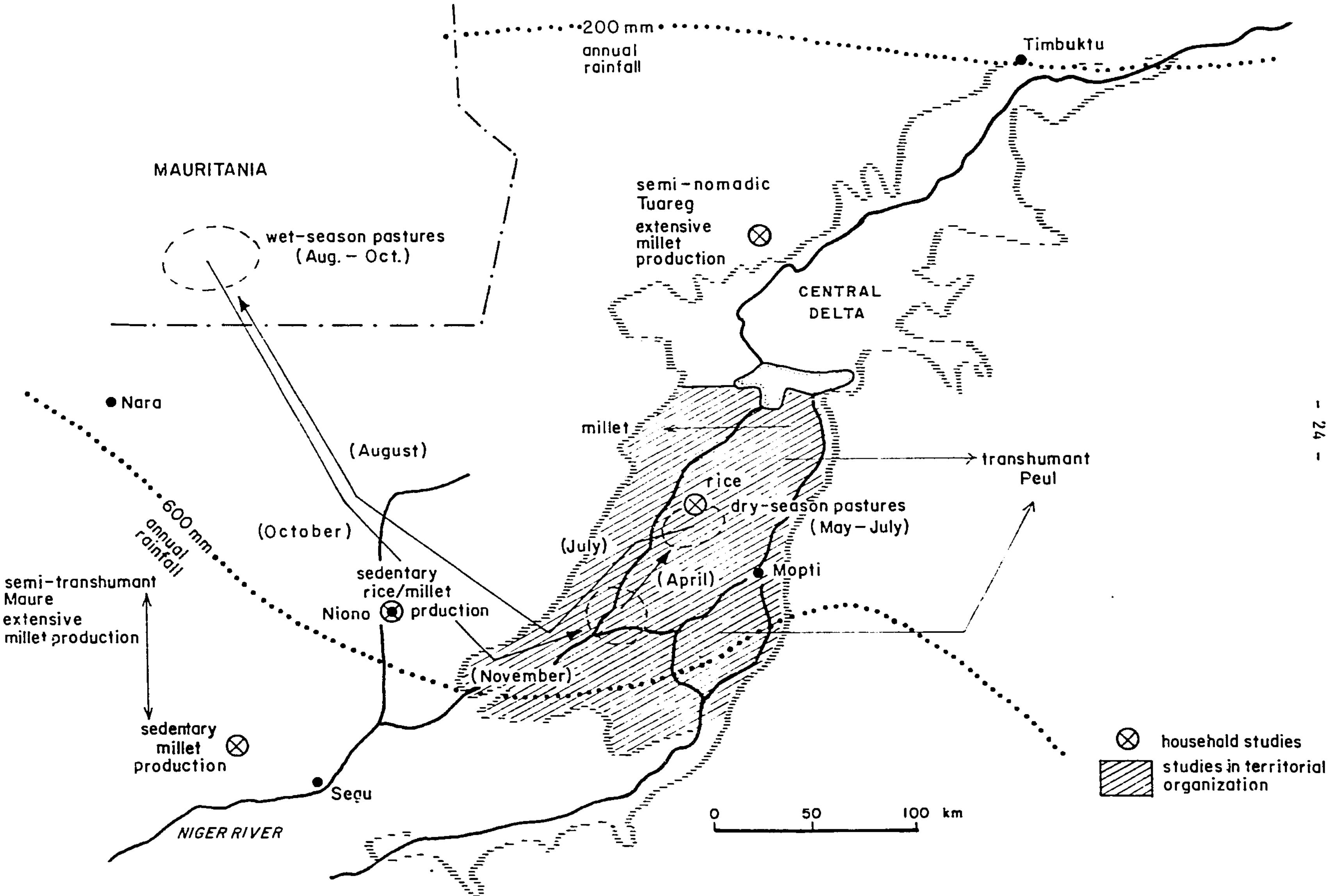
The 1978 intensive phase of the ILCA programme made it possible to assess the relative importance of the different production systems described above, and for logistical reasons it was decided that future attention would be concentrated on two of them: the agropastoral systems associated with rainfed millet cropping and the pastoral system associated with floodplain grazing and farming.

The millet agropastoral system was selected because of its importance throughout the Sahel, where it is one of the major systems because of the large human and livestock populations involved. In the early stages of ILCA's work in Mali some attention was also given to the agropastoral system associated with irrigation. However, once the main technical parameters had been established and the potential of a number of biological interventions demonstrated, the focus was shifted towards the agropastoral system associated with rainfed millet cultivation.

The floodplain system was chosen because of the relatively high chances of solving one of the most complex problems of pastoral systems in the Sahel, namely that of social-territorial organization. It was hoped that, once established, proper social-territorial organization and its associated institutions would provide a framework for introducing improved grazing and livestock management. Existing social-territorial structures in the Niger floodplain are much stronger than in the adjacent Sahel, serve as a basis for and could be used to develop a methodology for establishing new social-territorial units. Such a methodology could later be extended to other parts of the Sahel, where traditional forms are less well developed. The existence of a national livestock development project (the Office du Développement de l'Elevage de la région de Mopti, ODEM) interested in implementing findings in this field was a further advantage, because it seemed likely to lead to an early uptake. A further reason for choosing the floodplain system was that the inner delta of the Niger provides basic feed resources for a high proportion of Mali's livestock and human populations. Although not widespread in the Sahel, similar systems are found in Senegal, Mauritania and Sudan.

Thus, by early 1980, ILCA's main thrusts in the arid zones programme were in the agropastoral system associated with millet, and the pastoral system associated with floodplain grazing and farming. The centre of activities in the first system is Niono, with fieldwork in a number of villages and herds around the town and experimental work on the Station du Sahel. The second system is studied in the Mopti area of the Fifth Region, within the framework of ODEM which, through a special project agreement signed in October 1980, provides a considerable part of the funding (figure 7).

Figure 7. *The ILCA study area in Mali*

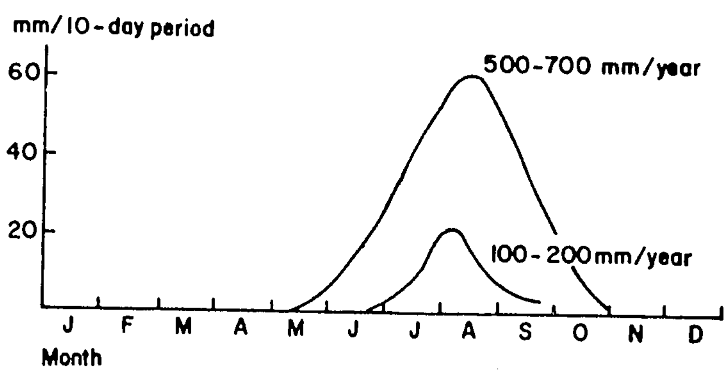


2. NATURAL RESOURCES

2.1 RAINFALL

The Sahel zone in West Africa is characterized by a single-peak monsoonal rainfall distribution with the 200 and 600 mm isohyets as its northern and southern limits (Figure 8). As illustrated in Table 5, the start and end of the rains as well as the duration of the growing season are positively correlated with the mean annual rainfall, while the reverse is true for potential evapotranspiration (Figure 9).

Figure 8 *Rainfall distribution per 10 day period for 2 Sahelian areas.*



Source: Davy et al (1976)

Table 5. *Water budget components of the Sahel region*

Mean annual rainfall (mm)	200	400	600
Effective rainfall (mm)	170	340	640
Start of rains[a/]	11/8	22/7	29/6
End of rains[b/]	13/9	21/9	28/9
Duration of rains (days)	32	60	90
End of growing season[c/]	21/9	4/10	16/10
Length of growing season (days)[c/]	40	75	105

a/ Start of rains is defined as the first 10-day period in which the amount of rainfall is equal to or greater than 25 mm but with a subsequent 10-day period in which the amount of rainfall is equal to at least half the evapotranspiration demand.

b/ End of rain is defined as the last 10-day period with at least 25 mm rain and with a rainfall in the previous 10-day period not less than the evapotranspiration.

c/ Growing season is defined as the number of 10-day periods in which evapotranspiration demands are met during the length of the rainy period plus the time to exhaust 100 mm of soil water (Kowal and Kassam, 1979).

Source: Compiled by author.

However, the average figures presented in Table 5 have limited value in the Sahel, because rainfall probability is low (Table 6), in particular for the early rains. This unreliability of rainfall distribution also affects prediction of the length of the growing season. Thus, Dancette and Hall (1979) put the limit at which the water requirements of 75-day millet will be satisfied with 80% probability at about the 450 mm isohyet, while Kowal and Kassam (1979) adopted the 580 mm line as that at which millet would grow safely 9 years out of 10.

For central Mali, Hiernaux (pers. communication) has tried to define the different phases of the rainy season, realising that the beginning of the growing season is not as easy to define as for the higher rainfall zones further south. Furthermore, the rainfall distribution during the early rains from late May to early August is of crucial importance in that it

Table 6. *Rainfall probability levels in Mali in relation to mean annual rainfall (MAR)*

MAR	Probability			
	20%	40%	60%	80%
200 mm	270	210	160	120
400 mm	500	420	360	290
600 mm	720	630	560	480

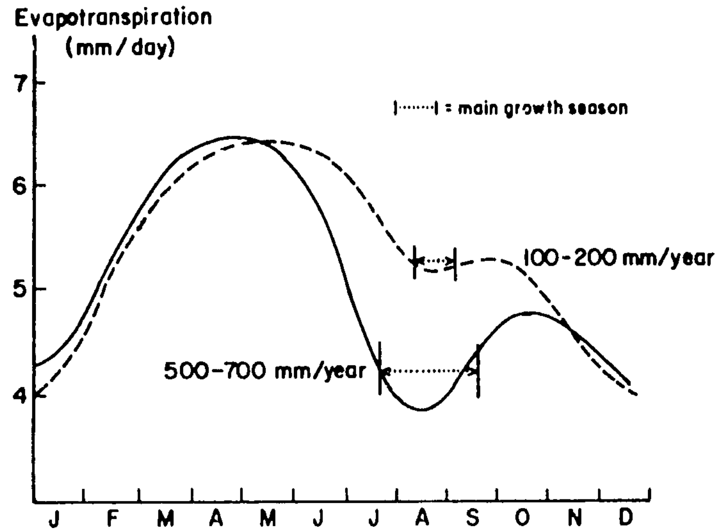
Source: Djiteye and de Vries (1980).

determines the germination and thereafter the seedling survival of the annual plants that dominate the natural vegetation. Therefore, before the effective start of the growing season, two preliminary rainfall periods can be distinguished. From early May there are often isolated showers that may trigger off germination waves of annual grasses, legumes and herbs and depending on subsequent showers the emerging seedlings either survive or die. The start to these rains (Figure 10) is defined as the first 5-day period with over 20 mm of rain. The same criterion also defines the end of the rains in September. Useful rains are those that guarantee the survival of seedlings and their continued growth and start when 20 mm/5 days has fallen followed by no further disastrous rainless spells. A positive soil water balance marks the beginning of the growing season and thus the period of uninterrupted regular plant growth. Figure 10 depicts the durations of these sequential rainfall periods for Central Mali between the 13 and 16 latitudes,

An example of inter-annual rainfall variation is shown in Figure 11. If the definitions for the beginning and end of the rainy season given by Kowal and Kassam (1979) are used, the durations of the rains for the 1977-1980 period on the Niono ranch were 40, 70 and 60 and 55 days respectively for each year within the period. Although the total annual rainfall between 15 June and 15 October for 1977-1980 was similar (375-380 mm), 1977 and 1980 were characterized by very erratic early rains and an abrubt stop between 10 and 13 September. In 1978 and 1979 the rains were better distributed but were very low during the growing season.

Estimates of the average useful rainfall are even less reliable, since the physical soil factors determining infiltration, run-off rates and moisture storage capacity add further to the unpredictibility of the moisture available for plant growth. Much rain is lost for plant growth, firstly

Figure 9. *Potential evapotranspiration for two Sahelian area*



Source: Penman, in Cocheme and Franquin (1967).

Figure 10. *Relationship between mean annual rainfall (MAR), latitude and characteristics of the rainy season in Central Mali*

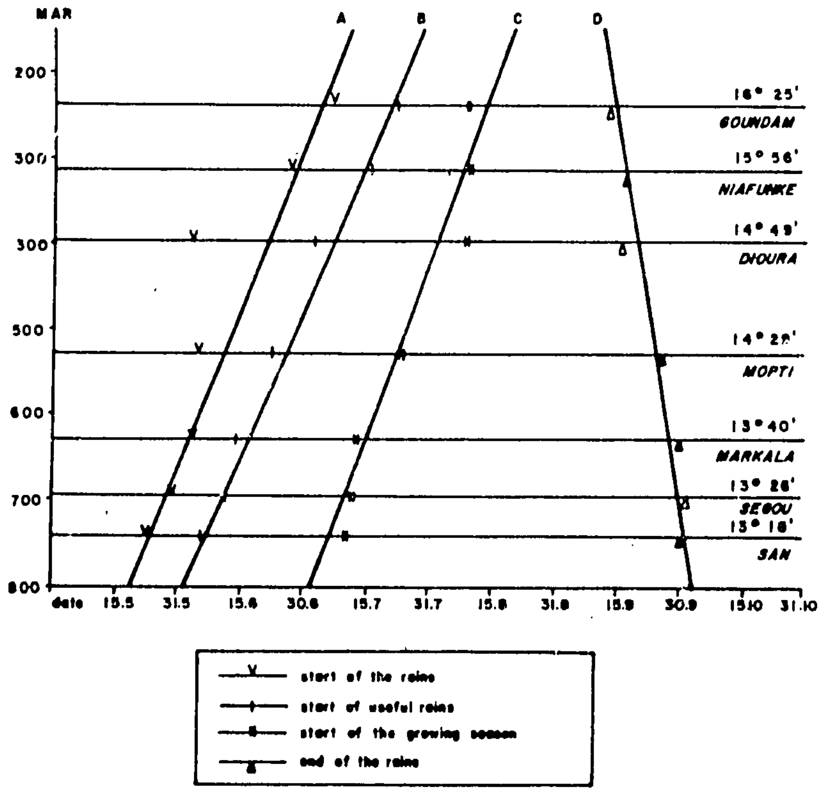
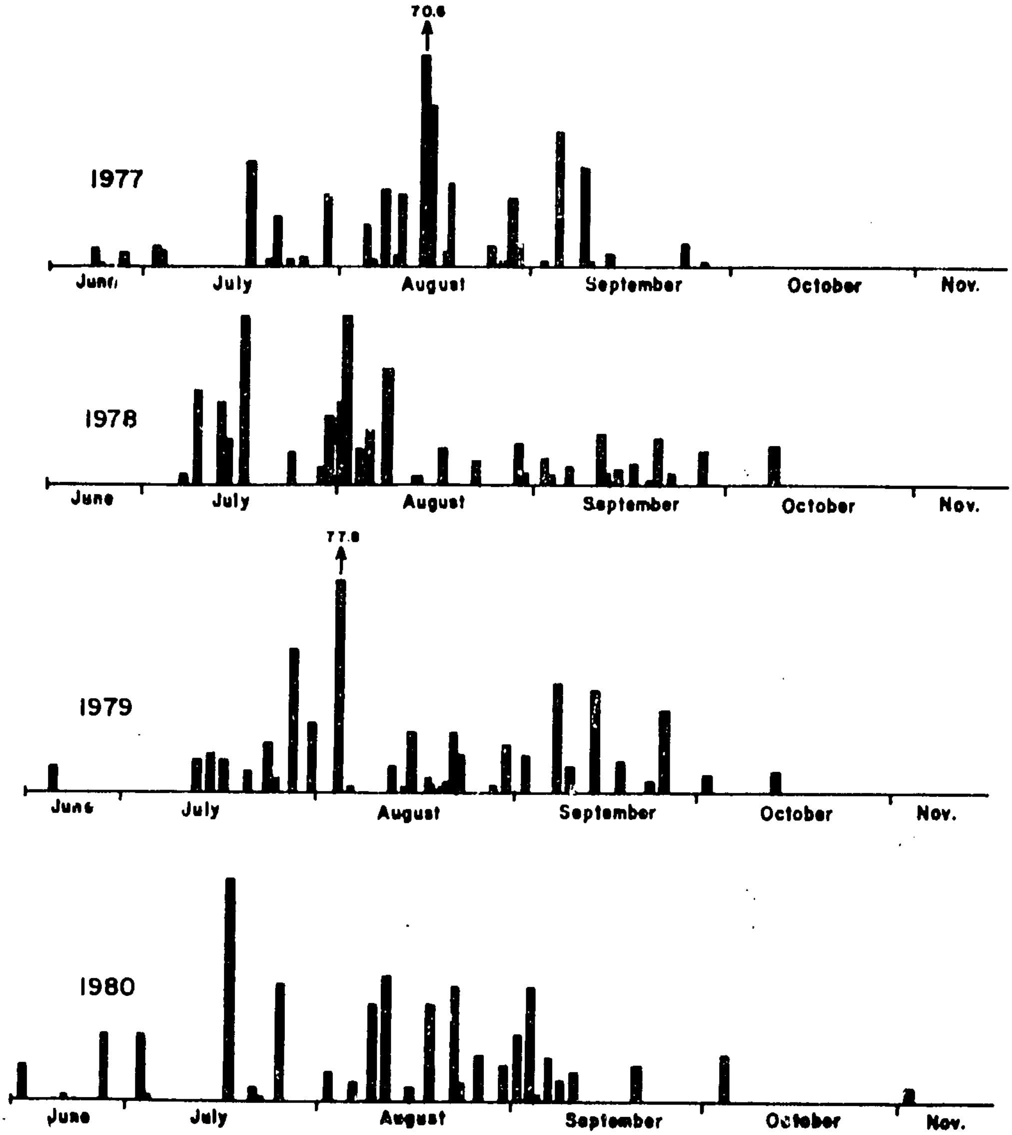


Figure 11, *Average daily rainfall for 1976-1979 at the station du Sahel.*



because of high evaporative demand (Figure 9) but secondly because of the concentrated nature of precipitation. For instance, on the Niono ranch during the 1976-1979 period, 51% of the rain fell in storms of 20 mm or more, with rainfall intensities of over 28 mm/hour (Table 7).

Table 7. *Shower size distribution as a percentage of total annual rainfall on the Niono ranch*

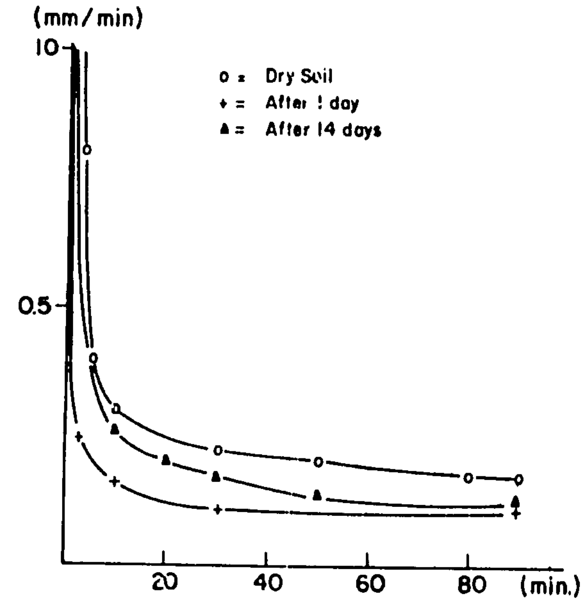
	Shower size		
	0-5 mm	5-20 mm	> 20 mm
1976 (%)	5	32	62
1977 (%)	8	40	52
1978 (%)	10	50	40
1979 (%)	6	46	49
Mean	7	43	51

Source: Djiteye and de Vries (1980).

These heavy showers cause considerable run-off, estimated to range from 26 to 37% (Stroosnijder and Hoogmoed, 1980), for the larger storms of 20-30 mm. De Ridder (1980), in his water budget calculations for Niono rangeland, adopted an average run-off rate of 40%. The high run-off rate is due not so much to relief but rather to the texture of the soil surface horizon, which has a poorly sorted particle size distribution that is susceptible to severe crust formation. These crusts affect water infiltration, which is initially high, but once the crust has been soaked it stabilizes at a constant low rate of 0.2-0.3 mm/minute within 20 minutes of the start of the rain (Figure 12).

However, the presence of catenary sequences in many Sahelian landscapes containing soils of variable infiltration capacity adds to the diversity of the environment. It is mainly on habitats with run-on that tree and shrub densities are greatest and pockets of perennial grasses are found. It is also on these sites that temporary water holes develop during the rainy season, upon which exploitation by livestock depends.

Figure 12. *Infiltration rate of a fine sandy dune soil wetted once or twice.*



Source: Djiteye and de Vries (1980).

2.2 PHYSIOGRAPHY OF THE AREA

The ILCA study area in Mali lies mostly in the fourth and fifth regions of the country and covers about 160,000 km^2. It forms neither a natural nor a historical or administrative entity, nor is it the domain of a particular pastoral or agropastoral production system. Instead, it includes a variety of natural areas, the features and patterns of which allow the development of a wide range of agricultural and pastoral production systems, and the agropastoral systems which interact with them. On a regional basis, temporary submersion by the flood waters of the River Niger and its tributary the Bani is the major determining ecological factor as regards the nature, biology and productivity of grazing land. These floods, although occuring irregularly, distinguish two main components: the inner delta of the Niger subject to flooding, and the upland Sahel or continental pediplain, beyond the reach of the flood. Flooding in the past has also influenced a third area, known as the dead delta, which forms a distinct unit within the upland Sahel because of its geomorphology, vegetation and human settlement patterns.

The study areas thus includes three major natural areas (see Figure 13):

1. The continental pediplain or upland Sahel, sweeping through the study area in an arc from the southwest to the northwest of the delta zone
2. The dead delta, consisting of the former floodplains of the Niger and Bani rivers, west of the present live delta
3. The live delta, consisting of the present floodplains of the Niger and Bani rivers.

2.2.1 The continental pediplain

The continental pediplain consists mainly of sandstone overlying paleozoic schists which outcrop only in the far northwest and northeast of the study area, in the Mema basin and the lacustrine area. Although the sandstone confers a degree of homogeneity on the landscape, it outcrops only rarely, and is usually covered by a thick surface cover. The latter result from one or a combination of several erosion phases that occured in succession during the tertiary and quaternary areas:

(a) a phase of intense and prolonged erosion, giving rise to gentle overall relief and the considerable amount of detritus beds;
(b) a ferralitic phase, the remains of which are a series of shelved pediments which are increasingly well preserved from north to south;
(c) an aeolian phase, which has sculptured the surface sand cover into dunes which are now fixed, their orientation and shape varying according to the time at which they were formed.

Although the climate is universally characterized by a sharply contrasted short summer rainy season and a long dry season, a bioclimatic gradient is found running more or less from north to south of the pediplain. The gradient follows the increase in overall average annual rainfall from 300 mm/year to 800 mm/year and has a sharp impact on vegetation.

2.2.2 The dead delta

The dead delta consists of plains of alluvial origin, intermittently covered by a sandy film or mantle, with a few scattered hillocks or winding depressions indicating the pattern of runoff. However, over and above their common alluvial origin, formations differ locally, consisting of:

(a) alluvial formations hidden by a sandy cover in the Sanarí and on the ancient alluvial surface;
(b) more recent alluvial formations, alternating between low clay plains and loamy elevations, with highly eroded remains of steep alluvial slopes and embankments in the Falla plains and the plains of the left bank of the Bani
(c) alluvial formation modified by a more recent lacustrine phase, with vast flat plains having soils which are generally very heavy, as in the Mema and upper Farimakē.

The bioclimatic gradient of the dead delta is identical to that of the continental pediplain, but understanding the progressive changes in the vegetation is more difficult since the bioclimatic zonation is disrupted by local geomorphological features associated with the age and structure of the surface alluvial deposits.

2.2.3 The live delta

In the live delta the bioclimatic gradient is almost entirely replaced by the influence of the annual flooding of the Niger and its tributaries. The main parameters of this yearly flood determine the flora, productivity and phenology of the rangeland and are as follows:

(a) the maximum height reached by the flood water;
(b) duration of submersion;
(c) initial date of submersion and the time lag between the start of the rainy season and the beginning of submersion;
(d) date of end of submersion;
(e) the rate at which the flood waters rise and fall.

Each of these parameters has specific impact through its average or extreme values and their interannual regularity, as well as an interaction with the others. The values are linked with the geographical situation, in other words altitude, but also position along the course of the river,

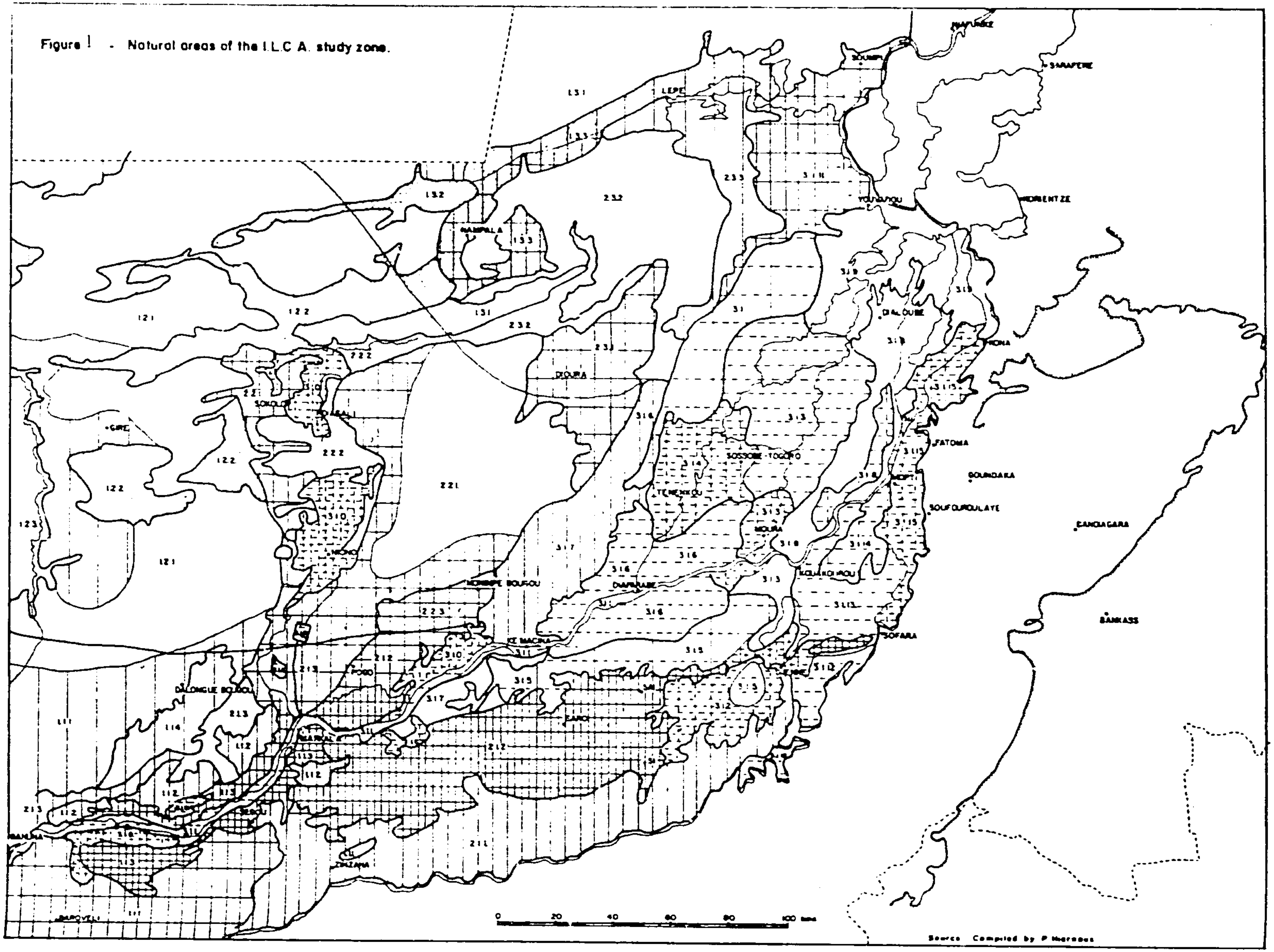


Figure 1 - Natural areas of the I.L.C.A. study zone.

Legend to Figure 13

A. Landscape units and ecological sectors

1.	The continental pediplain
1.1	Northern Sudanian sector
1.1.1	Ferruginous pediplain overlying sandstone basement
1.1.2	High terraces of the Niger
1.1.3	Middle terraces of the Niger
1.1.4	Fossil erg of Dalonguebougou
1.2/1.3	Southern and central Sahelian sectors
1.2.1/1.3.1	Ferruginous pediplain overlying sandstone basement
1.2.2/1.3.2	Fossil ergs of Ougadou
1.2.3	Vallée du Serpent
1.3.3	Nampalari sandy plain
2.	The dead delta
2.1	Northern Sudanian sector
2.1.1	Alluvial fossil plains
2.1.2	Alluvial fossil plains of Sanari and Pogo
2.1.3	Fossil alluvial plains of the Falla
2.2/2.3	Southern (2.2) and central Sahelian (2.3) sectors
2.2.1/2.3.1	Ancient alluvial plain
2.2.2/2.3.2	Lowland plains of the Falla de Sokolo and the Mema
2.2.3/2.3.3	Sandy fringes of delta/high Farimake
3.	The river delta and irrigated perimeters
3.1	The live delta
3.1.1	Stream bed of R. Niger
3.1.2	Yongari and Pondori basins
3.1.3	Central basins
3.1.4	Diaka plains of Macina
3.1.5	Drowned erg of Samaye
3.1.6	Upland plains of Diafarabé
3.1.7	Peripheral plains of Toguéré and Sanari
3.1.8	Former levees of Peroudii, Kaimankou and Dialloube
3.1.9	Debo-Walado basin and lake
3.1.10	Wuro Ndia plains
3.1.11	The Farimaké plains
3.1.12	Bani plains
3.1.13	Upland plains of Soye
3.1.14	Lowland plains of Bani-Niger confluence
3.1.15	East bank plains
3.1.0	Irrigation Schemes

B. Land Use

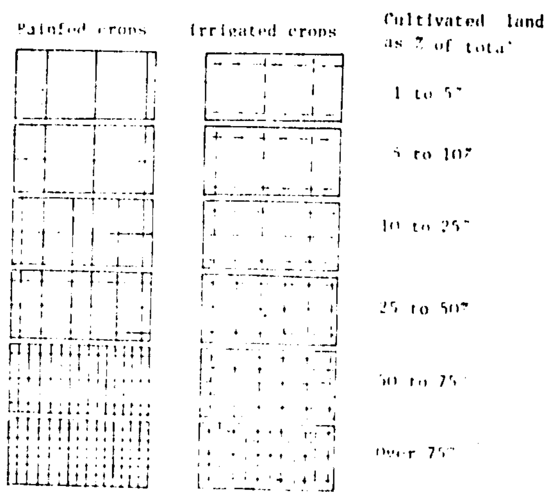
1. Dominant crop

millet

sorghum

Rice or Sugarcane

2. Area of land under cultivation



distance from the river or its various branches, and local relief. These factors give rise to local peculiarities in the flood pattern, which in turn result in characteristic combinations of grazing features. The live delta may thus be subdivided into 16 ecological sectors, the main features of which are summarized in Table 8 as a function of flood regime.

2.3 LIVESTOCK RESOURCES

2.3.1 Seasonal livestock distribution in the delta and its fringes

Introduction

The objectives of the aerial surveys undertaken in this area were to estimate the overall livestock population, herd and flock sizes and seasonal distribution and relate the latter to the natural environment of the zone, its grazing resources and agricultural land use.

Up to date three surveys have been completed. The first, in February 1980, covered an area of about 28,000 km^2. For the second and third surveys the survey area was widened westwards and eastwards and encompassed about 37,000 km^2. The second was carried out in October 1980 and the third during March 1981.

The frequency and time-frame selected for the surveys are believed to provide an adequate basis for evaluating seasonal fluctuations in animal populations and will assist in assessing the resource utilization strategies of transhuman pastoralists.

The three periods cover:

(a) October - November : return of most herds from their wet-season grazing areas, followed by concentration in the transitional zone;

(b) February - March : height of the delta grazing season, with maximum spatial dispersion of herds;

(c) June - July : contraction of herds in the delta and start of transhumance to upland Sahel.

The methodology for the three surveys was basically the same except that, during the first, data collection was restricted to animal counts. Systematic sampling of ecological and land-use parameters was added only during the second survey. The methodology used is described in Milligan and Keita (1981).

Table 8. *Ecological zones of the delta and their* ***major characteristics*** *as a function of flood regime*

Zone and no. in Figure 11	Aerial Survey Unit no.	Depth of flood (m)						Duration of flood (months)						Regularity of flooding					Date on which waters rise			Speed at which waters rise					Dominant geomorpholog formations
		N F [a]	0.1 0.3	0.3 0.6	0.6 1.5	1.5 2.8	>2.8	N F [a]	<1	2-3	4-5	6-7	>7	N F [a]	VI [b]	I [c]	R [d]	VR [e]	Jul-Aug	Sept-Oct	Nov-Dec	N F [a]	S [f]	St [g]	F [h]	VF [i]	
Main bed of Niger 3.1.1	-	+	+	+	+	++	+++	+	+	+	+	++	+++				++	+++	+++						+	+++	Minor beds; alluvial levees channels; point bars system
Pondori basin 3.1.2	17		+	++	++	+			+	+	++	+				+	+		+++				+	++	+		Floodplain with drainage basins
Central basins 3.1.3	18		+	++	+++	+			+	++	+++	+					++		++	++			+	++	+		Floodplain with drainage 1 and channels
Macina 3.1.4	14	+	++	+++	++	+		+	+	+++	++	+			+	++	+		++	+			+	++	+		Floodplain with sandy *toguè*
Drowned erg of Samaye 3.1.5	6	++	+++	+	+			+	++	+	+	+		+	++	+			+	++		+	+	++			Alluvial surface masked by dune formation eroded by fl
Upland plains of Diafarabé 3.1.6	12	++	+++	+	+			+	++	+	+			+	++	+			+	++		+	++	+			Alluvial plain with fossil channels
Peripheral plains with *toguérés* and Samari 3.1.7	9,6,8	+++	++	+				+++	++	+				+++	++	+				+			+				Alluvial plains criss-cross fossil levees and dunes
Former levees of the Peroudji, etc 3.1.8	11	+++	+	+				+++	+	+				++	+					+			+				Fossil alluvial plains and levees
Debo-Walado lakeland basin 3.1.9	19,16				+	++	+++			+	++	+++	+++					+++	++	++				++	++	+	Lacustrine alluvial plains levees and mounds
Wuro Ndia plains 3.1.10	7,13	+	+	++	+++	+		+		+	++	+			+	++	+			+	++		++	+			Mixed floodplains: delta an lacustrine; with *toguérés*
Farimaké plains 3.1.11	7	+++	+	+	+	+		+++		+	+	++	+	+++	+++	+					+++	++	++	+			Eroded erg intersected with lacustrine plains
Bani plains 3.1.12	10	++	++	+	+			++	++	+	+			++	+	++			+			+		+	++	+	Floodplain with channels
Upland Soye plains 3.1.13	10	++	++	++	+	+		++	++	++	+	+		++		+	+		++	+		++	+	++	+		Floodplain with fossil leve Femaye dune
Lowland plains of Bani-Niger Confluence 3.1.14	15			+	++	+++	++			+	++	+++	+			+	++	+	++	+				+	++	+	Drainage channels, point b levels.
East bank plains 3.1.15	15	+	++	+++	++	+		+		+	++	++		+		++	+		-	++	+	+	+	++	+		Floodplain
Rice and Sugar cropping perimeters 3.2	-	+	+	+++	+			+		+	+++	+	+	+	+++				++					+	+++	+	Rice plots

ological zones of the delta and their major characteristics as a function of flood regime

	Aerial Survey Unit no.	Depth of flood (m) N F[a]	0.1 0.3	0.3 0.6	0.6 1.5	1.5 2.8	>2.8	Duration of flood (months) N F[a]	<1	2-3	4-5	6-7	>7	Regularity of flooding N F[a]	VI[b]	I[c]	R[d]	VR[e]	Date on which waters rise Jul-Aug	Sept-Oct	Nov-Dec	Speed at which waters rise N F[a]	S[f]	St[g]	F[h]	VF[i]	Dominant geomorphological formations	Dominant plant species
	-	+	+	+	+	++	+++	+	+	+	+	++	+++				++	+++	+++						+	+++	Minor beds; alluvial levees and channels; point bars systems	Highly varied mosaic
	17		+	++	++	+			+	+	++	+				+	+		+++				+	++	+		Floodplain with drainage basins	*Oriza longistaminata*; *Vetiveria* ; cultivated rice
	18		+	++	+++	+			+	++	+++	+					++		++	++			-	++	+		Floodplain with drainage lines and channels	*Oriza longistaminata*; *Echinochloa stagnina*
	14	+	++	+++	++	+		+	+	+++	++	+			+	++	+		++	+			+	++	+		Floodplain with sandy *toguérés*	*Oriza longistaminata*; *Vetiveria nigritiana*; cultivated rice
	6	++	+++	+	+			+	++	+	+	+		+	++	+			+	++		+	+	++			Alluvial surface masked by a dune formation eroded by flooding	*Vetiveria* ; *Andropogon gayanus*; *Hyparthelia dissoluta*. *Hyparrhenia rufa*
	12	++	+++	+	+			+	++	+	+			+	++	+			+	++		+	++				Alluvial plain with fossil effluent channels	*Vetiveria* ; *Andropogon gayanus*; *A. Canaliculatus*; *Eragrostis barteri*
amari 3.1.7	9,6,8	+++	++	+				+++	++	+				+++	++	+				+			+				Alluvial plains criss-crossed with fossil levees and dunes	*Panicum anabaptistum*; *Vetiveria nigritiana*; *Hyphaene thebaica*
.1.8	11	+++	+	+				+++	+	+				+++	+					+			+				Fossil alluvial plains and levees	*Acacia sieberiana*; *A. nilotica*; *Dyospyros mespiliformis*; *Mitragyna* spp; *Piliostigma reticulata*
9	19,16				+	++	+++			+	++	+++	+++					+++	++	++				++	++	+	Lacustrine alluvial plains with levees and mounds	*Echinochloa stagnina*; *Oriza Longistaminata*
	7,13	+	+	++	+++	+		+		-	++	+			+	++	+			+	++		++	+			Mixed floodplains: delta and lacustrine; with *toguérés*	*Eragrostis barteri*; *Oriza longistaminata*; *Vetiveria nigritiana*; *Panicum anabaptistum*
	7	+++	+	+	+	+		+++		+	+	++	+	+++	+++	+					+++	++	++	+			Eroded erg intersected with channels; lacustrine plains	*Acacia nilotica*; *A. seyal*; *Diospyros mespiliformis*; *Sporobolus helvolus*
	10	++	++	+	+			++	++	+	+			++	+	++			-			+		+	++	+	Floodplain with channels	*Vetiveria* ; *Oriza longistaminata*; *Panicum anabaptistum*; rice
	10	++	++	++	+	+		++	++	++	+	+		++		+	+		-+	+		++	+	++	+		Floodplain with fossil levees; Femaye dune	*Vetiveria* ; *Hyparrhenia rufa*; *Oriza longistaminata*; *Andropogon gayanus*. rice
ani-Niger	15			+	++	+++	++			+	++	+++	+			+	++	+	-+	+				+	++	+	Drainage channels, point bar systems, levels.	*Echinochloa stagnina*; *Oriza longistaminata*
	15	+	++	+++	++	+		+		+	++	++		+		++	+		-	++	+	+	+	++	+		Floodplain	*Oriza longistaminata*; *Vetiveria nigritiana*; rice
3.2	-	+	+	+++	+			+		+	+++	•	+	+	+++				-++					+	+++	+	Rice plots	Rice; Sugar cane

b/ VI: very irregular; c/ I: irregular; d/ R: regular; e/ VR: very regular; f/ S. slow; g/ St: steady;
very fast.
igns denotes degrees of relative frequency.

Landscape units and land use

To provide a consistent basis for data comparison, in particular of seasonal livestock populations, it was believed useful to subdivide the delta and its surroundings into 19 landscape units. These units are principally based on geomorphological criteria, since these in turn govern the level and the duration of flooding, the distribution of vegetation types, land use and settlement patterns.

Because farming activities are likely to exert a profoundly modifying influence on the utilization of grazing resources, a second level of subdivision has been introduced based on the proportion of land under cultivation and recent fallow of rice, rainfed crops or both.

To arrive at a satisfactory partitioning into units, several sources of information were used in addition to the ecological and land-use data collected during the aerial surveys. These sources were:

(a) published information (Gallais, 1967; Boudet, 1970; Haywood, ILCA: 1980);
(b) a preliminary interpretation of the 1952, 1971 and 1975 aerial photographs, as well as LANDSAT imagery;
(c) data from several reconnaissance vegetation surveys done by ILCA ecologists during 1976-1980 (Hiernaux et al, 1977-79).

The units range in size from 1100 to 3200 km^2 and their geographical locations are shown in Figure 14, while percentages of farming and flooded/and for groups of units are listed in Table 9 and illustrated in Figure 15. This data indicates that about half the survey area can be termed upland Sahel with little or no flooding and is cultivated to rainfed crops with varying degrees of density[1/]. On the western fringe, farming is highest in the Mema Jura (unit 2), to the east of Mopti (unit 4) and in the Sanari plains along the southern fringes of the area (unit 6).

1/ The proportions of flooding and farming are based on estimates from the October 1980 survey. In this year flood-retreat was very rapid and it appears that the levels recorded in October 1980 would usually occur in January. Thus, the degree of flooding shown in Figure 15 may provide an indication of the average availability of grazing land at the start of the delta grazing season.

Figure 14. *Landscape units in the delta and its fringes*

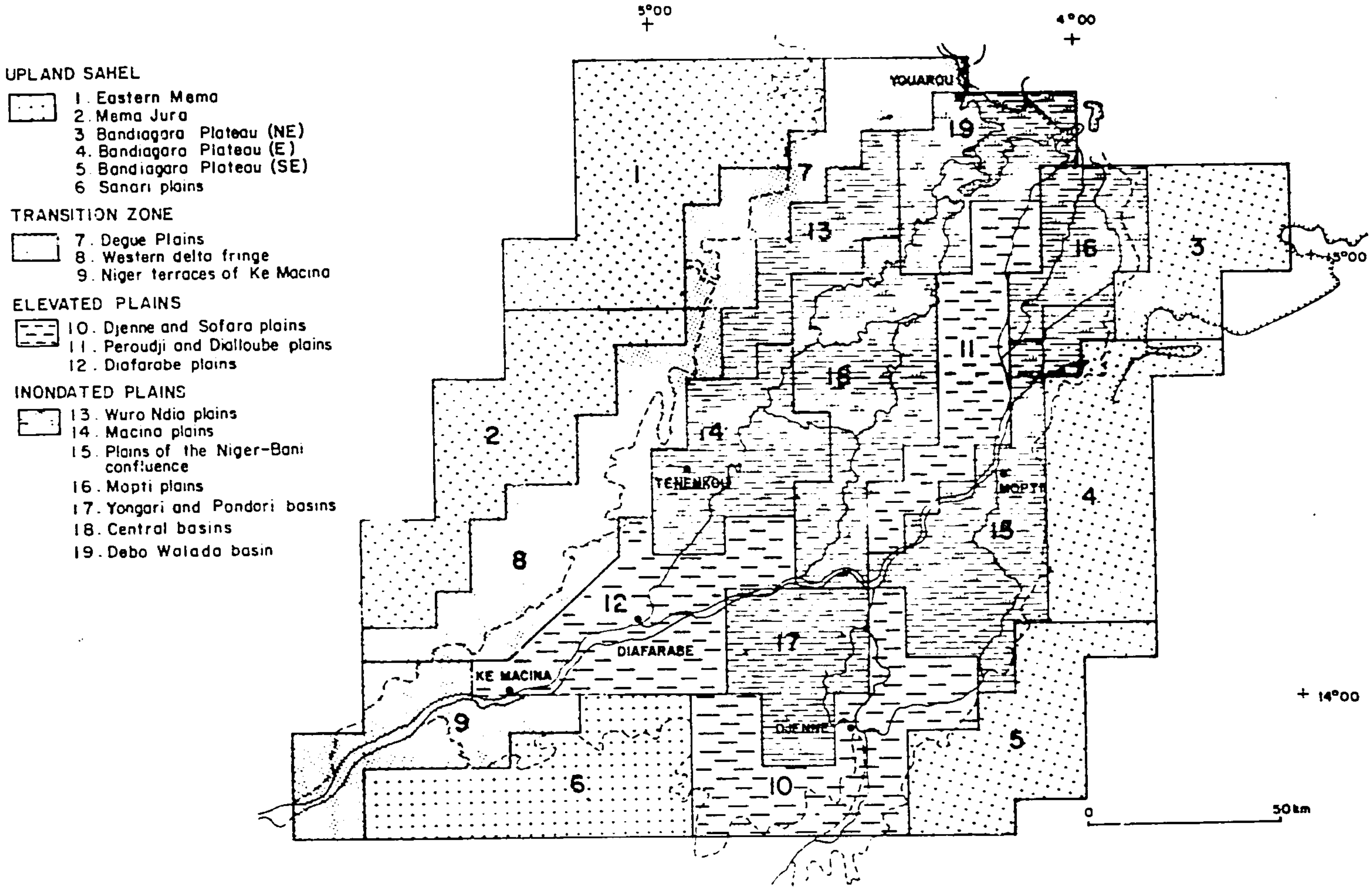


Figure 15. *Flooding and farming on the delta and its dry fringes*

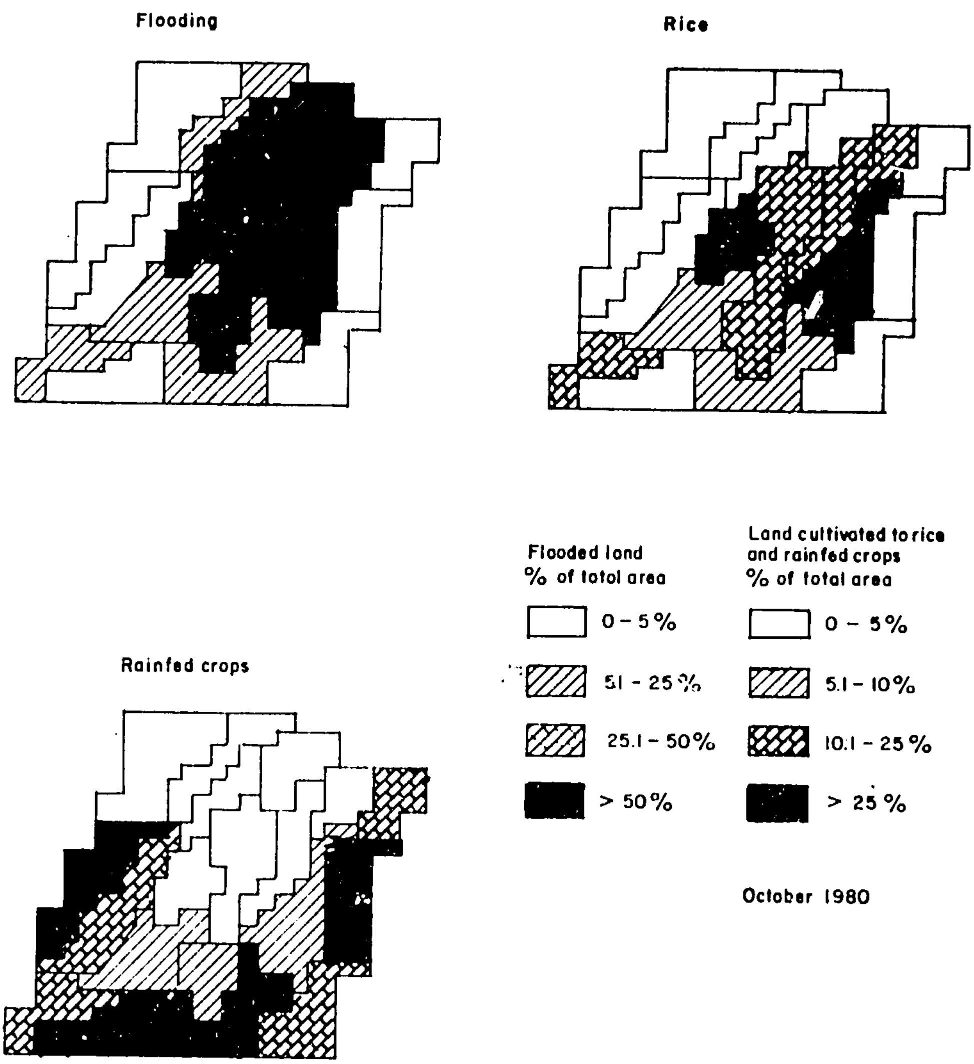


Table 9. *Flooding and farming in the Delta and the surrounding upland areas.*

Landscape Type	Area Km^2 (%)	Flooding %	Rice %	Rainfed crops %
Upland Sahel	13,500 (37)	0	0	21
Transitional zone	5,900 (16)	9	5	17
Elevated plains	6,100 (16)	21	8	25
Inundated plains	11,500 (31)	69	20	3
Total/mean	37,000 (100)	26	8	16

The remainder of the survey area consists mostly of flooded plains and backswamps (31%) with considerable land devoted to floating rice cultivation[2/]. The highest level of rice farming was recorded in the plains of Macina (unit 14) and those south of Mopti (unit 15). These plains are broken by higher-level terraces, levees and pointbar systems, which are much less inundated and show a mixture of rainfed and rice farming (units 10,11 and 12).

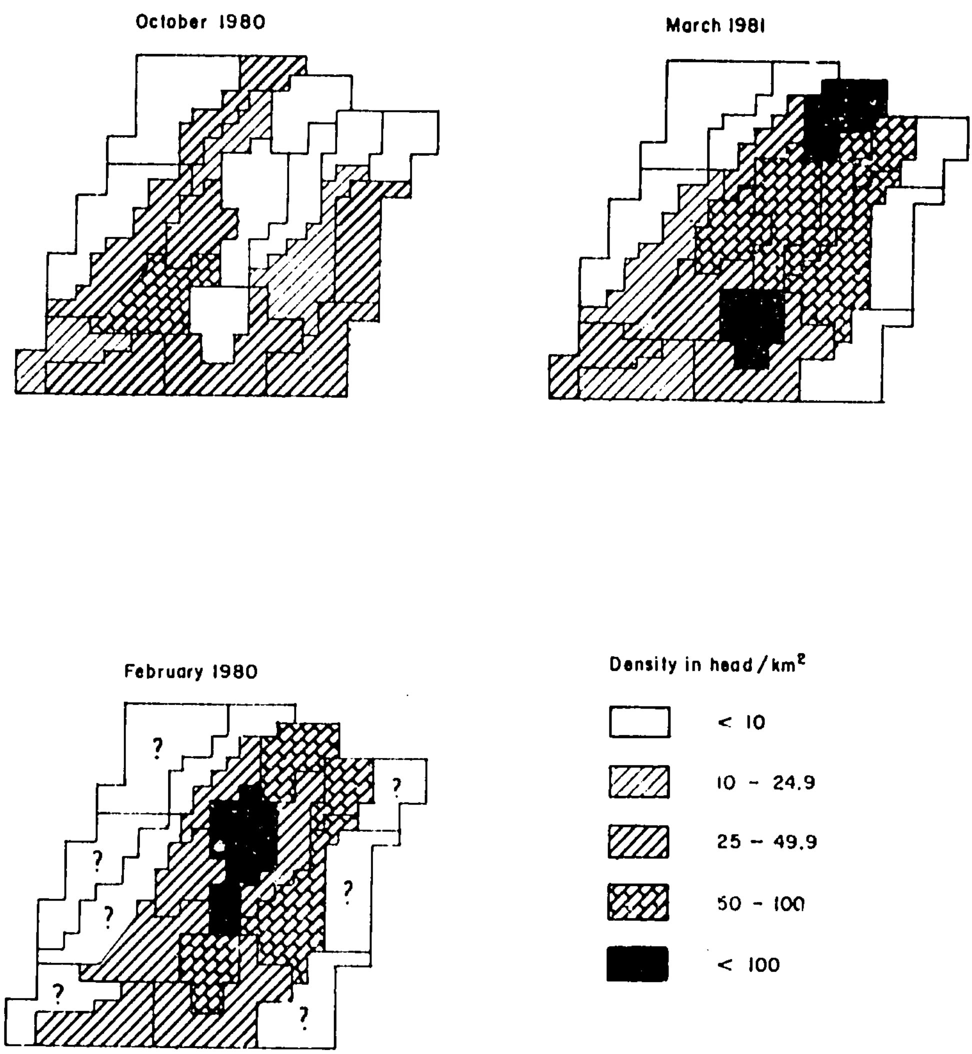
Cattle distribution in October

The general overview presented in Figure 16 shows a simple picture of high densities in the transition zone surrounding the delta and low populations where water is lacking, as in the Mema (units 1 and 2) and in areas inaccessible due to flooding or because they are protected by river barriers. It is also evident that the river crossings of the Diaka and the Niger, officially scheduled for the end of November 1980, created large concentrations of cattle near the main crossing points. There was a mass of cattle awaiting the crossing at Diafarabe estimated at some 370,000, being the total found in units 8, 9 and 12 and on the western edge of unit 14. If it is assumed that the herds located further south in units 6 and 10 will also cross at a later stage, another 150,000 should be added (Table 10).

The remainder of the October herds were recorded in two regions: about 100,000 grazed a narrow band of land west of the Wuro Ndia plains

2/ Estimates of rice farming should be treated with caution, especially those recorded in the inundated plains, because at the time of the October survey wild rice *(Oryza longistaminata)* could easily be confused with sown rice.

Figure 16. *Cattle density in the delta and its dry fringes*



(unit 13) awaiting further flood recession, whilst about 125,000 cattle had gathered at the edge of the Bandiagara Plateau for entry from the east.

As a consequence of this aggregated distribution, cattle densities were extremely variable, not only between but also within units, ranging from 3 - 4 head/km^2 in the Mema (units 4 and 5) in the east. Similar densities occur in the transitional zone and the elevated plains, except in the Perudji (unit 11), where entry is blocked by the Niger River (Table 10). However, the western transition zone covers about 11,000 km^2 and at this time contained 45% of the cattle enumerated. In 16% of this area densities were greater than 100 head/km^2, occasionally rising to 300 head/km^2, while in 38% of the zone densities were below 10 head/km^2 3/.

Table 10. *Cattle distribution according to landscape types at three survey dates*

Landscape type	October 1980 Population ('000)	(%)	density head/km^2	March 1981 Population ('000)	(%)	density head/km^2	February 1980 Population ('000)	density head/km^2
Upland Sahel	227	(28)	17	65	(5)	5	?	?
Transitional zone	236	(29)	40	91	(7)	16	?	?
Elevated plains	240	(29)	39	221	(16)	36	(339	55)
Inundated plains	120	(14)	10	995	(72)	87	(857	75)
	832	(100)	22	1372	(100)	37	?	?

Cattle distribution in February - March

The cattle distribution in this period showed that herds continue to move away from the upland Sahel and the transitional zone and concentrate in the inundated plains, which in March 1981 carried 72% of the total population (Table 10 and Figure 16). Total numbers remained fairly constant in the elevated plains, but there is a distinct shift from the southwest to the Dialube/Debo area in the northeast. This is in contrast with the February distribution, which showed much higher densities in the elevated plains (units 11, 12 and 13) and the areas south of the Niger (units 15 and 16).

3/ Detailed maps giving herd and cattle densities per sample unit (85 km^2) can be found in Milligan and Keita (1981).

Another distinct feature of cattle distribution is its division into two subpopulations: one located mainly south and southwest of the River Niger, the other to the north and northwest. The analysis in Table 11 shows not only that the total population within the delta proper - i.e. the elevated and inundated plains - hardly changed between 1980 and 1981, but that the two subgroups are equally constant in numbers.

This picture fits the description of transhumance routes into the delta by Gallais (1967), such that the 500,000 southern cattle mainly represent the influx from the south and northeast, while the northern herds, amounting to 700,000 head, belong to pastoralists entering from the north and west, the Niger forming the natural boundary (see also figure 18).

Within each territory the herds tend to follow the same transhumance pattern, moving from the upland Sahel and the transitional zone through the elevated plains and eventually reaching the inundated plains during February and March. Whether these movements continue to the very end of the delta

Table 11. *Transfer patterns of cattle populations in the Central Delta between mid-February 1980 and late March 1981*

Landscape	Units S. of Niger	Population ('000) Febr.	March	Units N. of Niger	Population ('000) Febr.	March
Elevated plains	10,12	213	137	11	126	83
Inundated plains	15,17	301	382	14,18[a/]	304	262
				13,16,19[a/]	253	350
sub-total		514	519		683	695
Grand total Febr: 1,197,000; March: 1,214,000						

a/ Units 14 and 18: Central inundated plains
Units 13, 16 and 19: Northern inundated plains.

grazing season, so that finally all herds congregate in the inundated plains, can only be ascertained by another aerial survey in June. It seems that in addition to these two subpopulations a third group of 40,000 head is found in the upland Sanari plain (unit 6), representing resident cattle belonging to Bambara farmers.

Distribution of small ruminants

The distribution patterns of sheep and goats conform fairly well to those of cattle, except that in late October 1980 the entry into the transitional zone was much less advanced than for cattle. Consequently, numbers in the upland Sahel were high, representing 45% of the total, while flocks in the Delta proper accounted for only 21% (table 12).

That there was delay of small ruminant flocks to enter the transition zone was further confirmed by a reconnaissance flight of a principal transhumance route during early November. Most flocks along the track consisted of Macina wool sheep, which were en route to the zone but had not yet arrived there[4/].

Table 12. *Sheep and goats distribution according to landscape type at three survey dates.*

Landscape type	October 1980 population density			March 1981 population density			February 1980 population density	
	('000)	(%)	head/km^2	('000)	(%)	head/km^2	('000)	head/km^2
Upland Sahel	116	(45)	12	75	(18)	9	?	?
Transitional zone	89	(34)	15	61	(15)	10	?	?
Elevated plains	21	(8)	3	46	(11)	8	(58	9)
Inundated plains	33	(13)	3	235	(56)	20	(356	31)
	259	(100)	7	417	(100)	12	?	?

Based on the October data, it appears that three sub-populations of small ruminants can be distinguished. First, there is a very high concentration of large flocks in the Northern and Western fringe of the Delta, amounting to some 163,000 head or 63% of the total counted. Most flocks were large and an analysis of size confirmed that over 75% of this population were

4/ For an excellent description of these wool sheep, their management system and attempts during the colonial period to improve the wool production of this breed see R.T. Wilson (1980).

As photographs have been taken of the majority of large flocks (both in October 1980 and March 1981) a separation of Macina wool sheep flocks from mixed sheep/goats is feasible, since the former consists of only white animals that are easily recognised.

herded in units greater than 100 head. A similar average flock size was measured for the eastern flocks coming from or through the Bandiagara Plateau area. These amounted to some 48,000 head with 70% in herds greater than 100 head.

The remainder, another 48,000 head, was found in the southern part of the survey area (in units 6,10 and the edge of 16; see fig. 17). In contrast to the other sub-populations in the survey area, flock size was much smaller and only 23% of the total population occurred in flocks over 100 head in size. It may be hypothesised that most of those small groups are sedentary and do not take part in long-distance transhumance movements.

A further indication of the proportion of sedentary flocks within the total population may be drawn from a comparison of the October counts and those done in February 1980 and March 1981. It may be argued that small ruminant flocks in the drier part of the survey area are either resident or belong to nomadic groups that rely on deep wells within the upland Sahel (particularly in unit 1 and 2, where settled farming communites are almost non-existent). Apart from small ruminants, belonging to scattered Tuareg and Peul groups[5/], it appears that most of the 75,000 head are sedentary whereas the same may apply to the 61,000 head counted in the transitional zone.

Much greater numbers are found in the delta proper. These total some 280,000 during the March 1981 survey and 414,000 during the February survey in 1980. Relatively small numbers are found in the "elevated plains" (46,000 in 1981 and 58,000 in 1980), thus the greater part was counted in the inundated plains (235,000 in 1981 and 356,000 in 1980).

In comparison to the cattle distribution, small ruminants are much more concentrated north of the Niger. In 1981, about 84% of all flocks or 273,000 were found there compared to 372,000 animals in 1980.

2.3.2 Livestock population in Central Mali

In addition to the information presented in Chapter I and section

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5/ In March 1981, temporary huts of Peul and tents of Tuareg were counted during the survey flights. It appears that the small ruminant herds found in the upland Sahel units 1 and 2 coincide well with the location of these camp sites.

Figure 17. *Sheep and goat densities in the delta and its dry fringes*

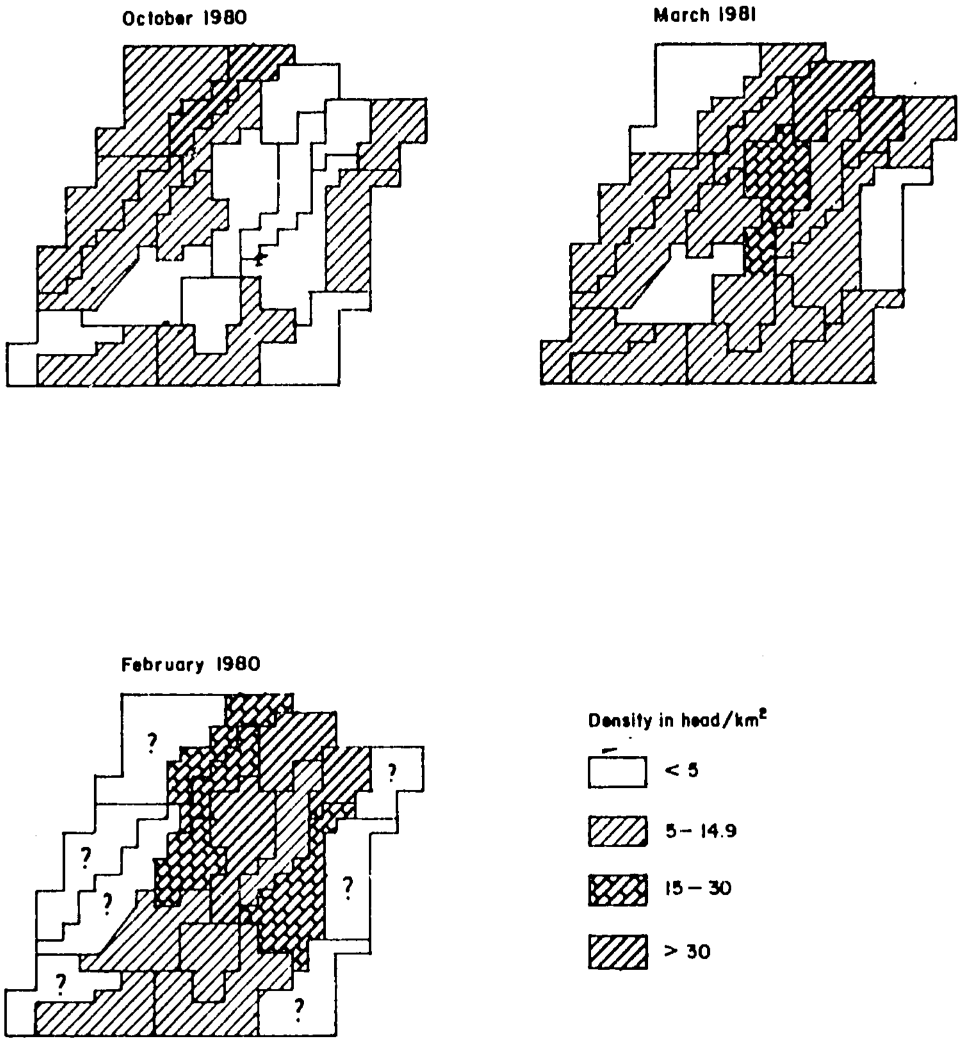
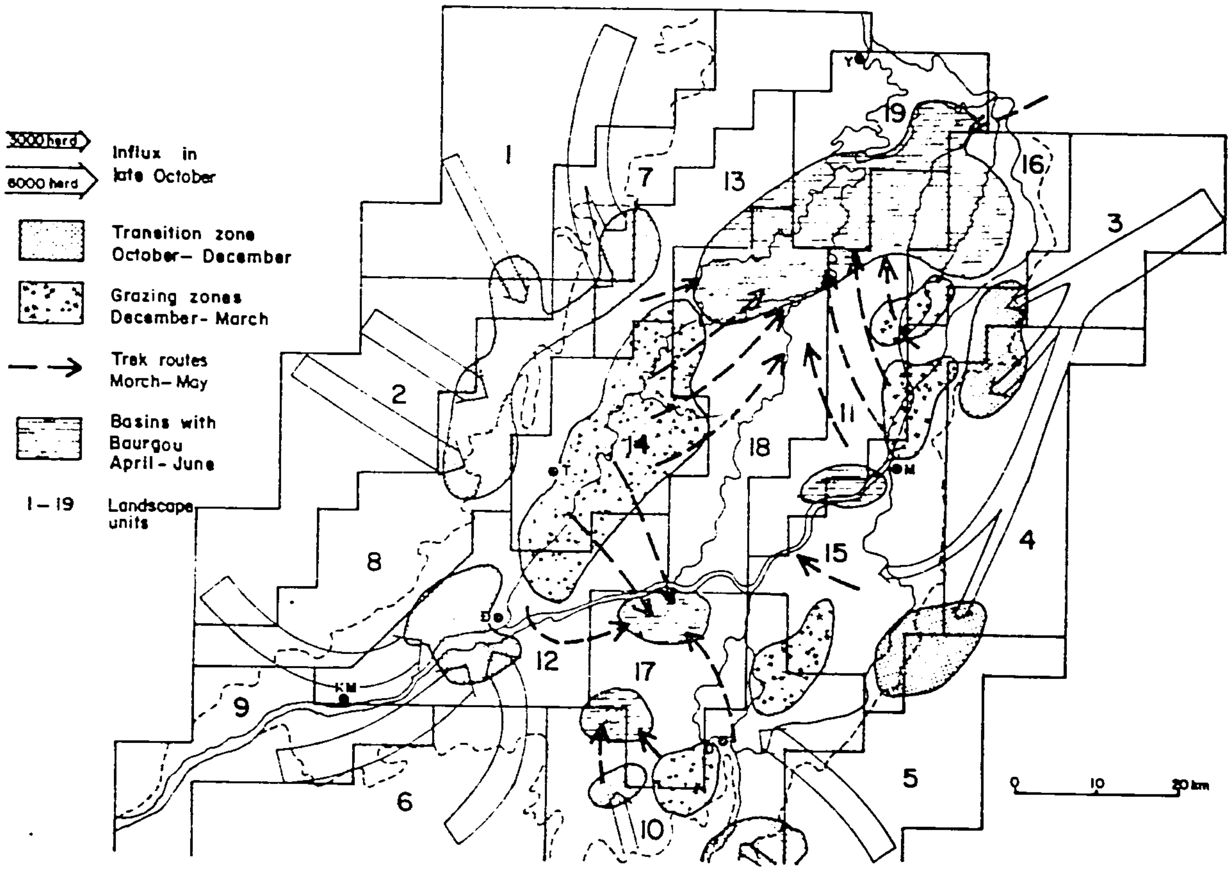


Figure 18. *Cattle movement within the delta during the dry season*



2.3.1, containing supplementary data on livestock population obtained from aerial surveys for a substantial area of the inner delta of the Niger. Although these data have not yet been fully analysed, it seems worthwhile to place them in a regional context.

The inner delta of the Niger and its immediate vicinity provide highly productive dry-season grazing and have therefore functioned as a magnet for livestock owners spread over a considerable surrounding area. However, the attractiveness of the delta as dry-season grazing area diminishes with the distance away from it and with the decreasing mobility of herds. In other words, the further herds move away from the delta during the wet season and the more sedentarized they are, the less they depend on it as a dry-season grazing resource.

The major influx of herds into the delta is from the west and northwest. The herds are managed by transhumant and nomadic herdowners having wet-season pastures in the dead delta, the Mema and as far afield as the Hod Harbi area of Mauritania. There is another influx, from the northeast, associated mostly with "pure" pastoralists from the western Gourma and Farimaké areas. A third influx is mainly from the south and seems to penetrate the delta no further than the south bank of the Niger river (figure 18).

The aerial survey carried out in late October 1980 counted some 820,000 head of cattle (only 60% of the total found in late March 1981), but it is believed that the proportions making up this early dry-season count nevertheless provide an estimate of the relative importance of these three axes of entry to the delta. Analysis shows that about 60% of the cattle came from the northwest or the southwest, 26% from the south and southeast and only 14% from the northeast and east.

Livestock populations on a regional scale can be extracted from data accumulated by the Service d'Elevage. A rather arbitrary set of districts have been taken as being within the "pull" of the inner delta, representing a cattle population of about 1.8 million and a sheep and goat population of about 2.8 million, or 1.7 million TLU altogether. About 45% (or 0.82 million) of cattle and 27% of small ruminants (or 0.76 million) have been registered in districts that lie within the delta itself or its immediate surroundings. The remainder 55% of cattle and 73% of small ruminants, located outside the delta to the north, south and east. The estimated numbers for cattle are about 0.44 million to the north, 0.23 million to the east and 0.35 million to the south, while for sheep and goats they are 0.98 million to the north, 0.58 million to the east and 0.46 million to the south (Table 13).

Table 13. *Estimated livestock population of central Mali*

Region	Area ('000 km^2)	Cattle ('000)	Sheep and goats ('000)	TLU/km^2	TLU/Capita
Delta and surroundings[a/]	53.1	822	764	13.0	1.04
Northern[b/] region	103.6	445	983	2.7	1.42
Eastern[b/] region	30.6	229	583	7.7	0.80
Southern[d/]	34.7	348	456	8.6	0.45
Total mean	222.0	1,844	2,786	7.6	0.87

a/ Delta districts: Niono, Macina, Tenenkou, Youvaru, Mopti, Djenné.

b/ Northern districts: Goundam, Niafunké and Diré.

c/ Eastern districts: Segou, San, Tominian, Bankass.

Source: Adapted from ILCA (1981 b).

If it were assumed that the deltaic herds rely in their entirety on delta dry-season grazing resources, while of the peripheral herds only 50% would enter the delta during the dry season, a total deltaic population of 1.3 million cattle would result, which is close to the uncorrected aerial count during the late-March survey.

A very roughly estimated influx of 50% of all peripheral herds is of course very unlikely to be true and it seems more acceptable to align the influx with the proportions established for the entry-axes during the October aerial survey. A higher than average entry from the drier areas is more acceptable, as these have a more mobile cattle population than areas to the south, where sedentary cattle husbandry is a more common mode of production.

Although the problems associated with carrying capacity estimates will be touched upon several times within this report, a cursory look at the balance between primary resources and demand from secondary "consumers" may be worth the effort. It would appear that in general grazing resources in the delta are probably adequate to meet overall demand, but that local imbalances do exist, especially during the dry-season in areas with highly valued *burgu* pastures.

Whether during the rainy season when herds are dispersed accross the region, the total population of about 1.7 million TLU can be maintained on the 120,000 km^2 of available rainfed rangeland in the districts taken into account is more difficult to determine (Table 14). A total area of 7.5 ha/TLU is certainly theoretically sufficient in terms of feed supply. Djiteye and de Vries (1980) estimated that between 1.5 to 2.5 ha of rangeland were needed for a 5-month rainy season, while wet-season stocking rate trials on the Niono range indicated that 1.0-1.5 ha/TLU was an acceptable long-term stocking rate.

Table 14 *Rainy season land resources available for livestock grazing in central Mali.*

Total land (km^2)	222,000
Not available:	
Delta and its surroundings	-23,000
Irrigation projects, towns, villages, roads, etc (5%)	-11,000
Cultivated land and fallows (10%)	-22,000
Subdesert area[b]	-46,000
Total available rainy season rangeland (km^2)	120,000
Total population (TLU)[a]	1,685,000
Rangeland (ha/TLU)	7.5

a/ From ILCA (1980)
b/ 50% of Goundam District

Source: Compiled by author.

for a 4-mongh period (de Leeuw and Hiernaux, 1981). However, so much depends on available water resources, that overall carrying capacity estimates for the whole area have little value. On average it may well be true that, during the height of the rains from the end of July to late September, grazing is little restricted by lack of water supply. Immediately before and after this period - i.e. for about 3 months in all - water is only locally available, placing large parts of the upland area out of bounds for grazing livestock. The same situation, or an even less favourable one, applies to the permanent dry-season population of 0.5 million cattle and 2.5 million sheep and goats, which remains outside the delta. There is little doubt that there are sufficient grazing resources, at least in terms of biomass quantity, but again water supplies are the overriding factor determining use. Maps depicting potential carrying capacity based on standing biomass should therefore include an assessment of the seasonal distribution of water resources if realistic appraisal of actual carrying capacity is to be obtained.

3. THE AGROPASTORAL SYSTEM

3.1 GENERAL DESCRIPTION

The agropastoral system in central Mali has already been classified into three subsystems. The first, much the more important for the arid zones in general, is the rainfed millet subsystem on upland soils. The second, more local in importance but nonetheless fairly widespread, is the irrigated rice subsystem. The third, found in the wetter areas further south, is a cash and subsistence cropping system.

The agropastoral systems have traditionally been crop- rather than livestock-oriented and it is probably only recently that livestock have become more important in total household resources. Nowadays, the majority of farmers in both the rice and the millet subsystems own at least a few ruminant animals and many have a donkey. Cattle holdings of the sedentary Bambara population of central Mali have increased considerably over the past 30 years, probably as a result of favourable agricultural conditions, high prices for groundnuts during the 1950s, and the relative price movements of millet and livestock (especially during the 1972/73 drought). The ownership of livestock now plays an important part in these agropastoral systems, absorbing surpluses and cushioning deficit periods resulting from the interannual variability of rainfall and millet yields. Households without livestock are reduced to more costly methods of surviving grain deficit periods, for instance by sending sons out to work for other households during the rainy season.

Official statistics on livestock numbers are of doubtful reliability. The Office du Niger carries out its own census of animals within the irrigated perimeter, another count being made by the government census. However, there is seldom a close relationship between the two. Table 15 gives some statistics on livestock holdings for a number of villages in both the millet and rice subsystems, and also shows the importance of ploughs and carts. The small ruminant figures are misleading not only as to ownership and total numbers but also as regards the ratio of goats to sheep. In the official census, where goats and sheep are supposedly shown separately, individual families are usually shown to have equal numbers of each, our own observations, however, indicate that there are more goats than sheep by a ratio of 5.4:1 in the millet subsystem around Niono, 1.9:1 in the villages where the socio-economic studies are carried out, and 1.4:1 in the rice subsystem. Table 16 details the ownership patterns of small ruminants for 43 owners in the Niono area.

Table 16. *Ownership pattern and flock sizes for small ruminants in the agropastoral system.*

	Millet villages		Rice villages	
	Goats	Sheep	Goats	Sheep
Total number of flocks	16		27	
Number owning species	16	7	26	15
Number owning goats only	9		12	
Number owning sheep only	0		1	
Mean flock size[a/]	38.19	7.46	8.96	6.41
Mean flock size[b/]	36.19	12.56	9.31	11.53
Range in flock size	2-91	0-58	0-23	0-58

[a/] For all owners, i.e. irrespective of whether the holding of one species is nil.

[b/] Of only those flocks in which animals are held, i.e. nil holdings excluded.

Source: Compiled by authors.

These tables show that in the millet subsystem three out of every five families (61.2%) own cattle, although only one out of every two families (50.5%) owns an ox-drawn plough. In the irrigated subsystem four out of every five families (80.1%) own cattle, with slightly more than that number also owning ploughs. Evidently there is more mechanization in the irrigated system

Table 15. *Livestock holdings according to official statistics in a sample of villages in the millet and rice subsystem.*

Subsystem/village (No. of households)	Cattle % owning	Cattle Range in numbers[a]	Sheep % owning	Sheep Range in numbers	Goats % owning	Goats Range in numbers	Donkeys % owning	Donkeys Range in numbers	Ploughs % owning	Carts % owning
Millet[b]										
Pogo (62)	71.6	1 - 70	70.0	1 - 50	80.0	2 - 150	51.7	1 - 4	66.7	43.3
Kamono (10)	100.0	1 - 50	90.0	5 - 60	80.0	8 - 60	80.0	1 - 2	80.0	70.0
Sissako (33)	75.8	1 - 40	81.8	3 - 20	87.9	5 - 20	36.4	1 -10	45.5	24.2
Teninzana (29)	72.4	2 - 30	72.4	5 - 55	75.9	5 - 55	65.5	1 - 3	62.1	20.7
Siguinê (21)	80.9	1 - 25	85.7	2 - 35	85.7	2 - 35	71.4	1 - 2	57.1	23.8
Thing (40)	75.0	1 - 50	77.5	2 - 66	75.0	3 - 66	57.5	1 - 2	60.0	50.0
Siraouma (26)	96.2	1 - 12	0.0	-	88.5	5 - 20	53.9	1	84.6	57.7
Ndebougou (114)	53.5	2 - 30	0.0	-	54.4	2 - 30	44.7	1 - 2	40.5	5.6
Ntile (62)	38.7	2 - 22	3.2	2	38.7	2 - 50	29.0	1 - 3	27.4	1.6
Bamada (39)	23.1	1 - 14	5.1	2 - 8	20.5	1 - 15	30.8	1 - 3	41.0	28.2
Cenabougou[d]	89.7	1 -120	63.1	3 - 80	79.4	2 - 100			90.0	90.0
Falabougou[d]	40.9	2 - 32	86.4	1 - 25	100.0	3 - 50			27.0	27.0
Rice[c]										
N6 (35)	85.7	2 -140	0.0	-	8.6	10 - 18	60.0	1 - 2	71.4	57.1
N9 (72)	63.9	2 - 40	1.4	5	4.2	5 - 10	43.1	1 - 2	59.7	34.7
N5 (27)	85.2	2 - 50	21.7	2 - 10	0.0	-	48.1	1 - 2	92.6	48.2
N10 (53)	83.0	1 - 38	0.0	-	3.8	5	54.7	1 - 2	84.9	77.3
B1 (55)	96.4	1 - 39	7.3	1 - 3	21.8	1 - 4	70.9	1 - 2	98.2	67.3
B6 (39)	89.7	1 - 15	33.3	1 - 8	33.3	1 - 8	69.7	1	100.0	54.6

a/ Nil holdings excluded for all species.

b/ Millet subsystem figures are from the government census, except for Cenabougou and Falabougou where data were collected by ILCA.

c/ Rice subsystem figures are from the Office du Niger census.

d/ Villages where ILCA conducts socio-economic studies.

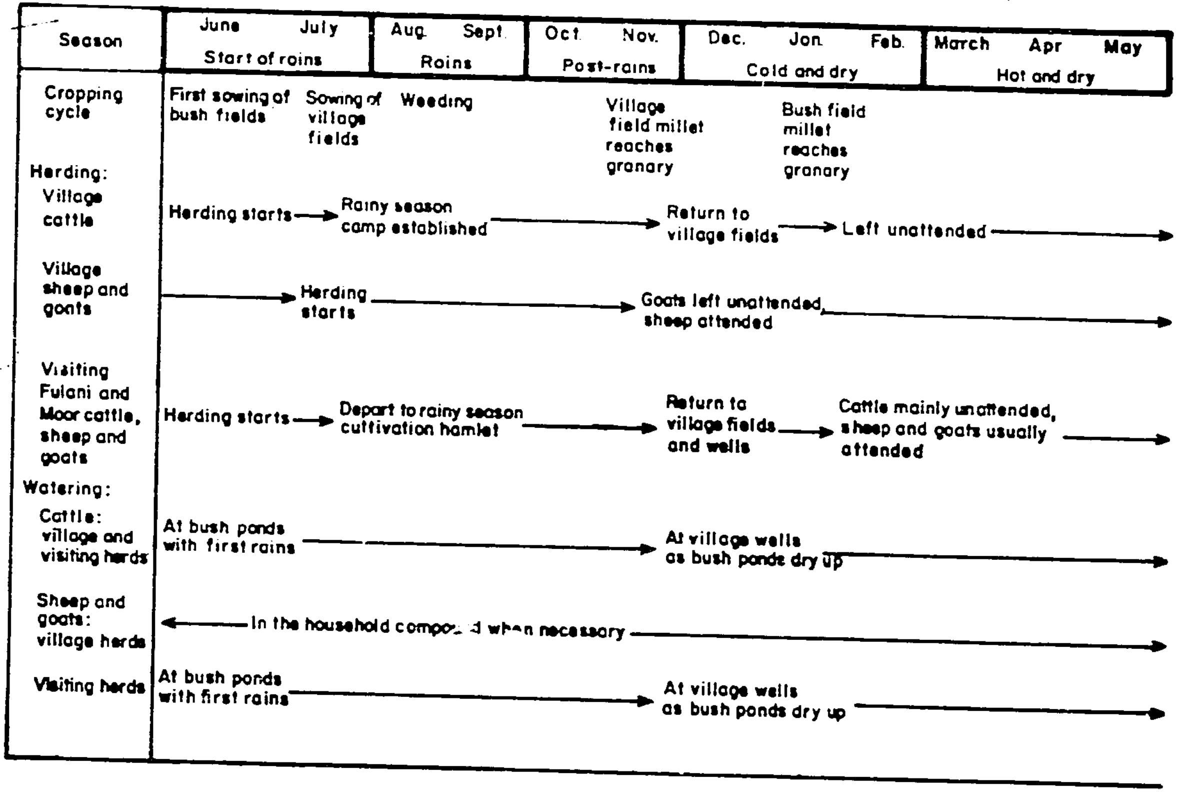
than in the rainfed. The numbers of oxen and ploughs owned per family are also higher in the rice system, so that, the degree of mechanization and its effects on herd structure are greater than a simple appraisal of the figures would suggest.

Ownership of animals has been facilitated for Office du Niger tenants in the rice subsystem by a scheme for the credit purchase of work oxen. This class of stock is, in terms of feed requirements and economic value if not in absolute numbers, by far the most important in the subsystem.

Although in general terms the livestock of the agropastoral system may be considered sedentary, the real situation is more complex. Seasonal movements do occur, mainly to suit the needs of agricultural operations. In particular, the cattle of the rice subsystem are fairly mobile during the wet season, and movements of 80 - 100 km regularly take place. The herds of the millet farmers move less far and for shorter periods, distances of 30-50 km being the norm. On the other hand, sheep and goats, particularly the latter, can be considered sedentary, although part of a family flock may be moved for a longer or shorter period to a family member living in another village. Some ethnic groups, with a lesser or more recent interest in agriculture, are also more mobile than the traditional crop farmers.

An example of livestock management as affected by seasonal and farming requirements in Cenabougou, a village in the millet subsystem, shows that herding work starts with the first rains at the beginning of June and continues throughout the rainy season and harvest periods, until all the millet is in the granaries, by January or February. From then until June, cattle are free to wander in the bush after being watered, returning by themselves at night. Watering at the village wells starts once the ponds in the bush dry up, towards late November, and continues until the following rainy season. Cattle are usually watered once a day, although they are able to go for 2 or even 3 days without drinking. During the rainy season the herds pass the night in a camp set up some distance from the village (up to 4 or 5 km), away from the bush fields and near a pond where they can be watered. In the dry season they return to spend the night on the fields of the herdowners. Fulani hired herders and their families move house with the herds. Whether hired herding labour is employed or not, the herdowner or one of his family visits the herd every day (figure 19).

Figure 19. *The livestock management system of Cenabougou.*



Source: Compiled by authors.

Close supervision by the herdowner is needed, since the relationship between farmers and their herders is fraught with conflict, exacerbated by the general political tension between farmers and Fulani over access and rights to land. Owners accuse the herders of taking too much milk at the expense of the calf and of selling animals which they then claim to have lost. The herders for their part cite the ignorance and neglect of their cattle by the owners, their meanness and failure to fulfil obligations to their herders (especially in helping plough the herders' fields), and their demand for milk even during the dry season.

As in the case of cattle during the dry season, it is common for goats (and occasionally sheep) to be left unguarded during the day, particularly in the upland millet areas, a practice which often results in considerable numbers of "lost" animals.

The rice subsystem appears to have certain advantages over the millet subsystem, leading to increased productivity. In the rice subsystem, for instance, the stall-feeding of castrate sheep, known throughout francophone West Africa as *moutons de case*, is much easier owing to the greater availability of crop residues. Water is also abundant all the year round, whereas in the millet system it is restricted during the dry season. Table 17 lists some of the main differences between the millet and rice subsystems which account in large part for the better performance of the latter.

3.2 THE MILLET SUBSYSTEM

3.2.1 Introduction

Since May 1980 the millet subsystem has been studied in a group of villages 75-90 km southwest of Niono. The research aims to provide data on (i) patterns of land use and labour allocation between agricultural and livestock production, (ii) productivity of land, labour and livestock under the present system, (iii) social factors affecting producer strategies.

Producer strategies are determined within an environment of high risk. Research on the social and economic dimension of the system therefore attempts to explain and quantify the responses to this environment by households and communities. Attention has focussed on the social organization of production, on patterns of distribution, exchange and consumption, on the way producers view the system and their roles within it and finally on the dynamics of the system, including both cyclical and linear changes.

Table 17. *Management and environmental factors in the millet and rice subsystems.*

Factor	Millet	Rice
Water availability	Restricted in dry season	Abundant all year round
Crop residues	Limited in time, quantity and quality	Longer season of availability (later in dry season), better quality
Dry-season fodder	Very limited, some early browse in hot dry season	Weed regrowth on irrigated fields
Supplementary feeding	Generally not practised (little surplus cash). Salt occasionally provided	Fairly common, especially for sheep: rice bran, legume haulms, leaves of *Khaya senegalensis*. Work oxen sometimes fed but insufficient quantity and poor quality
Energy expenditure	High in dry season due to long distance to water and sparse food availability	Lower for longer period on account of proximity of water and longer growing period

Source: Compiled by authors.

The area of study lies towards the northern limit of the zone of agricultural predominance, and has many of the characteristics of a transitional region between agriculture and pastoralism. It is characterized by annual rainfall of around 500 mm, low population density and dispersed settlement. Availability of water rather than of land is the main factor affecting settlement size and density. Settlements are thus of three kinds: those with sufficient water to attract dry-season visitors and their herds to their fields; those unable to do more than meet their own needs for water; and those forced to send their livestock elsewhere for water during the dry season.

Land is not, at present and in the particular area under study, a scarce resource. But there is evidence that pressure on both land and water resources is increasing, and that competition for them between and within local groups will intensify in the future. The area under cultivation is expanding as a result of population growth, now at about 2.5% annually, increased cropping by primarily pastoralist groups, and the recent widespread introduction of the ox-drawn plough. Most striking is the rate of immigration into the area, both permanent and seasonal, of farmers from the south and west searching for more fertile land and an escape from the ravages of birds near the irrigated zones. There is also conflict over rainy-season pasture and water between the sedentary or short-distance transhumant groups native to the area and the longer-distance transhumant groups. Conflicts mostly concern damage to crops by transhumant herds.

3.2.2 Sampling and data collection

Research covers a 100% sample of five villages (A, B, C, D and E) and two wet-season hamlets (a and b). Details of the samples and data collected are presented in Tables 18 and 19. The villages represent the three kinds of settlement found relative to water resources outlined above. They range from village A, where fairly plentiful water at 15 - 20 m has allowed a system of privately-owned wells to develop, to village E, which has a dry-season water supply barely adequate for household needs.

Research in the first year (May 1980 to April 1981) concentrated on the intensive study of a sample (1) of 50 households in village A and B belonging to the sedentary Bambara system. More extensive coverage for comparative purposes applied to second Bambara sample (2) in villages, C, D and E. Also covered was a further sample (3) of Fulani herding households attached by contract to Bambara cattle owners, in so far as these households form part of the same agropastoral system.

Table 18. *The sample communities and their human and livestock population.*

Sample no.	Group	Location	No. of households	Total population	Livestock: Cattle	Sheep/goats	Agriculture[a/]
1.	Bambara	Villages A,B	51	640	900-1000	1000-1100	(i)(ii)(iii)
2.	Bambara	Villages C,D,E	30	500	700-800	900-1000	(i)(ii)(iii)
3.	Fulani (contract herders)	Villages A,E	10	50	40-50	300-400	(i)
4.	Fulani (transhumant)	Hamlets a,b village B	8	120	600-650	-	(ii)
5.	Bambara. Size and further details to be determined.						

[a/] Agriculture: (i) permanent (manured) fields, early millet/cowpeas; (ii) shifting bush fields, late millet/cowpeas, groundnuts; (iii) minor crops, including fonio, voandzou, maize, sorghum and tomatoes (often cultivated by women).

Source: Compiled by authors.

Other agropastoral groups, such as the short-distance transhumant Fulani and Moor, were only considered in the first year to the extent that their activities impinged on those of the intensive sample. In the second year it is planned to extend coverage to a small sample (4) of transhumant Fulani who spend the dry season round the village wells and cultivate in the wet season at hamlets a and b. Extensive coverage is also to continue, with inclusion of another sample (5), chosen following the ILCA demographic survey of the Doura Arrondissement in April/May 1981[1/] and the aerial survey of the same date, in order to test hypotheses based on rapid survey methods. Preliminary analysis of the aerial survey results, which covered 18 villages, suggests that the five-village ground-level sample is representative of the region as a whole.

[1/] This survey involved a rapid census of all villages and hamlets, covering about 10,000 people, and concentrated on the fertility and mortality of the population.

Table 19. *Type of data and collection methods.*

Type of data	Collection method	Frequency	Sample no.
Labour and budget	Monitoring by interview/ questionnaire	Daily/weekly	1
Labour and budget	Monitoring by interview/ questionnaire	Weekly/2-weekly	3
Budget	Interview	Monthly/6-monthly	1,3,4
Livestock:			
Holdings	Census	Annual	1,2,3
Births, deaths, losses	Census	2-monthly	1,3,4
Sales, purchases	-	-	-
Milk production and marketing	Observation/interview	2-weekly	1,3,4
Grazing movements	Observation/interview	2-weekly	1,3,4
Agriculture:			
Field management (incl. manuring)	Observation (field dossier)	Weekly/twice weekly	-
Areas cropped	Measurement	Annually	1,3,4
Yields	Measurement/estimation	Annually	1,2,3,4
Nutrition (human)	Questionnaire/interview	2-weekly	1,3
Family history, attitudes, etc	Informal interview	Continuous	1,2,3,4

Source: Compiled by authors.

To collect the data, two researchers (one economist and one social anthropologist) live in village A with three field assistants who are responsible for much of the routine monitoring. A fourth field assistant lives in village B. The other villages and hamlets or camps are visited regularly. All the field assistants are male Bambara speakers, and one is also fluent in Peul.

Formal and informal methods of inquiry are combined, with open-ended interview and participant observations complementing standard questioning. In household-level research, despite greater difficulties in processing the data, better results seem to be obtained by a flexible adaptation of methods to suit the situation, and by keeping open all possible channels of information, than by a formal apparatus which tends to reflect an "official" (usually senior male) version of events.

3.2.3 Social organization

Villages consist of one or several exogamous patrilineal groups whose members claim descent through males from a common male ancestor. These groups divide and subdivide into segments forming households, which are the units of production and consumption. However, marriage exchanges between lineages, and the system of patrilineal descent which is the social basis of household formation, create a network of descent and affinal ties between households. It is within this network that production strategies are determined. Households cannot therefore be considered as discrete units in isolation from one another, or from the historical context of settlement patterns and the resulting village social structure. Again, exchange of women between lineage groups in different villages creates channels along which other exchanges flow, especially the redistribution of millet through female relatives.

The founding lineage or lineages hold the chiefly office, which is filled by the senior male. The chief is expected to consult at least the oldest household heads over important questions, and his effective power is in inverse proportion to the number and influence of co-founding lineages present in the village. These founders, the first to clear the land for farming, have the authority to permit incoming strangers to settle and to assign them land. Rights to land are usufructuary and depend on establishing a tradition of utilization. A lineage segment has the right to continue to use its part of the lineage's land, but not to dispose of it, and the land reverts to communal ownership if cultivation lapses.

Villages are autonomous in the sense that each is represented by its chief to the government, and is the proprietor, as a community, of the land around it. The village territory extends to the midway point between the village and its nearest recognized neighbour. In theory, new settlement in this territory, whether these are temporary farming hamlets becoming permanent, offshoots of older villages or immigrant communities, are considered as outsiders subject to the authority of the older village. In practice, however, while this jurisdiction may be respected for certain tax and administrative purposes, a village has little control over the use of land on the edge of its territory. Still less can it control settlement and movement in this outlying area of Fulani influence, since the latter are not part of the same jural and ritual community.

Table 20 and Figure 20 give data on present village populations and household sizes in villages A and B. Household here means that group of people who farm a single field and eat from a common granary, a definition corresponding to the Bambara term *gwa*[2/]. The figures reflect significant differences in the structure as well as the size of households, in particular in the ratio of producers to consumers and in the economic roles of women and the aged. The smaller household sizes in village B, itself the smaller village of the two, suggests the effects of poverty, out-migration and the inability of men to marry early. These households are more vulnerable to risk and less able to benefit from the economies of scale achieved by the larger extended family, in which the peaks and troughs of changing dependency ratios are flattened out.

Table 20. *Total population and household size.*

Village	Population	No. of households	Persons per household
A	450	29	15.5
B	190	22	8.6

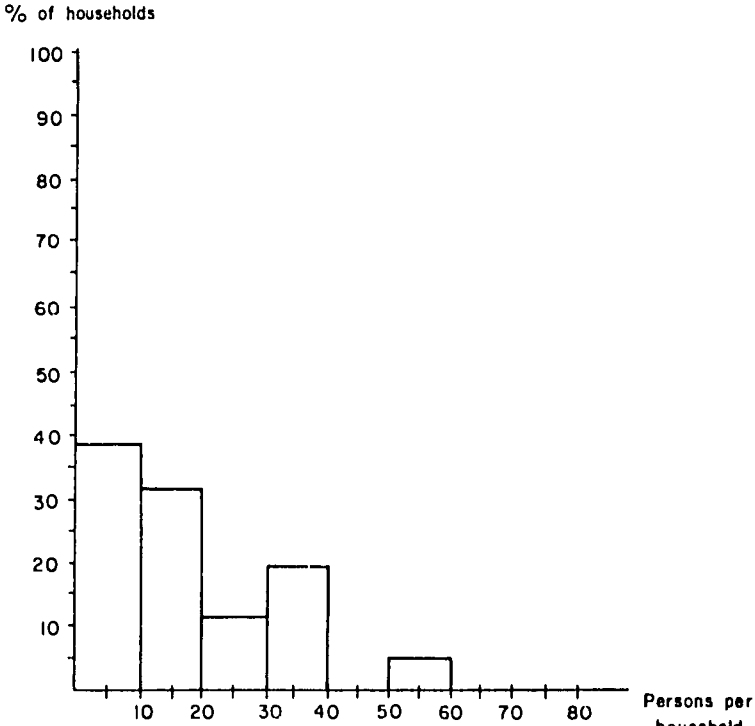
Source: Compiled by authors.

Two opposing trends, towards fission of the household or group brought about by rivalry between patrilineal relatives, and towards unity to preserve the advantages of large productive groups, can be recognized, and each household budget represents a temporary compromise between individual and communal interests. Tension between the trends is exemplified by the difference between agricultural production, where there is a constant movement away from the individual towards communal production by men in the same household, and livestock production, where patterns of ownership and inheritance accentuate the pressures leading to fission.

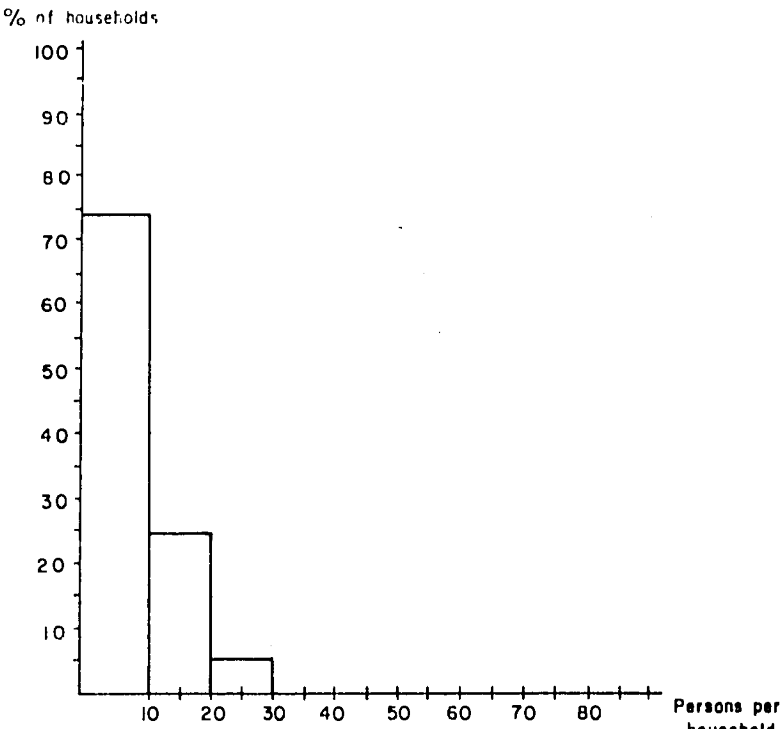
Village institutions which cut across both descent and affinal ties include the system of age-grades and the *ton*, or communal labour association, the *komo*, or men's initiation cult, in some predominantly pagan

2/ In some of the large households there is a division of the product of some of the family fields into separate granaries, and certain meals at certain times of year are eaten in groups smaller than the whole household.

Figure 20. *Distribution of household sizes.*



(I) Village A



(II) Village B

Source: Compiled by authors.

villages and, in villages still having access to a large area of bush, the hunters' association, in which membership and seniority are based on master-pupil relations.

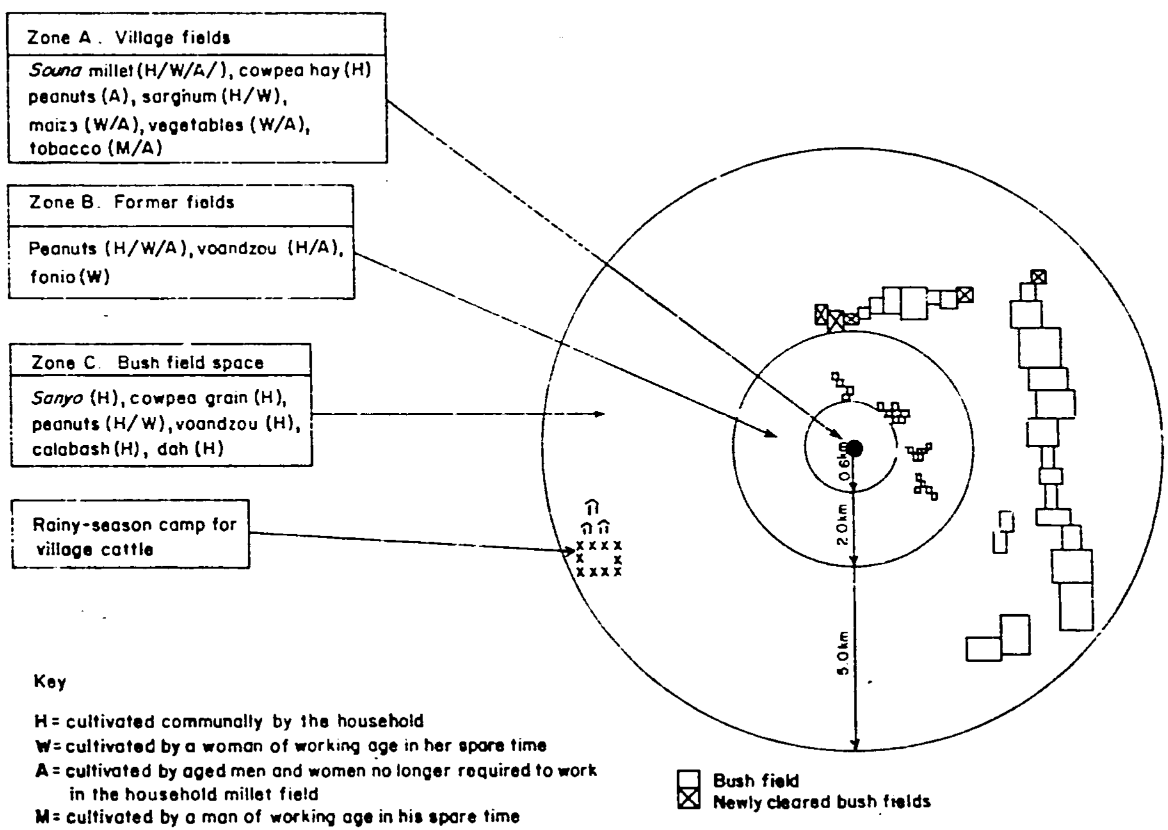
3.2.4 Cropping and land use

The main crop is millet, but sorghum, groundnuts, cowpea, voandzou and other minor crops are also grown. Two main varieties of millet are cropped: a rapid 90-day variety, *souna*, cultivated on the permanent manured village fields, and a longer-season variety, *sanyo*, cultivated on the unmanured, shifting bush fields. There are many varieties of both *souna* and *sanyo*, with different growing cycles, grain colours etc. Each village has a mixture of such varieties and it is common for a farmer to experiment with different seed grains from his own or a neighbouring village reputed to have particular characteristics.

Groundnuts, introduced in the 1940s, are cultivated by households and individuals in varying quantities for sale or for home consumption. Voandzou, grown by almost all households, occupies a special place because it ripens before the early *souna* crop is ready, providing food for those with empty granaries and a more varied diet for those who still have millet. Fonio, although formerly cultivated by the household on substantial areas of land, is now a women's crop, with plots seldom reaching 0.25 ha. Women also cultivate other minor crops in the village fields, such as tomatoes, okra, maize and sorghum. Only in villages further south does sorghum occupy a more important place.

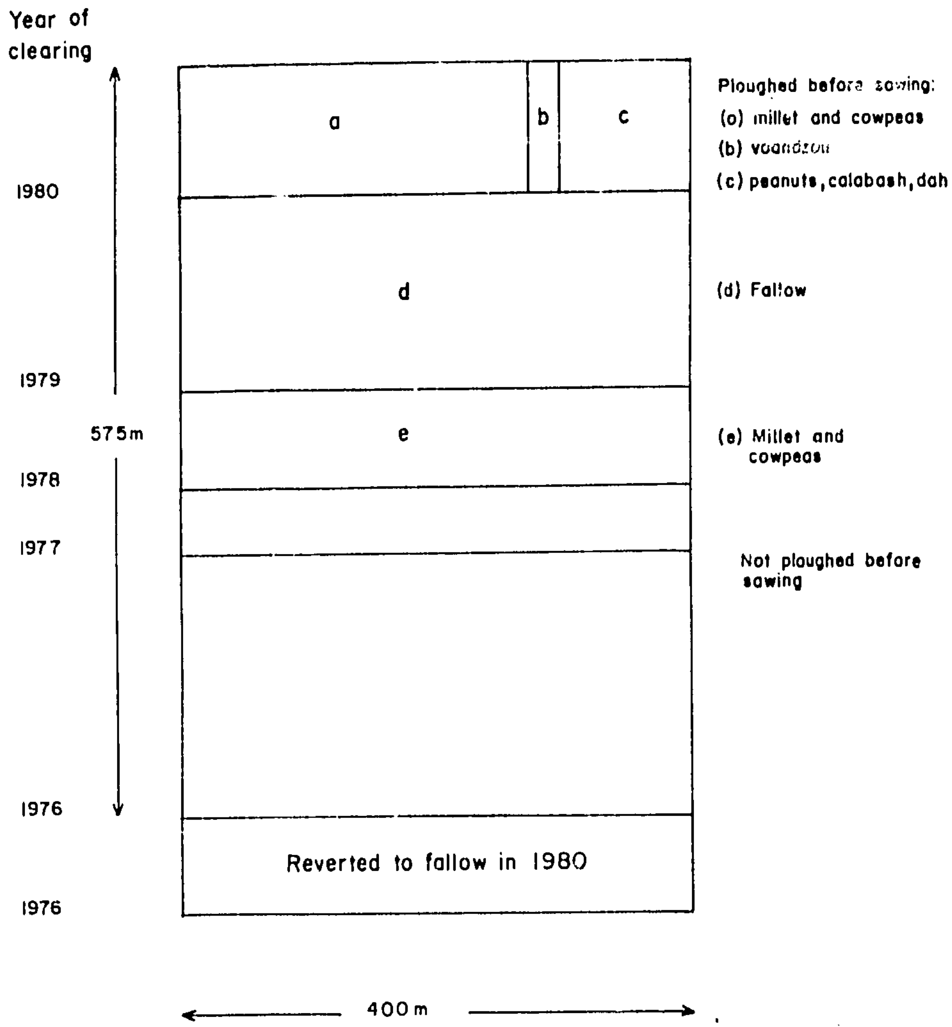
The land use pattern is typical of West African dryland cropping, forming a series of concentric rings around the village (Figure 21). Zone A consists of the ring of millet fields immediately surrounding the village, continuously cultivated and "owned". The circle grows outwards as the village grows and as individual households increase their capacity to manage a larger area. Zone B consists of land that was used for bush fields some years ago but is now mostly left fallow with a small proportion used for the shifting cultivation of groundnuts, voandzou and fonio. Zone C represents the area in which the villagers can cut a bush field, its outer boundary depending on the distance to the neighbouring village and the distance that household members are prepared to travel to reach the field every day. Figure 22 shows how a bush field slowly advances over the years, adding a new piece of land and leaving behind the oldest strip in the field each year. Land is farmed

Figure 21. *Land use zones around the village.*



Source: Compiled by authors.

Figure 22. *Annual shifting of a bush field (Sample household, 1980).*



Total surface area = 23.0 ha
Old bush field = 19.0 ha (83 %)
Newly cleared land = 4.0 ha (17 %)

Source: Compiled by authors.

on average for 4 years, although some bush fields may still contain land that was cleared as long as 7 years ago. Once a bush field reaches a distance of about 5 km from the village, either a new field is cut or the working members of the household set up a rainy-season hamlet on the edge of the existing field. Land in zones B and C is not permanently "owned": an abandoned field reverts to bush, becoming available to other households in the future. The length of fallows in zone C appears to be at least 30 years. According to aerial photographs bush fields are about as extensive now as they were in 1952. In village A, five households started completely new bush fields in 1980, having abandoned those farmed in 1979 following crop damage by transhumant cattle herds during the rainy season.

Tables 21 and 22 give details of the area under cultivation in each zone and of the crops grown in each for the village studied in 1980.

Table 21. *Total cultivated area by land use zone (village A, 1980).*

	Zone A Village fields	Zone B Former bush fields	Zone C Bush fields and newly cleared land
Total zone area (ha)	105	1150	6600
Total cultivated area (ha)	105	33	657 (425 + 232)[a]
% of potential area cultivated	100%	3%	10%

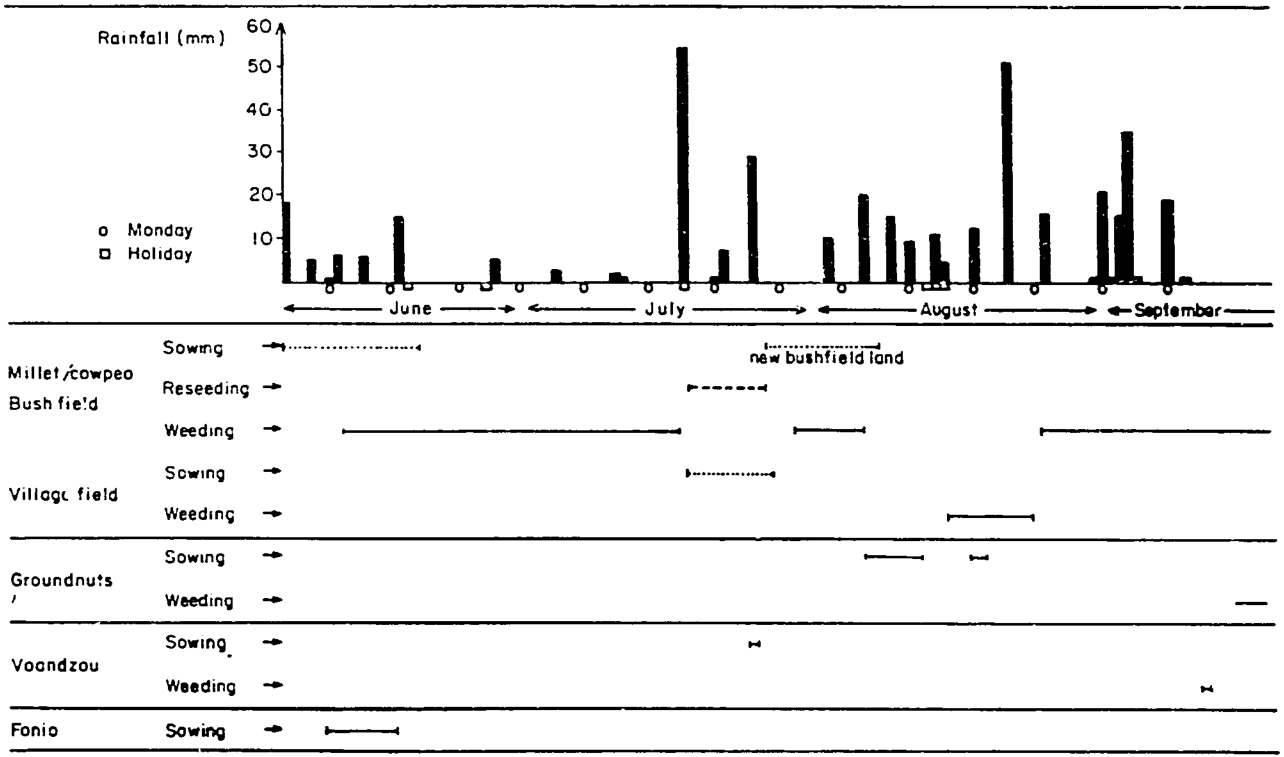
[a] Of the 657 ha of bush fields cultivated in 1980, 425 ha had been farmed the previous year while 232 ha was newly cleared land.

Source: Compiled by authors.

Figure 23 shows the timing of agricultural activities during the cultivation period, alongside the distribution of rainfall. A number of points can be made:

First of all, variations between households in the timing of operations are minor (although in such a short season even these may be critical). At the important moments, such as starting to sow the bush fields or to plough and sow the village fields, the whole village synchronises its work, even though no formal or public decision has been made. Secondly, no bush land except that newly cleared is ploughed before sowing. The previous season's weeding, using plough and hoe, has left new ridges between the old lines of millet, on which the new millet in sown. By this

Figure 23. *Cultural operations as a function of rainfall distribution (village A, 1980).*



Source: Compiled by authors.

Table 22. *Main crops by land use zone (village A, 1980).*

	Zone A Village fields	Zone B Former bush fields	Zone C Bush field	Zone C Newly cleared land
% of land devoted to:				
Millet & cowpeas	99[a]	-	100[a]	83[a]
Peanuts	+[b]	54	-	16
Voandzou	-	31	-	1
Fonio	-	15	-	-
Sorghum	+	-	-	-
Maize	+	-	-	-

a/ Proportion of cowpea to millet, measured at harvest, was 8% in the village fields and 4% in the bush fields.

b/ + indicates the presence of a crop in small quantities.

Source: Compiled by authors.

means farmers avoid the need to plough in the following year, so that fields can then be sown as fast as possible. Thirdly, households which have rapidly sown and weeded their old bush land are free to take advantage of whatever rain falls during the rest of June and early July to plough and sow the new bush land cleared during the dry season and to be added to the bush field that year. A household's capacity to plough new land early depends on the proportion of new land to old, the number and level of nutrition of their work oxen, soil type and luck with rainfall. Lastly, village fields must be ploughed before sowing. The previous year's ridges are almost completely destroyed, grass has become established and manure has to be mixed into the soil. As with newly cleared bush fields, ploughing produces closely spaced ridges. Weeding is then effected in such a way as to re-inforce the existing ridges, unlike the weeding practice used in established bush fields.

The ploughs used are of two kinds, a two-blade ridging plough for preparing village, groundnut, voandzou and new bush fields for sowing and a single-blade plough for weeding. Both types were introduced in the 1940s, becoming widespread by the 1960s. The 1980 distribution of ploughs in villages A and B is shown in Table 23.

Table 23. *Households with permanent access to a plough team (village A and B, 1980).*

Households with:	Ox-plough team	Donkey-plough team	None
Village A	26 (90%)	0	3 (10%)
Village B	6 (27%)	11 (50%)	5 (23%)

A household relying on borrowed oxen or plough is obviously at a disadvantage in terms of timing its operations in accordance with rainfall. When rainfall is infrequent and unpredictable, the farmer's ability to take advantage of every passing shower is an important determinant of final yield. Often a household keeps three oxen for one plough, so that despite the poor level of nutrition for work oxen at the start of the cultivation season, rotating the animals allows a longer period of work during the day. The spare animal is left to graze at the edge of the field.

3.2.5 Labour

Most households obtain all their labour during the cultivation season from their own members. The household may claim the labour of its members for work in the field from the beginning of the rainy season to the end of the harvest. Only Mondays are reserved for crops other than the household millet field and for individual production. Farming for the household is undertaken by all fit members, both men and women, between the ages of (approximately) 12 and 55. The ages at which children start work and at which old men and women are permitted to stop vary with household circumstances and age-structure. The same applies to the contribution of unmarried girls.

Old men and women, no longer required to work in the household field, cultivate small plots of their own, combining this part-time work with keeping an eye on small children left in the village, and the management of smallstock during the rainy season. Women of working age also cultivate individual plots on Mondays and at other spare moments. Farming activities are also undertaken by the youth association, or *ton*. In some villages, the *ton* cultivates its own millet field, calling on its members for two mornings' work per week during the rainy season.

The culcivation season witnesses a period of intense activity in the field. The shortness of the rainy season and the unreliability of rainfall require maximum labour output by the household while there is still moisture in the soil. The length of the male working day increases from 7 - 8 hours of work during June and early July to 9 - 10 hours from mid-July to mid-September, when weeding demands are greatest. Women work shorter hours in the field because of household duties and food preparation. Labour allocation during the cultivation period is illustrated in Table 24 and 25.

Table 24. *Land to labour proportions for different fields (village A, 1980).*

	Village fields		Bush fields	
	Average	Range	Average	Range
Size of household field field (ha)	4.2	1.1-9.3	23.5	6.4-58.9
Hectares/worker[a/]	0.6	0.2-2.0	3.1	1.6-4.2
Fields measured	13		28	

[a/] A system of weights was adopted to construct a broad index of a household work force, according to the following approximate age-categories: youths and men (aged 15-55 years) = 1.0; girls and women (aged 15-50 years = 0.7; young boys and girls (aged 12-15 years) = 0.4.

Source: Compiled by authors.

Table 25. *Distribution of labour between different crops (village A, 1980)*[a/]

	Man-days (excluding harvest)		
	Average (%)	Lowest (%)	Highest (%)
Bush-field millet *(sanyo)*	78.3	65.2	82.7
Village-field millet *(souna)*	12.7	7.5	21.8
Groundnuts	6.2	0;8	12.7
Voandzou	2.3	0.0	4.4

[a/] Excluding the 5 households with newly cleared bush fields.

Source: Compiled by authors.

Non-household labour during the cultivation season is relatively insignificant, although it may be vital for the individual household concerned. It may come from a variety of sources:

(a) grain-deficit households may send a youth to work for another household in exchange for millet (4-5 kg per day);
(b) exchange of labour between households;
(c) *ton* labour, hired by the household head to help weed a field that has got out of hand;
(d) hired labour from outside the village (two cases in 1980, both in village B);
(e) visitors and friends;
(f) labour in exchange for services, such as loan of a plough team.

Labour from outside the household nevertheless becomes significant after the cultivation period, during harvesting and winnowing. At this time women and girls travel to stay with relatives in other villages and participate in harvesting the two millet crops and in winnowing, of which the latter is a uniquely female activity. For this work they are paid in grain, and after 3 or 4 months they may leave with up to 300 kg of millet. During this period in 1980 village A received 80 visitors and village B 15.

Labour for threshing is mobilized through the age-set. All the age-sets comprising the *ton* are required to participate, their seniors supervising and working when necessary. In village A and most larger villages, threshing is done on a ward or *quartier* rather than a village basis, as are other communal operations such as the digging and finishing of wells.

3.2.6 1980 crop yields

Millet was the only crop harvested in 1980 in village A, apart from small quantities of fonio, groundnuts and voandzou. The last of the rains fell in the first week of September, although normally rainfall might have been expected to continue into October. Many groundnut and voandzou fields did not even produce enough to provide next year's seed, because of late planting in an exceptionally short rainy season. Most of the millet sown on the new bush land did not produce grain, having in many cases been sown as late as the second week in August.

The average millet yield recorded by ILCA for 13 village fields was 1150 kg/ha, whereas for 22 bush fields it was only 225 kg/ha. According to the villagers, 1980 was an exceptionally good year for the village fields, cropping the early maturing variety of millet, but the bush field harvest was very poor. The large difference in yields is therefore probably abnormal.

However, the experience of the same village over different years and of different villages in the same year leads to the conclusion that concepts such as 'normal' and 'average' performance are not very useful in any case. For example, the 1980 harvest from village fields of a village only 50 km west of village A failed completely. It is thus evident that when the rains are short, 'good' and 'bad' years are highly localized, largely dependent on the haphazardous distribution of rainfall. At any rate, no significant correlation was obtained between work input and yield per hectare for either village or bush fields. A multi-variate analysis for bush field yields s in progress, taking account of a number of factors, notably the proportion of new land to old and the date of sowing.

Both village and bush fields are extremely heterogenous, the former with regard to the amount of manure received, and the latter with their variety of soils, termite mounds, baobab groves and other features. Bush fields also vary in age-structure: in other words the proportion of the field made up of land cleared in different years varies. These factors would clearly influence yield, and in a year in which the rains end early, the proportion of new land to old and the speed at which it is sown are obviously important. The amount of time devoted to weeding and the speed at which the first weeding is accomplished also have significant influence on yields, although for the village fields it is likely that, in a year like 1980 when the short-cycle millet got off to a very good start, the most important determinant is the level of manuring rather than the weeding effected.

The average yield per worker in village A for 1980 was 1200 kg of millet, consisting of 700 kg from bush fields and 500 kg from village fields. However, these figures, like those for total yields, must be treated with suspicion for the reasons given above.

3.2.7 The village economy

The villages under study operate within two economic spheres. The first is the village itself and its surrounding communities, exhibiting some degree of specialization (farming villages, blacksmith communities, Fulani camps), in which millet is the medium of exchange. The second consists of the regional or national economy, based on cash. The large market towns and urban labour markets, which pay cash to rural migrants, form the fabric of the national economy, to which the government's taxation and grain buying systems also contribute.

Almost all transactions in the local economy can be carried out with millet. Typical goods or services purchased for varying amounts of grain might consist of a new plough or other goods from the blacksmith, herding services from a Fulani, livestock and milk purchases from Fulani and Moor groups, sauce condiments (dried fish, peppers etc) from village or travelling dealers, or assorted services such as hair plaiting, calabsh repairs, etc. The extensive role of millet as a medium of exchange in the local economy is partly a function of the considerable distance from the nearest market, 60 km in the case of village A.

Such involvement in the cash economy as does exist arises from the need for cash to fulfill specific obligations, for instance tax payments or marriage expenses, or make specific purchases, such as a donkey cart or a sack of raw cotton. The main sources of cash are migration earnings, millet and groundnut sales, and sales of livestock or craftwork. The commonest need for cash is the annual tax payment which each household must make: it is this that forces all households into the cash economy at least once a year. A number of petty traders in the village are more extensively involved in the cash economy.

Details of household budgets, income and expenditure within the millet and cash systems, are being collected for the two villages under intensive study. As regards expenditure, wells are a major investment item for households in village A, where a system of privately owned wells on household fields is found. This system has developed fairly recently, starting in the late 1950s and accelerating in the 1970s. Eleven wells out of a total of 35 in and around the village were completed over the last 2 years. Only 7 households now own no well, while 17 own one well and 5 own two. Eight of the 35 wells are not privately owned. The wells are dug to attract dry-season livestock onto the well-owner's field, water being exchanged for manure. Visiting Fulani and Moor make an agreement with a well-owner at the beginning of the dry season. The importance attached to the manuring of fields for the short-cycle *souna* crop may be judged from Table 26, which shows the livestock numbers watering at village A during the 1980-81 dry season.

In 1981 it cost some MF 50,000 to dig a well if a blacksmith was hired to do it. Some households, however, use their own labour if the well is dug during the dry season. The well also has to be dug out again every few years to prevent it silting up; this cost MF 5000 - 10,000 in 1981.

Table 26. *Dry-season watering of livestock (village A, 1980/81).*

Date	Cattle			Sheep and goats		
	Village	Visiting	Total	Village	Visiting	Total
December 1980	700	300	1000	700	0	700
February 1981	700	1100	1800	700	1250	1950
May 1981	700	800	1500	700	1250	1950

Source: Compiled by authors.

Returns on the investment can be expected in the form of higher yields of *souna* millet. An outlay of MF 50,000 is equivalent to 666 kg of millet at the official government price for 1981. The average size of herd that can be watered at a typical well is rather less than 100 cattle or their sheep/goat equivalent. Given the variability of rainfall, such a sum may therefore well not be returned in the following year.

Dry-season visiting herds are not the only source of fertilizer available. For example, a cattle owner forming part of a village or local herding group with 'n' members is entitled to have the herd on his land every 'n^{th}' year. Manure can be brought from the rainy-season pastures by anyone with an animal in the herding group. Village rubbish, another source of fertilizer, is transported by carts either from individual households or from the rubbish tips on the edge of the settlement; such transport may be by the household's own cart, or paid at the rate of 1 measure of millet per trip (the main clients in the latter case being women). Chemical fertilizer is almost never used: it is considered expensive and effectively unavailable.

The 1981 costs of wells and other major farm investments are shown in Table 27.

Table 27. *Costs of major farm investments in MF and in millet (village A, 1981).*

Item	Cash cost (MF)	Millet equivalent (kg)
Single-blade weeder	15,000	200
Double-blade soil breaker	25,000	333
New donkey cart	50-75,000	666-1000
Adult male donkey	45-60,000	600-800
Young ox (2-3 years)	35-45,000	466-600
Well (blacksmith's digging fee)	50,000	666

Source: Compiled by authors.

3.3 LIVESTOCK PRODUCTION

3.3.1 Materials and methods

Studies on animal production began at the outset of the intensive phase in January 1978 with the setting up of a continuous recording system for representative herds in both the irrigated rice and rainfed millet subsystems of the agropastoral system. By the end of January 1981 data for a continuous 3-year period were thus available for a number of herds, but further herds had been added at different times over the study period, such that the basis for data analysis was as shown in Table 28.

Table 28. *Distribution by system, village, flock and species of animals used in long-term data analysis.*

Species	Animals recorded (31.1.81) Millet subsystem: Villages	Millet subsystem: Flocks	Millet subsystem: No	Rice subsystem: Villages	Rice subsystem: Flocks	Rice subsystem: No	Animals previously recorded	Total animals
Sheep	3	15	288	4	16	205	773	1266
Goats	5	14	449	2	6	173	886	1508
Cattle	3	4	222	2	5	400	112	734
Total	4	17	959	4	18	778	1771	3508

Source: Compiled by author.

Initial problem analysis had consisted of fieldwork and a review of the available literature. The fieldwork was concerned with the establishment of parameters which could not be obtained from study of the literature. It concentrated largely on demographic studies of small ruminants (in the pastoral as well as the agropastoral system) and of the cattle herds in the irrigated rice sector of the agropastoral system. From the population structures established by questioning herders or owners and from a knowledge of livestock population dynamics in similar production systems in analogous ecological zones, it was possible to establish livestock production parameters which were adequate, at the time, as a basis for further studies. In total more than 10,000 head of animals were physically handled and examined during this stage, and life histories were constructed for a large proportion of them.

A number of owners in several villages in both millet- and rice-cultivating situations were subsequently selected for continuous monitoring of their herds and flocks over the longer term. The large numbers of animals (see Table 28) involved in the study, giving rise to some 7,500 animal-years of data, have probably reduced any bias inherent in the sample, which was not randomly selected.

At the start of the survey each animal was identified individually by an eartag. As much information as possible was obtained on the animal - age (by dentition and/or owner's estimate), weight, sex, physical description, relationships with other animals in the group - and an individual record card established. Visits to each group were made regularly, at intervals of about 2 or 3 weeks for small ruminants and of 2 months for cattle, throughout the period of study. At each visit all events such as births, deaths, slaughters and sales occurring since the previous visit were recorded and entered on field data sheets for subsequent transfer to the individual record cards.

In the early stages the data were analysed using pocket calculators. However, the analysis reported here was carried out on ILCA's HP 3000 - III computer, using the Statistical Package for the Social Sciences (SPSS) and Sysnova. The latter is a general least squares technique (i.e. multiple regression) in which "dummy variates" correspond to treatment effects and models are solved by the method of fitting constants.

3.3.2 Cattle

The first step towards assessing cattle productivity was to determine herd structures in the two subsystems and compare them with those in pastoral systems. The results, summarized in Table 29, amply demonstrate the effect of management objectives on herd structure. The Fulani transhumant herds are primarily a dairy herd with a reserve of mature males for transfer as draught animals to the neighbouring agropastoral systems The herds of the latter, in particular those of the rice subsystem, cannot maintain themselves in a stable state, and mature draught animals have to be purchased from outside to maintain herd numbers and structure. Such an unbalanced herd structure has obvious repercussions on the stocking rate, and as a result each head of cattle in the rice subsystem has to be counted as 0.94 of a TLU and each in the millet subsystem as 0.90. These levels compare with a "normal" value for cattle herds of 0.73 TLU per head.

Table 29. *Cattle herd structures relative to production systems.*

Sex and age group	Type of herd (% of all animals)			
	Rainfed millet	Irrigated rice	Delta[a] pastoral	Theoretical[b] stable state zebu
Males:				
1 year	5.6	7.2	9.9	9
1-3 years	8.5	9.3	12.5	13
3 years	32.7	46.3	15.6	6
Total	46.8	62.8	38.0	28
Females:				
1 year	6.2	5.7	10.2	9
1-3 years	11.3	11.1	15.2	22
3 years	35.7	20.2	36.1	[illegible]
Total	53.2	37.0	62.0	72
Oxen as % of total herd	32.3	43.4	9.3	-

Sources: Author and
[a] Coulomb (1972).
[b] Ministère de la coopération.

Various parameters affecting reproductive performance were obtained, including total lifetime production of calves, age at first calving, calving rate and interval, seasonal distribution of births and breeding cow longevity. The ILCA data were then compared with results from other sources in Mali. Lifetime production of calves under the improved conditions of the Station du Sahel averages five per female (ILCA, 1978). However, under traditional management a relatively small number of animals produce more than four calves (Table 30), and in the ILCA data, where reproductive histories of individual cattle are known, a similar pattern has emerged. Most cows, then, do not have more than four offspring and, of a total of 339 calves recorded, only 10 were of fifth parity and only 3 of sixth parity.

Table 30. *Number of parturitions per breeding cow in Mopti sedentary cattle.*

Age (years)	Number of calves								Total		Number of cow reproductive years
	0	1	2	3	4	5	6	7+	Cows	Calves	
0 - 1	197								197		
1 - 2	180								180		
2 - 3	205	1							206	1	
3 - 4	145	27	1						173	29	86.5
4 - 5	28	95	14						137	123	205.5
5 - 6	12	56	43	2	2				115	156	287.5
6 - 7	6	23	51	19	1				100	186	350.0
7 - 8	2	3	18	20	31				74	223	333.0
8 - 9		1	7	8	6	4			26	83	143.0
9 -10	1		2	7	18	7	3		38	150	247.0
10+	1			1	3			1	6	23	45.0
Total	777	206	136	57	61	11	3	1	1,252	974	1,697.5

Source: Coulomb (1972)

Table 30 gives a theoretical calving rate for traditional herds of 57.4% over the long term. Calculations based on the herd structures given in Table 29 results in rates of roughly 52% for the millet subsystem and slightly over 70% for the rice subsystem, if calf mortality of 30% is assumed. On the Station du Sahel the calving rate (calculated from the calving interval) increased from 65% in 1966 to 78% in 1973 (ILCA, 1978)

For practical purposes it is therefore reasonable to assume that the long-term calving rate in the agropastoral system is in the region of 60% of cows in the herd over 3 years of age, and that it is slightly superior in the rice subsystem.

The calving interval observed at the Station du Sahel fell from 561 days in 1966 to 423 days in 1973. ILCA data on calving intervals are shown in Table 31, from which it can be seen that the mean interval for the 22 known cases in which two parturitions have occurred was 511 days. This represents calving percentage of 71.4% which might be appropriate for the rice subsystem, although in fact the data relate to both millet and rice sectors. It is likely that, as the study has only been effective for a period of 2½ years, only the shorter intervals have so far been obtained, and in a longer-term investigation the overall interval would increase, perhaps to about 600 days. If this were the case then an overall calving rate of 60% could be assumed. (In fact the addition of a further 10 calving intervals to the end of April 1981 has already had the effect of extending the mean interval to 531.5 days). While it is likely that the present parturition interval is on the low side, the pattern shown in Table 31, of a reduction in interval up to the fourth parity followed by an increased interval thereafter, is probably accurate.

Table 31. *Recorded parturition intervals for cattle in the agropastoral study herds.*

Birth parity	Interval in days	± 1.s.d.	n
1 - 2	578.0	272.94	2
2 - 3	490.8	361.41	6
3 - 4	321.3	397.97	6
5 - 6	493.0		1
"9" (3)	674.0	196.80	7
All births	510.9	321.22	22

Source: Compiled by author.

From Table 30 it can be calculated that the cumulative percentage of animals having had at least one calf is 0.5%, 16.2%, 79.6% and 89.6% for females having reached 3, 4, 5 and 6 years of age respectively. The mean age at first calving for traditional herds was 51 months. On the Station du Sahel, year of birth was found to be the most significant factor affecting age at first calving, which varied between 36.7 and 58.2 months. In the present ILCA study, where first parturitions have occurred since recording began, 2 took place while the dam had two pairs of permanent incisors (2.5 - 3.25 years), 15 while the dam had three pairs of permanent incisors (3.25 - 4.25 years) and 11 while the dam had four pairs of permanent incisors (over 4.25 years).

During the continuous studies a total of 150 calves were born into the herds up to 31 December 1980. No specific management practices are aimed at controlling the breeding season in either of the subsystems. However, it is apparent from Figure 24 that a marked seasonality occurs in conceptions, so that the majority (61%) of calvings occur from mid-April to early July. Most conceptions must therefore occur from mid-July to early October, coinciding with improved nutritional status during rainy season.

As regards breeding cow longevity, the average figure of 51 months at first parturition found for traditional herds, together with the assumed average calving interval of thereafter, 600 days imply that cows having had four calves have reached an average age of 9 years 7 months. If culling usually occurs after weaning of the fourth calf (as has been inferred from Table 30 and from reconstruction of calving histories), then the majority of cows are removed from the herd at between 10 and 12 years of age.

Turning to weight and growth, although actual birth weights were recorded, extrapolation from subsequent weighings gave indicative weights of 18 kg for males and 16 kg for females. These results compare with 20.5 kg and 19.9 kg for males and females respectively on the Station du Sahel, a difference which can be accounted for by breed characteristics - there are large numbers of Moor cattle on the Station as opposed to Delta Fulani, which predominate in the traditional sector - and by the better management and nutrition on the station.

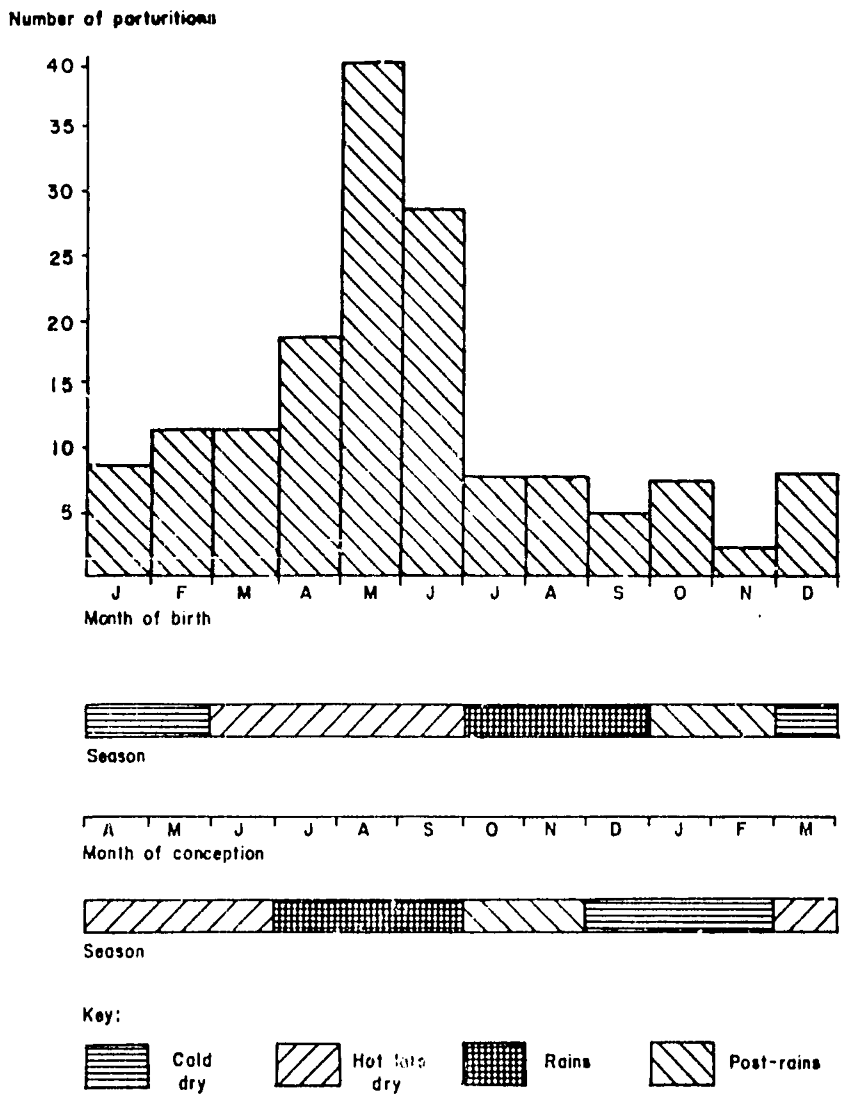
To monitor growth from birth to maturity, scattergrams were computed for animals of known birth date using SPSS and regression equations calculated for all data points from 0 to 730 days of age. The calculated linear regressions for these data were:

Female calves: $y = 30.3 + 0.137x \quad r^2 = 0.77$

Male calves: $y = 23.2 + 0.180x \quad r^2 = 0.84$

Pooled data: $y = 26.5 + 0.160x \quad r^2 = 0.80$

Figure 24. *Distribution of parturitions by month of birth for cattle in the agropastoral system.*



Source: Compiled by author

where y is the weight in kg at x days of age and r^2 is the correlation co-efficient. There is no significant difference between the growth rates of males and females, between the two subsystems. Further studies over a longer term may well show significant differences, however.

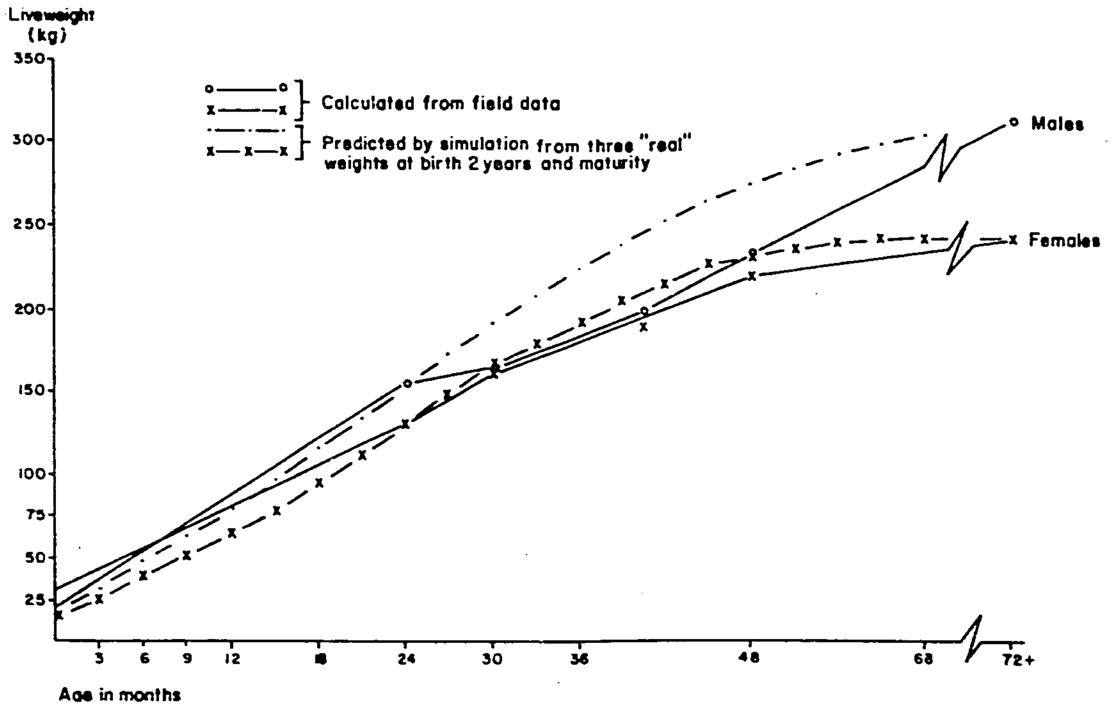
For animals over 2 years old all data were pooled for those in a given dentition group (1, 2, 3 and 4 pairs of permanent incisors) and the result was assumed to be the average weight for age at the supposed mid-point between the times of eruption of these pairs of teeth. The growth curves from birth to maturity (when males averaged 314 kg and females 242 kg) are plotted in Figure 25. Superimposed on this figure is the simulated average weight from birth to 72 months based on the parameters of 18 and 16 kg birthweights for males and females, the mature male and female weights just quoted and an inflection in the growth curve at 2 years of age, corresponding to 154 kg for males and 130 kg for females. The low observed weights of males in the middle age groups present a anomaly. Perhaps they are partly due to the small numbers of animals in these data sets, a problem which may be overcome by the addition of further data for 1981.

The marked seasonal changes in the semi-arid zone are reflected in the considerable changes in weight which occur in older cattle. As can be seen from Figure 26 there is virtually no period in the year when weight remains constant. Maximum gains occur with the flush of new growth brought on by the July rains, which continue into August and September. It is probable that some constancy of weight is achieved overall during the latter part of the rains and during the early part of the post-rains period. However, the reduced digestibility of rangeland forage is not fully compensated by the availability of crop residues in the cold dry season from December to the end of February, and when these are exhausted the hot dry period from March to the end of June exerts considerable pressure on the animal, as is shown by the accelerated weight loss during this time.

Mortality in the continuous study herds was lower than might have been expected. It is possible that the 2 years (1979 and 1980) for which firm data are available were not fully representative. Mortality in calves to 1 year old was 21% of animals born, and over 1 year old it was 3.15%. For the whole herd mortality was 6.91% per year.

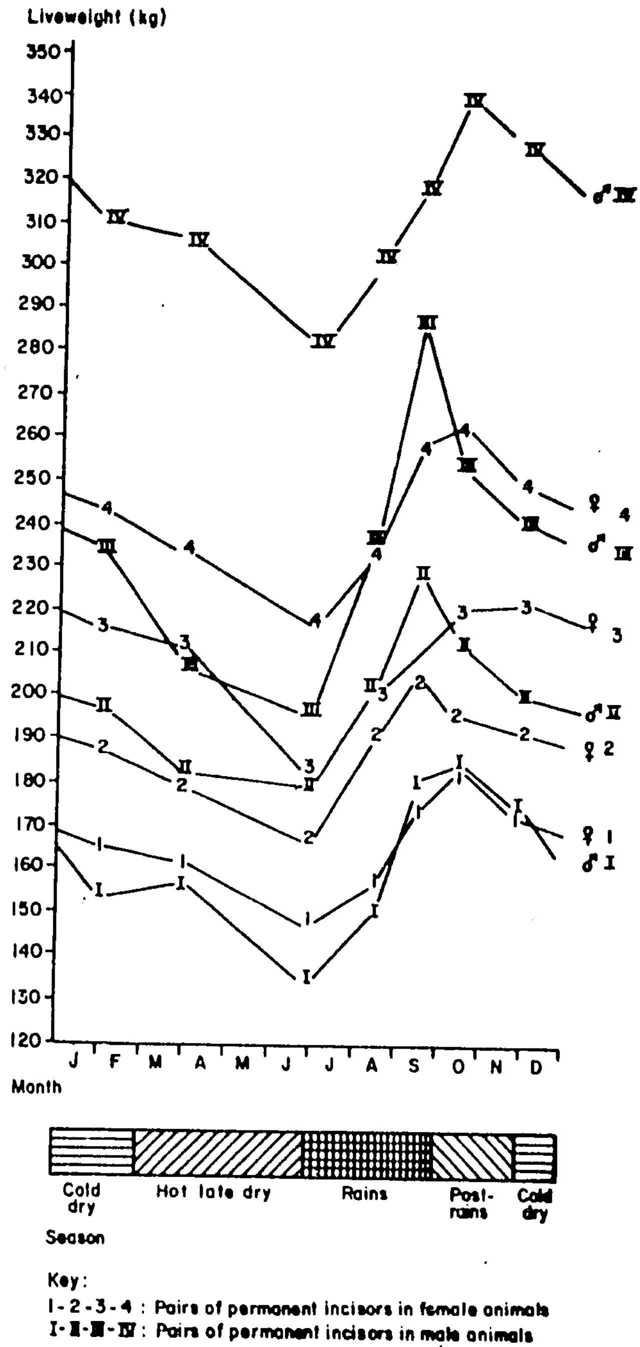
As regards offtake, sales amounted to 7.4% of all animals in the herds. They consisted of old cows sold for local slaughter, and older work oxen, which are bought mainly for transfer outside the region, either to

Figure 25. *Cattle growth curves in the agropastoral system.*



Source: Compiled by author.

Figure 26. *Seasonal weight changes for cattle of specified sex and age.*



Source: Compiled by author.

Bamako or towards the meat-deficient countries to the south. A small number of animals were removed from the herds as gifts, while only one was slaughtered for home consumption.

3.3.3 Small ruminants

If cattle are considered as the capital or deposit account of a livestock enterprise, then it is reasonable to contend that sheep and goats are its current account. Flocks are characterized by a rapid turnover of new entrants - particularly males - and the balance in the account is constantly changing. In spite of this rapid turnover the composition of the flock (Table 32) remains remarkably constant in terms of sex and age structure under normal conditions. This statement is obviously difficult to justify at the level of the household flocks, where numbers in the group are very small, but it is true at the wider level of the extended family, the village and the system. Without exception in the semi-arid zone, traditionally-owned subsistence flocks are breeding units aimed at producing the maximum number of young with a view to the home consumption or sale of male for meat, and to the replacement of older breeding females by younger ones. Milk, more especially from goats, is a by-product of these management aims in the agropastoral system. The need for small amounts of cash for such items as personal taxes, condiments and other foods which are not home produced can easily be met by the sale of a sheep or goat. Commercial offtake of this nature is very often an older female (45% of goats and 70% of sheep slaughtered over a 2-year period at Niono abattoir were mature females, indicating that most male sheep and a fair number of male goats are retained for home consumption).

The effects on flock structure of these management objectives are such that females account for about 75% of total flock numbers and that breeding females (considered to be all females over 10 months old) are about 55% of all animals, as shown by Table 32 for several situations in the agropastoral systems of central Mali. There are no significant differences in flock structure between the millet and rice subsystems (management objectives evidently being the same or very nearly so) and no attempt has therefore been made to treat them separately. Castrates are numerically unimportant in both sheep and goat flocks except in the case of the Moor pastoralists, whose major management objective for sheep is to provide hair for tent manufacture.

Table 37. *Sheep and goat flock structures relative to production systems.*

Area/ethnic group	Sheep				Goats			
	Males (%)		Females (%)		Males (%)		Females (%)	
	Total	Older than 15 months	Total	"Breeding"	Total	Older than 15 months	Total	"Breeding"
Dalonkebougou/Bambara	24.5	2.8	75.5	54.4	29.5	8.6	70.6	50.5
Niono/millet and rice	25.5	5.2	74.5	52.8	24.9	5.5	75.1	56.4
Dalonkebougou/Moor	22.0	7.0	78.1	58.1	20.2	3.2	79.8	55.1
Dead delta/Fulani					28.6	7.9	71.4	56.9
Goundam/Tuareg and Fulani					26.2	6.8	73.8	53.5
Ségou/Fulani	25.9	1.2	74.1	52.3	22.7	2.2	77.3	51.8
Diafarabé/mixed	29.1	5.5	70.9	50.2				

Source: Compiled by author.

As in the case of cattle, the parameters of reproductive performance were analysed. Enquiries during the intensive phase showed that the number of parturitions per breeding female (not the number of young produced, because this is affected by multiple births) could be as high as 8 for sheep and 10 for goats. By the end of January 1981 data had been obtained on 862 parturitions for sheep, of which 24.6% were fifth parity or greater and 5.3% were seventh parity or greater, with a maximum parity of 10. Data on 943 goat parturitions had also been collected by the same date, of which 35.8% were fifth parity or above and 8.2% were seventh or above, again with a maximum parity of 10. It can thus be concluded that goats generally have longer productive lives than sheep. By the end of 1981 data on parities up to the twelfth may well have been obtained.

Table 33 gives details of births in the continuous study flocks since January 1978. Not unexpected, goats have a higher incidence of multiple births, greater than that generally given for indigenous goats in the semi-arid zone, while that for sheep is about the same as the accepted norm for this species. Average litter size estimated from least squares means was 1.20 for goats and 1.06 for sheep. The analysis of variance showed that species, parity and season of birth all significantly affect litter size in both the millet subsystems but that individual flocks with the rice subsystem did not differ. There were highly significant differences between parities across the two species.

Table 33. *Births in sheep and goat flocks during the continuous study period in the agropastoral system.*

Parameter	Goats	Sheep
Number (%) of parturitions	756 (100.0)	734 (100.0)
Single	581 (76.8)	697 (95.0)
Twin	170 (22.5)	36 (4.9)
Triplet	5 (0.7)	1 (0.1)
Number (%) of young	936 (100.0)	772 (100.0)
Single	581 (62.1)	697 (90.3)
Twin	340 (36.3)	72 (9.3)
Triplet	15 (1.6)	3 (0.4)

Source: Compiled by author.

The distribution of parturition intervals observed in the continuous study flocks is shown in Figure 27. The analysis of variance on the least squares means for this trait showed that parity, season and flock in the millet subsystem have significant effects on the interval, while there are no differences between species, systems or flocks in the rice subsystem. There are no interactive effects of parity with species, the parturition interval decreasing with each successive parity for both sheep and goats. The effects of the season in which the previous birth took place are very pronounced: when birth occurs in the hot late dry season (March - June), the subsequent parturition interval is 28 days le than the mean, showing the influence of nutrition during the rainy season. For births during the rains (July - September) there is a slight effect, while birth during the post-rains period (October - November) has the effect of lengthening the next interval.

In traditional flocks with open breeding seasons and constantly changing numbers of animals, percentage birth rate is one of the most difficult parameters to determine and is the subject of much controversy. An attempt has been made to solve this problem in two ways:

1. By using two components of the annual reproduction rate, namely the mean parturition interval and the average litter size. The contributions of these two components are shown in Figure 28. The calculation used is:

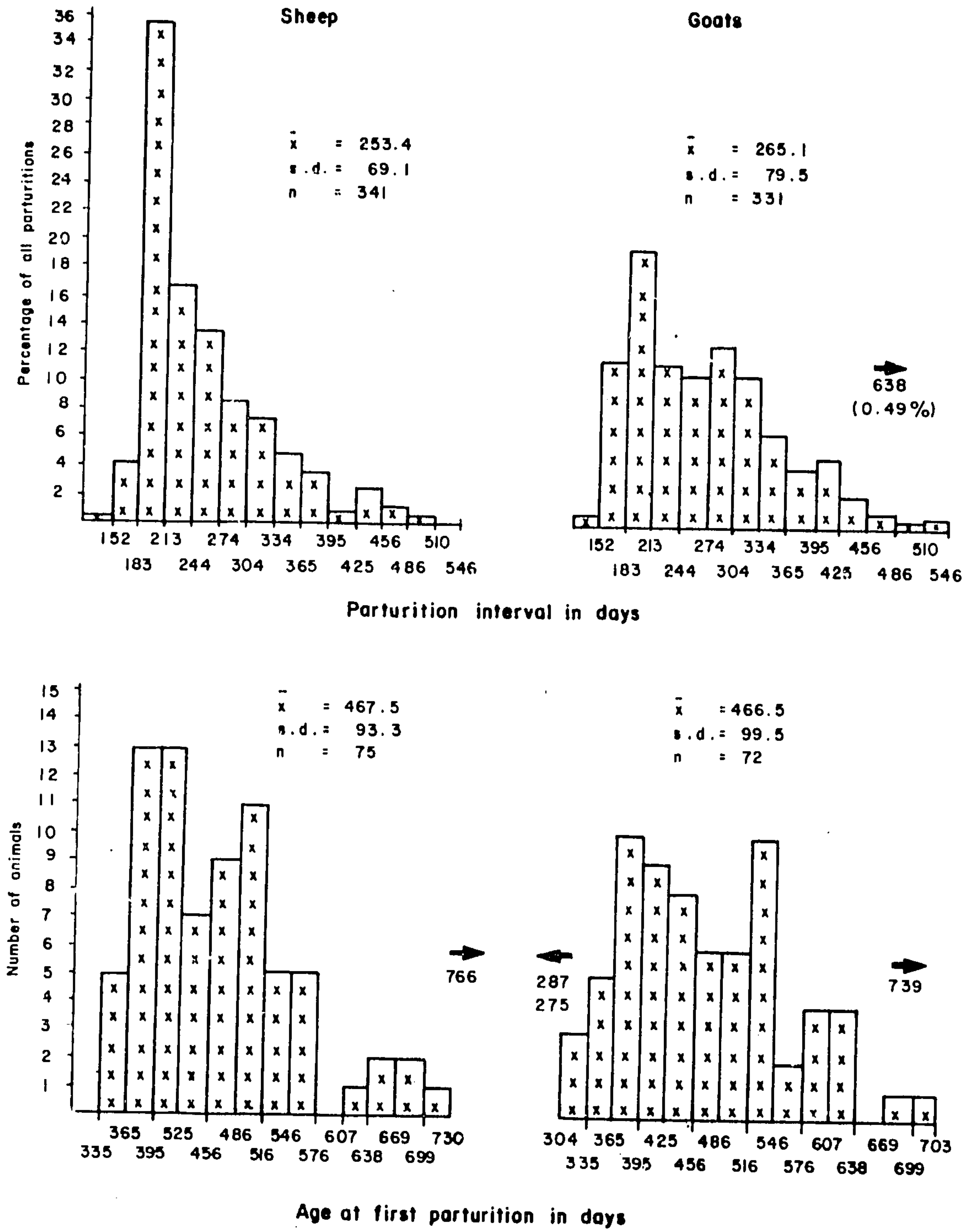
$$\text{Annual reproduction rate} = \frac{\text{Average litter size x 365}}{\text{Parturition interval}}$$

and, using the least squares means, gives an annual kidding rate of 167.7% (1.68 kids per breeding female per year) and a lambing rate of 160.6% (1.61 lambs per breeding female per year).

2. By calculating the number of young born in each month as a percentage of breeding females (those over 10 months old) in the flock at the end of that month and then adding the totals for 12 months. The data obtained by this method are shown in Figure 29. For goats the 3-year average is 140% and for sheep 125%.

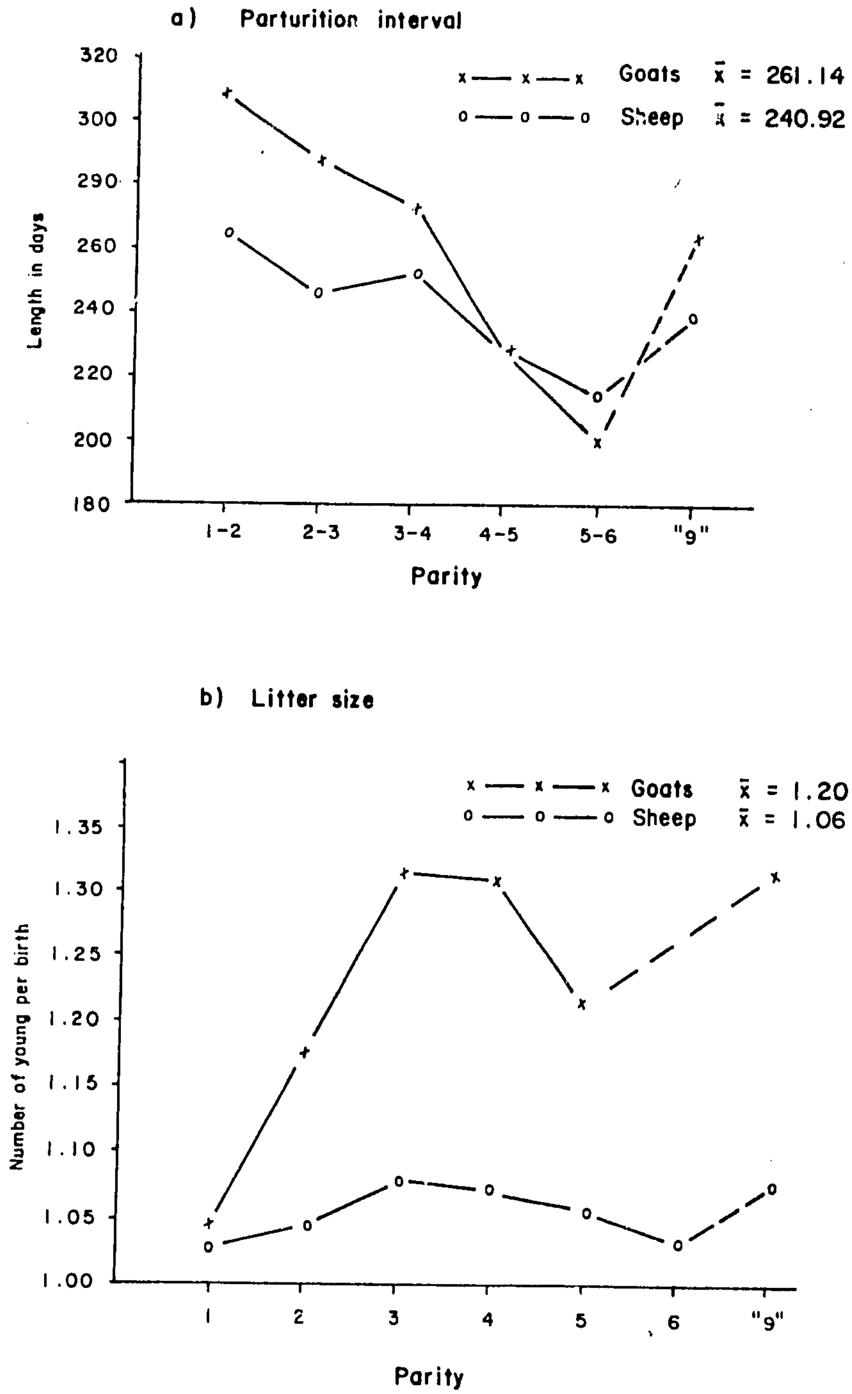
The first method suffers from taking into account only those animals which gave birth more than once during any study period, and in any case it accounts only for those females which actually produced young. The second method undoubtedly errs on the other side since it considers all females, a number of which were not available for service during the previous

Figure 27. *Distribution of parturition intervals and age at first parturition in small ruminants in the agropastoral system.*



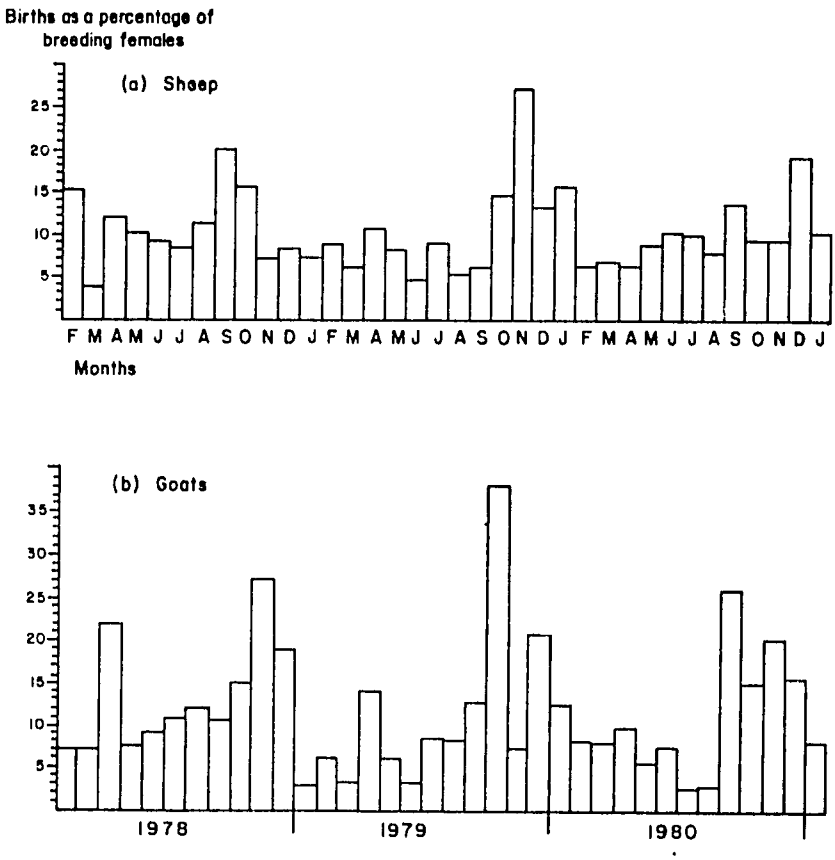
Source: Compiled by author.

Figure 28. *Components of percentage birth rate in goats and sheep.*



Source: Compiled by author.

Figure 29. *Monthly births as a percentage of breeding females present in the observed flocks at the end of the month.*



Source: Compiled by author.

gestacion period. It is thus probable that the true reproductive rate falls somewhere between the two figures, and is around 150 - 160% for goats and 135 - 145% for sheep.

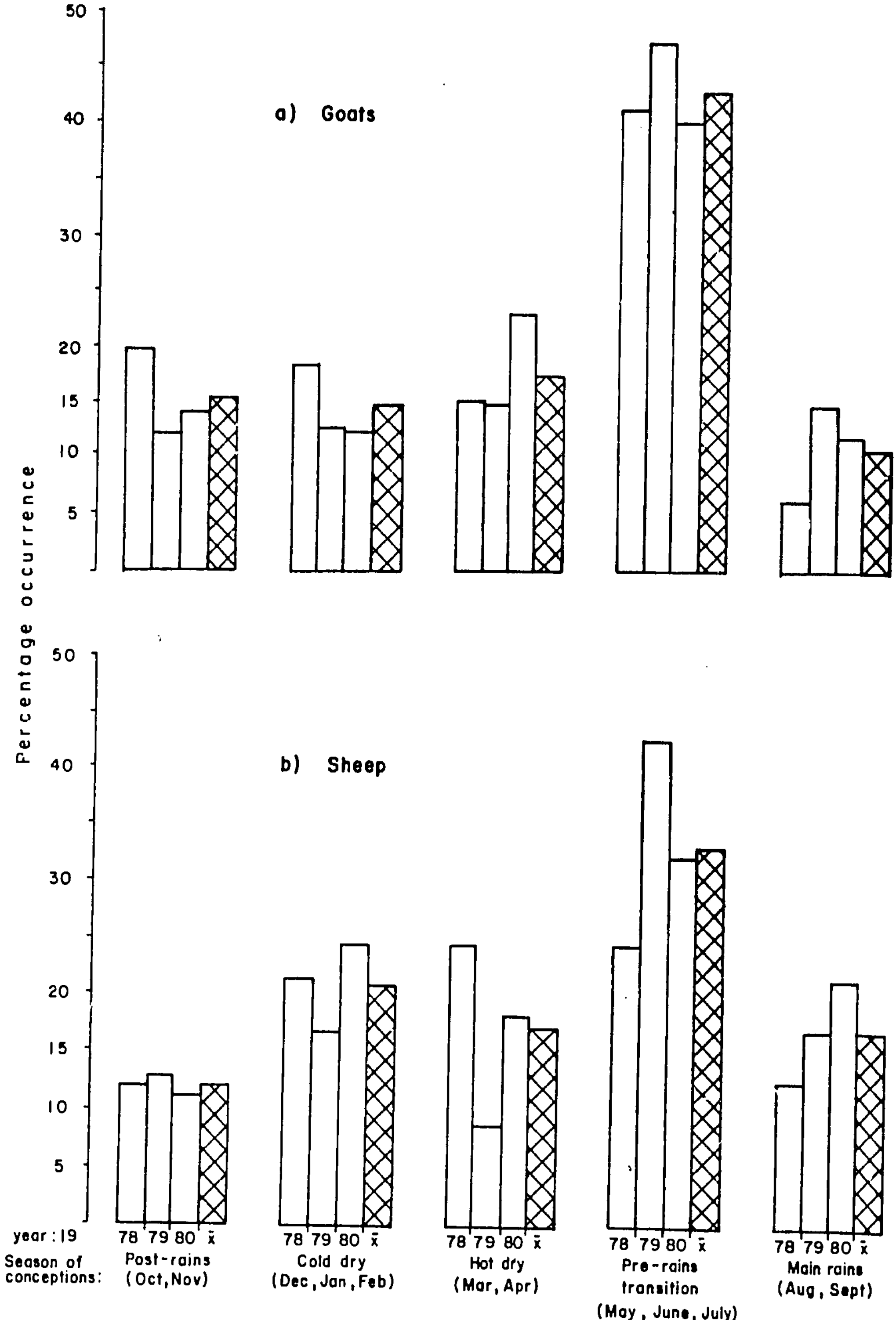
The observed ages at first parturition for sheep and goats are shown in Figure 27. The least squares means for various factors (system, species, birth type, parity, birth month and flock) were all of no significance (P = >0.05), although there was a continuous decrease in age at first parturition with increasing parity of the dam.

As Figure 29 clearly indicates, births in both sheep and goats occur throughout the year. However, the impression gained in the field was that births were related to climatic or nutritional events at the time of conception, 5 months previously. Figure 30 analyses the occurrence of conceptions and is based on the number of parturitions 5 months later. There is perhaps some evidence of seasonality here more so in goats than in sheep, although a fifth season had to be created for the effects to be at all apparent. It appears that goats (and, to a lesser extent, sheep) reach maximum fertility in the transition period from hot late dry season - when humidity is high and many browse species are at their best - to early rains. Supporting evidence for this lies in the shorter parturition interval associated with a previous birth in the hot dry season.

The observed age at first parturition in goats was 15.3 months, with subsequent parturitions occurring every 8.7 months. Assuming on average six parturitions per goat, the normal time of culling or death would be at just over 5 years, giving a life-time production of 7.2 young. Goats having had 10 parturition and producing 12 young would be approximately 8 years old. Sheep probably have one less parturition on average than goats, and tend to leave the flock at about 4.5 years, having produced 5.3 young. A sheep having had 10 parturitions would have a longevity similar to that of a goat with the same number of parturitions.

Weight and growth were also examined. Estimated least squares means for the birth weights of sheep and goats are given in Table 24. As might be expected, there is a highly significant difference in species; but differences between sexes are less significant than the effects of type of birth (singles, twins or triplets). Season has no significant effect on birth weight. Because of the paucity of data, flock, parity and systems effects were not included in this analysis.

Figure 30. *Percentage of births in sheep and goats at each season of conception.*



Source: Compiled by author.

Table 34. *Estimated least squares means for birth weight (kg) of sheep and goats in the agro-pastoral system.*

Variable	Sheep		Goats
Overall mean		2.218	
Species mean	2.596		1.840
Sex			
Male	2.698		1.942
Female	2.495		1.739
Birth type			
Single	2.879		2.123
Twin	2.417		1.661
Triplet			1.737

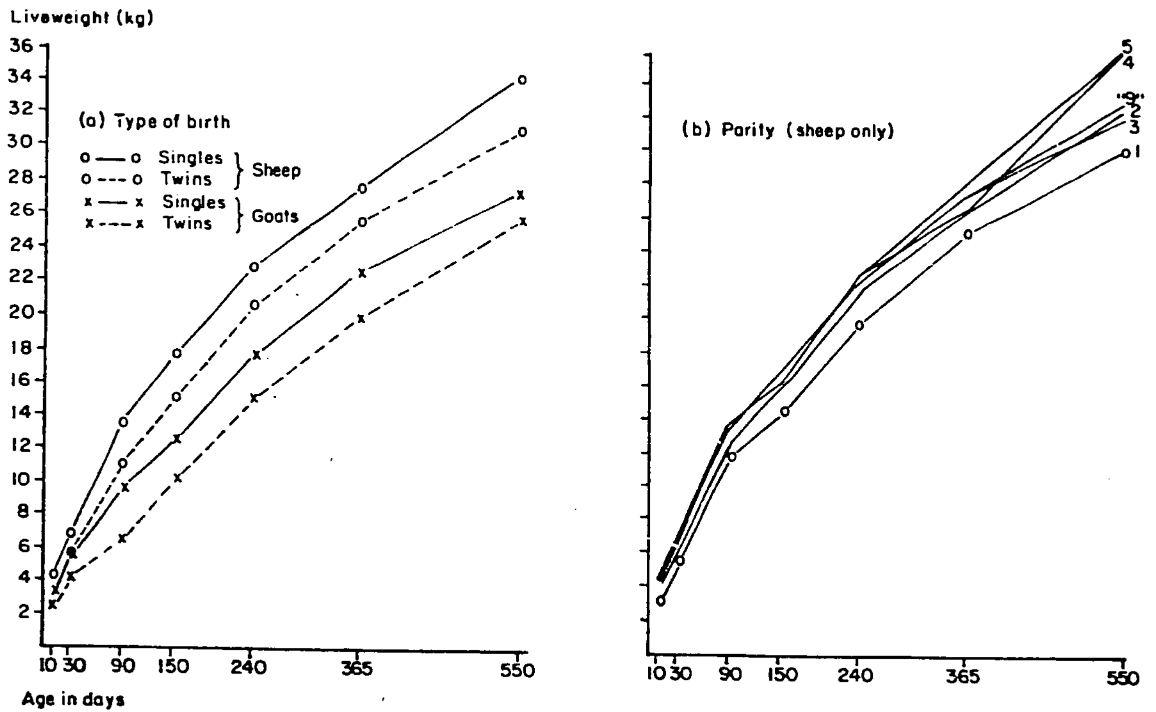
Source: Compiled by author.

A total of 31,804 data points were available for analysis of weight gain and changes. Two types of analysis were carried out for animals of known birth date: least squares estimates of weight at eight specific ages (10, 30, 90, 150 - assumed weaning age - 240, 365, 550 and 730 days), for which weights were calculated by simple interpolation from the single weight nearest to that age above and below it; and a complete analysis of all data points by SPSS, using the scattergram facility of that programme, so as to obtain a better visual impression of the type and range of the growth pattern. The significance levels of the least squares analysis indicated that all the sources of variance are highly significant to at least the age of 1 year.

As regards species effects, sheep are heavier than goats by 0.79, 1.42, 4.70, 4.93, 5.31, 5.57, 6.00 and 2,95 kg respectively at the eight different ages. A similar effect is apparent between sexes, with female weight differing from male by 0.23, 0.44, 1.68, 1.12, 1.84, 2.70, 4.02 and 7.09 kg at the different ages. By 18 months of age, of course, many females are lactating after parturition. This largely accounts for the greater divergence of weights at the last two age points.

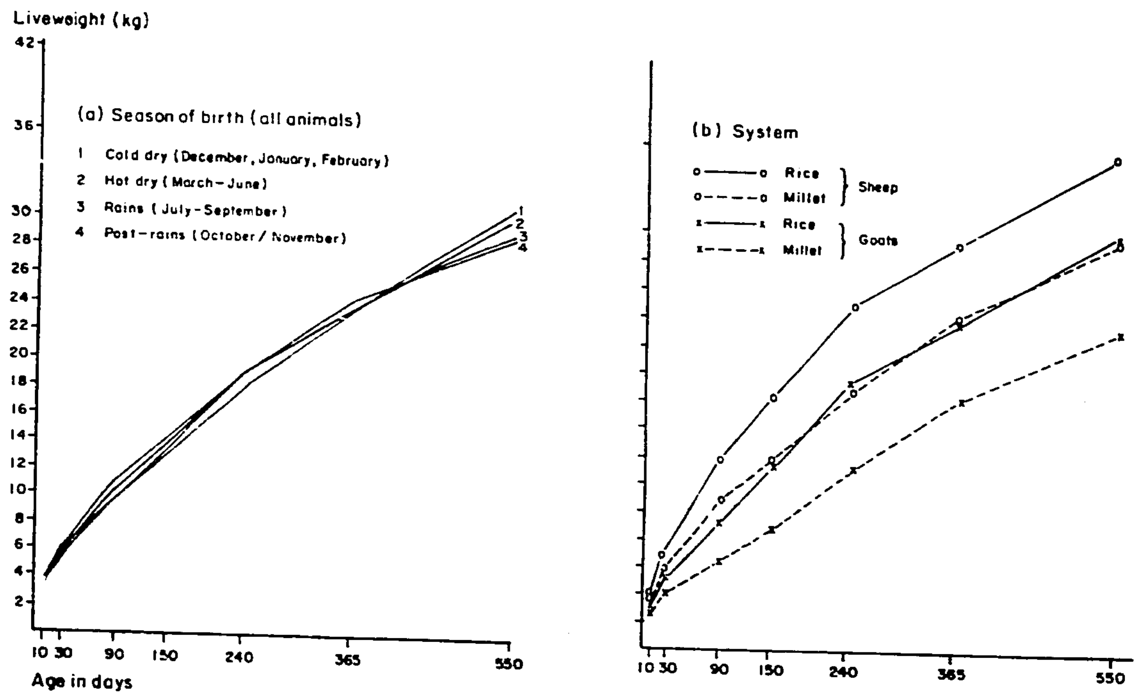
Effects of type of birth, parity, season of birth and system are illustrated in Figures 31 and 32. In general the analyses show the expected pattern of development. The effects of season, while small in real terms, are highly significant: at 150 days there is an advantage of 1 kg, at 240 days of 1.8 kg, at 365 days of 1.4 kg and at 550 days of almost 2 kg. The

Figure 31. *Effects of type of birth and parity on growth of small ruminants.*



Source: Compiled by author.

Figure 32. *Effects of season and system on growth of small ruminants.*



Source: Compiled by author.

most spectacular divergences are between systems: the rice subsystem confers advantages of 4.6 kg at 150 days, 6.1 kg at 240 days, 5.2 kg at 1 year and 6.1 kg at 18 months. For sheep alone the difference is 8 kg at 18 months and 9 kg at 2 years. The computer scattergrams shown as Figures 33 and 34 give a good impression of the growth differences for sheep in these two subsystems. The growth obtained by using SPSS was calculated as a power curve of the form:

$$\log y = \log a + v (\log x + 1)$$

and was very highly significant ($t = 7.084$, $P = <.001$, d.f. ∞).

In both subsystems the effects of flock are very highly significant. Table 35 lists the weight divergence from the average of all flocks at specified ages in the two subsystems. The divergence indicates an enormous variation in performance - and therefore management ability - between flocks, although since animals which died are not taken into account, actual flock performance will be even more divergent.

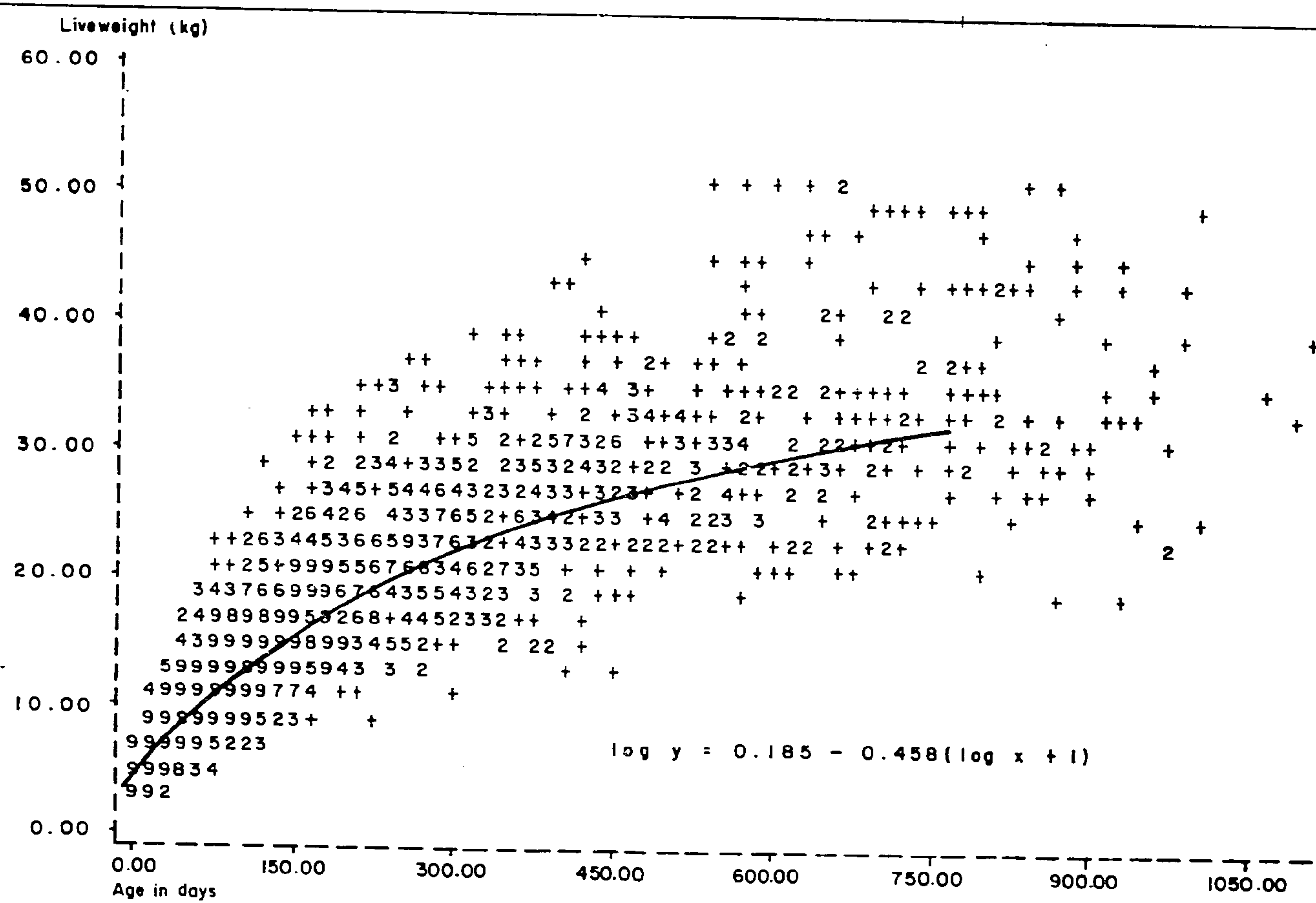
Table 35. *Weight divergences (kg) from overall average at specified ages for flocks in the millet and rice subsystems.*

Age of animals (days)	Divergence from overall mean weight			
	Millet subsystem		Rice subsystem	
	Best flock (+kg)	Worst flock (-kg)	Best flock (+kg)	Worst flock (-kg)
150	5.0	2.3	9.2	6.6
240	6.2	4.5	18.1	7.9
365	6.4	7.1	11.2	6.7
550	7.0	5.0	7.5	6.0
730	4.1	4.6		

Source: Compiled by author.

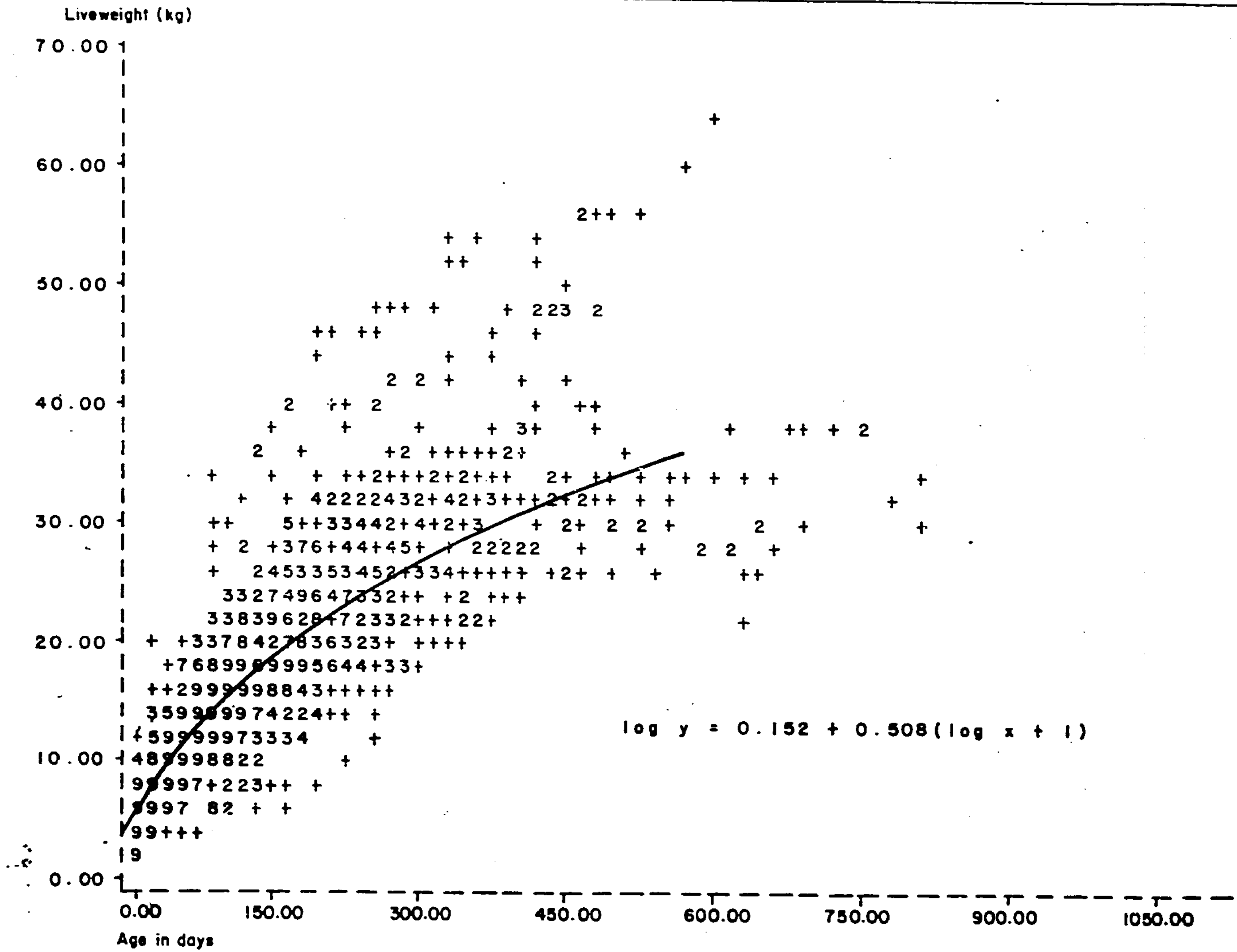
Under prevailing management conditions it is difficult to relate weight changes in mature animals to the effects of season. In practice, mature weights of females are more closely related to the effects of the percentage of animals pregnant and lactating, and further analyses on specific subgroups of animals would be needed to separate these effects. As can be seen from Figure 35, female weights are highest in October and perhaps

Figure 33. *Computer scattergram and calculated growth curve for sheep in the millet subsystem.*



<u>Source:</u> Compiled by author.

Figure 34. *Computer scattergram and calculated growth curve for sheep in the rice subsystem.*



<u>Source:</u> Compiled by author.

early November, which fits in well with late pregnancy at this time and so with a hypothesis of conception in the late hot dry season. A fair number of females are also heavier in March and April, probably again explained by the numbers in an advanced state of pregnancy at this time. The shorter subsequent parturition interval associated with births occurring during this period can then very neatly be fitted into the next period of weight increase.

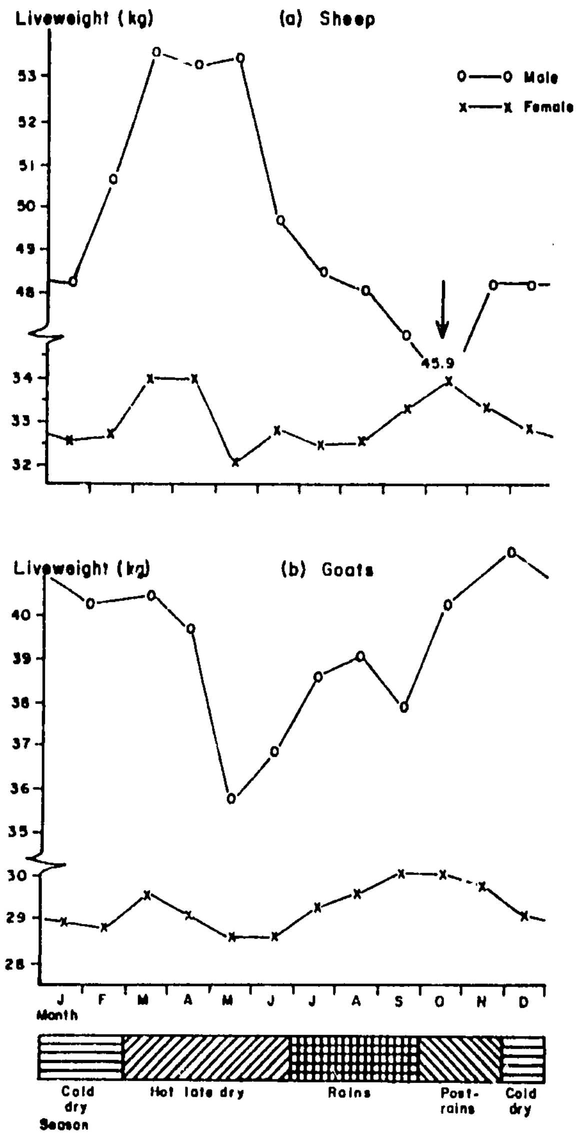
As regards males, for goats the situation is as might be expected. In sheep, however, a rapid drop in weight occurs in the late dry season and continues through the rains. This can be explained as due in part to the effects of over-succulent feed and of foot rot and other health problems. The weight pattern was also disrupted over the period of study by the principal Muslim feast, known locally as Tabaski, which occurs in October and November and leads to the sale of males for export and slaughter, in September as well as October and November. The apparent rise in weight in the dry season was thus partly due to the inclusion of additional mature animals in the analysis.

Species, parity, system and flock (in both the millet and rice subsystems) were very highly significant ($P < 0.001$) in their effects on the postpartum weight of dams. Season was highly significant ($P < 0.01$), while those giving birth to singles were significantly lighter ($P < 0.05$) than those giving birth to twins, although the few triplet births were significantly ($P < 0.05$) heavier than both. Animals giving birth to females were not significantly different ($P > 0.05$) in weight to those giving birth to males, and there was no effect of season on different species ($P > 0.05$). Table 36 gives details of postpartum.

In animals of known birth date deaths occurring before weaning (assumed at 150 days) were analysed by least squares means. The mortality rates relating to the various sources are shown in Table 37. The effects of birth type, season of birth and flock in the millet subsystem were all very highly significant ($P < 0.001$); those of species and system were significant ($P < 0.05$), while flock in the rice subsystem and sex overall were not significant ($P > 0.05$).

The effects of the length of the previous parturition interval on deaths before weaning were also tested, and it was found that parturition intervals of 183 days or less occasioned a 54.9% mortality rate, 184-213 days a 27.9% rate, 214-244 days a 29.2% rate and 245 days and greater a 25.25% rate. There was a highly significant reduction ($\chi^2 = 19.64$, $P < 0.01$) in the

Figure 35. *Seasonal weight changes in mature sheep and goats.*



Source: Compiled by author.

Table 36. *Estimated least squares means for postpartum weights (kg) of goats and sheep.*

Variable	Goats	Sheep
Overall mean	31.98	
Species mean	29.98	33.99
Sex		
Male	30.02	34.02
Female	29.94	33.96
Birth type		
Single	28.33	32.34
Twin	28.89	32.90
Triplet	32.72	36.73
System		
Millet	28.11	32.12
Rice	31.85	35.86
Season of parturition		
Cold dry (December, January, February)	30.07	32.87
Hot late dry (March - June)	30.91	34.98
Rains (July - September)	30.38	34.39
Post-rains (October/November)	28.50	32.51

Source: Compiled by author.

percentage mortality rate before weaning with increasing parturition interval, although there was no further reduction for intervals of over 274 days. The reduction was more marked in sheep than in goats. Out of all deaths in both species combined, 16.36% were abortions (an absolute total of 2.65% for sheep and 7.2% for goats), 21.6 were still births or occurred on the first day, 14.5% occurred at between 1 and 7 days, 8.2% at 8-30 days, 22.8% at between 1 and 3 months, and 16.4% at 3 and 4 months.

Exactly 70% of all deaths occurred at under 15 months (and 62.8% of these were in animals under 5 months), while 16.6% were in animals 15 to 33 months old and 13.4% in older animals. The total mortality rate during the 3-year study period (January 1978 to January 1981) was 37.7% for sheep and 43.5% for goats.

Table 37. *Estimated least squares means for percentage death rates before weaning for small ruminants in the agropastoral system.*

Variable	Goats	Sheep
Overall mean	32.44	
Species mean	34.59	30.29
Birth type		
Single	23.54	19.24
Twin	31.76	27.46
Triplet	48.47	44.17
System		
Millet	39.11	34.81
Rice	30.07	25.77
Season of birth		
Cold dry (December, January, February)	35.66	31.36
Hot late dry (March - June)	27.80	23.50
Rains (July - September)	38.27	33.97
Post-rains (October/November)	36.63	32.33

Source: Compiled by author.

Sales and slaughters for home consumption amounted to 18.4% for sheep (in a ratio of 2.7 sold to 1 slaughtered) and 15.3% for goats (in a ratio of approximately 2:1). Sales consisted largely of older females past their most productive age and, especially for goats, a number of males aged between 8 months and 2½ years. Home slaughter of sheep consists almost entirely of young males.

For a considerable period of the study it was impossible to distinguish clearly between deaths and animals slaughtered *in extremis* and then consumed. Latterly it has been established that about one third to one half of animals over 15 months old previously reported simply as dead were in fact slaughtered and consumed in this way. Taking these animals into account should have appreciable effects on the components of offtake.

In an attempt to make direct comparisons of production levels three indices of meat production performance were calculated which account for growth of young (all offspring of one parturition for one index), mortality, parturition and dam weight. These indices can then be compared, as were the simple parameters, for various sources such as parity, system, season, etc. The three indices are:

(a) Index I: weight of young (kg) produced per breeding female per year, calculated as:

$$\frac{\text{Liveweight of young at 150 days} \times 365}{\text{Subsequent parturition interval}}$$

(b) Index II: weight of young (g) produced per kg liveweight of dam per year, calculated as:

$$\frac{\text{Index I}}{\text{Postpartum weight of dam}}$$

(c) Index III: weight of young (g) produced per kg metabolic weight of dam per year, calculated as:

$$\frac{\text{Index I}}{\text{Postpartum weight}^{0.75}\text{ of dam}}$$

In Table 38 the estimated least squares means are listed for many of the variables. Effects of species, parity, birth type, system and flock in both systems were very highly significant ($P < 0.001$), and those of sex were significant ($P < 0.05$).

On the basis of these indices, which relate only to meat production, sheep are on average more productive than goats across all three indices in the ratio of 1.57:1. The indices do not take into account milk offtake, or other factors such as the advantages to a family of having a greater number of smaller animals available for sale or slaughter, where the financial and social benefits resulting from the one or the other species are not too disparate. Nonetheless, it would appear that in terms of resource utilization sheep are more efficient than goats. The higher abortion and subsequent mortality rate in goats accounts for this in some degree: if these effects could be overcome the balance would be redressed to a certain extent. The indices underline some interesting points, not always immediately obvious, which can well be used in the planning of interventions. In Table 39 the data from Table 38 are used to show comparative advantages in ratio terms for the various sources of variation.

Table 38. *Estimated least squares means for production indices for small ruminants in the agropastoral system.*

Source	Index I		Index II		Index III	
	Goats	Sheep	Goats	Sheep	Goats	Sheep
Overall mean	24.10		726.67		188.99	
Species mean	18.67	29.52	565.05	888.30	147.12	230.85
Sex						
Male	19.37	30.22	576.96	900.21	152.77	236.50
Female	17.97	28.83	553.14	876.39	141.47	224.20
Parity						
First	12.60	23.45	426.94	745.19	109.58	193.91
Second	17.21	28.06	558.17	881.42	140.05	223.78
Third	19.73	30.58	624.33	947.57	158.32	242.05
Fifth	21.30	32.15	644.92	968.17	165.96	249.69
"Ninth"	19.40	30.25	593.11	916.36	151.17	234.90
Birth type						
Single	17.51	28.36	507.88	831.13	124.76	208.49
Twin	24.02	34.87	753.19	1207.40	193.32	277.05
Season						
Cold dry	18.15	29.00	534.79	858.04	140.12	223.86
Hot late dry	20.79	31.64	660.19	983.44	169.52	253.25
Rains	17.71	28.56	543.29	866.54	141.11	224.83
Post-rains	18.03	38.88	522.13	845.38	137.73	221.46
System						
Millet	13.23	24.08	446.67	769.92	114.07	197.80
Rice	24.11	34.96	683.43	1006.68	180.17	263.90
Flocks						
Best millet	+12.68		+419.81		+104.04	
Worst millet	- 7.13		-288.27		- 68.54	
Best rice	+31.00		+964.24		+242.48	
Worst rice	-18.20		-407.93		-111.61	

Source: Compiled by author.

Table 39. *Ratios of comparative advantages for sources of variation in indices I, II and III for small ruminants in the agropastoral system.*

Source	Index I		Index II		Index III	
	Goats	Sheep	Goats	Sheep	Goats	Sheep
Sex:						
Males to females	1.08	1.05	1.04	1.03	1.03	1.05
Parity:						
All parities to first	1.54	1.29	1.42	1.25	1.40	1.23
Birth type:						
Twins to singles	1.37	1.23	1.48	1.45	1.55	1.43
Season:						
Best to worst	1.17	1.11	1.26	1.16	1.23	1.14
System:						
Rice to millet	1.82	1.45	1.53	1.31	1.58	1.33
Flocks:						
Millet best to worst	2.17		2.62		2.43	
Rice best to worst	9.34		5.30		5.58	

Source: Compiled by author.

3.3.4 Intervention possibilities

The population structures for both cattle and small ruminants appear compatible with the management objectives of the system, so that improvement in livestock productivity will need to be sought first of all through other aspects. Some comments, however, appear worthwhile.

It is likely that in both the millet and rice subsystems oxen are being kept to an age at which they are relatively inefficient producers of power. This probably results from the extremely slow growth rate and late maturity of this class of stock, the difficulties in replacing them and (even when supplied on credit) the amortization cost. There will, however, be a continuing demand for work oxen. The best means of fulfilling this demand is probably to improve early nutrition so as to ensure earlier entry into the work force, thus either prolonging the working life or enabling withdrawal at a younger age, when carcass quality is better. Whether limited feed resources should be devoted to this target, or whether they should be spent on animals currently breeding and working, is a question that needs further investigation.

As regards population structures among sheep and goats, it is currently fashionable in the Sahel countries to talk of "rejuvenating" small ruminant flocks. There is little evidence from the data obtained by ILCA that this needs to be, or indeed can be, done. In general, aged females account for about 5% of the total flock or around 10% of breeding females. In theory it would be possible to cull these animals at an earlier age, but it is doubtful whether this would very much affect overall flock performance as their parturition interval is no longer and their litter size probably greater than those of the young animals which would replace them. The majority of breeding females are already between 3 and 5 years of age, and it is just these animals (at third to sixth parities) which are the most prolific. It could also be argued that the number of mature males is over the strict requirement for breeding. However, this is not exaggeratedly so and it is probable that little real benefit can be gained from removing the small number of surplus males.

The management objectives for cattle in the agropastoral system are animal traction as the first priority and milk and meat production as the second and third priorities respectively. The uptake of animal traction has nevertheless been slower in the millet sector than in the irrigated rice areas where, as ownership patterns and herd structures show, saturation point has almost been reached. The main constraint in animal traction is the considerable weight loss, up to 18% by the end of the dry season, just when power requirements are highest. The poor condition of work oxen at this time is obviously a function of nutritional intake and requires further study. Herd milk and meat production are functions of age at first calving, cow viability, parturition interval, calf mortality, growth and lactation yield. An age at first calving of 4 years is quite reasonable, and cow viability (longevity) appears normal. The last four aspects would therefore seem to provide the best initial targets for improvement.

The parturition interval of 511 days could obviously be improved, when compared with the interval obtained for the same breed on the Station du Sahel. It seems to be heavily influenced by fluctuations in cow fertility. This seasonality is almost certainly affected by the quality of feed available in the dry season, although whether it is caused by mineral status or energy intake needs to be considered further. Nutritional studies strongly indicate that energy deficiency is the cause, but some assessment of the mineral status should also be made. Calf mortality at over 20% also leaves room for improvement. Clearly there are considerable nutritional effects here, but the clinical causes also need to be investigated. Milk production was not determined in this study, although preliminary estimates were made using data obtained during the nutrition study.

In order to validate the field data on herd parameters, these were compared with a computer simulation of herd parameters based on the input data for the nutrition study. The results are shown in Table 40. Whilst still preliminary, this validation was considered a suitable basis for testing simple interventions, first on the performance of milk cows and the rate of survival and weaning weights of their calves, secondly on the maintenance of weight in work oxen during the dry season. The interventions consisted of either one or two levels of supplementation, again tested by means of computer simulation. The simulations for weights and milk yields with and without supplementation are shown in Figures 36 and 37.

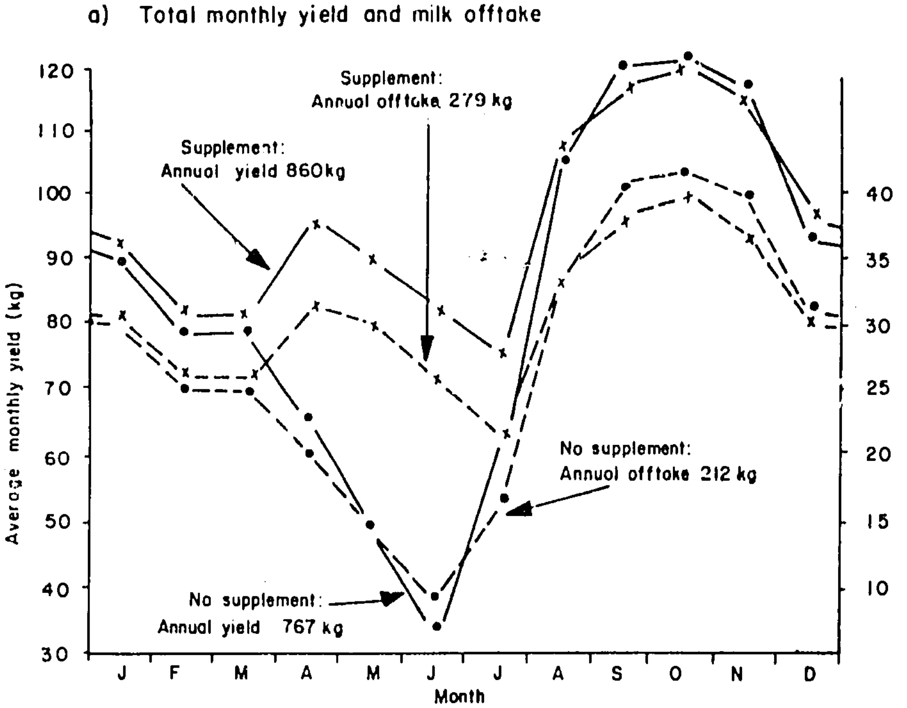
Table 40. *Computer-simulated parameters of an initial herd of 82 after 10 normal years, and observed results.*

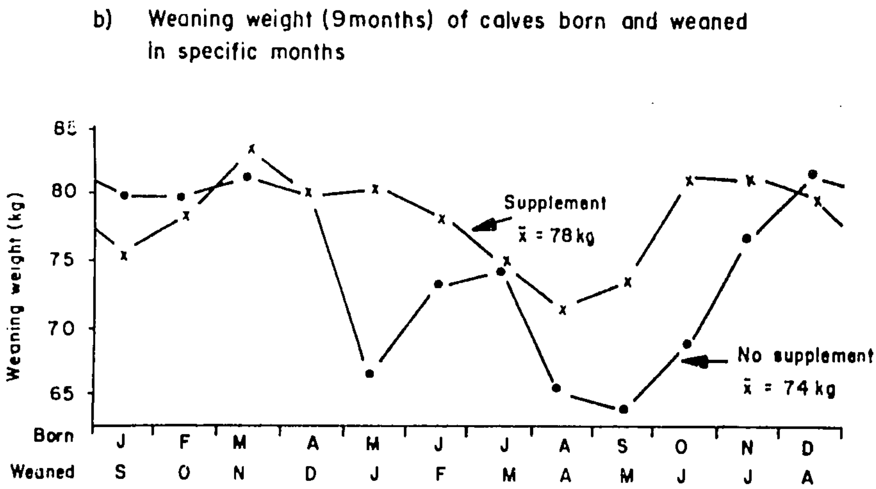
Parameter	Predicted by simulation	Field observations
Males in herd (%)	44.1	46.8
Females in herd (%)	55.9	53.2
Calving rate (%)	51	54
Mortality rate (%)	30.6	20

Source: Compiled by author.

The nutritional data had indicated that the digestibility of range fodder is below 50% in March, April and May. The model runs assessed the effects of providing a roughage supplement of 60% digestibility or over during these 3 months. No other interventions were envisaged. A supplement of 2 kg of cowpea hay per lactating animal was chosen (requiring at year 10 a total of 2,222 kg of supplement) and it was assumed that this would depress voluntary intake of range fodder by 1 kg, such that the reference cow of 241.7 kg would have an intake of 6.02 kg DM with supplementation, and not the 5.02 kg it would consume on free range. The main effects of this supplementation were on milk production and breeding cow weight, with only

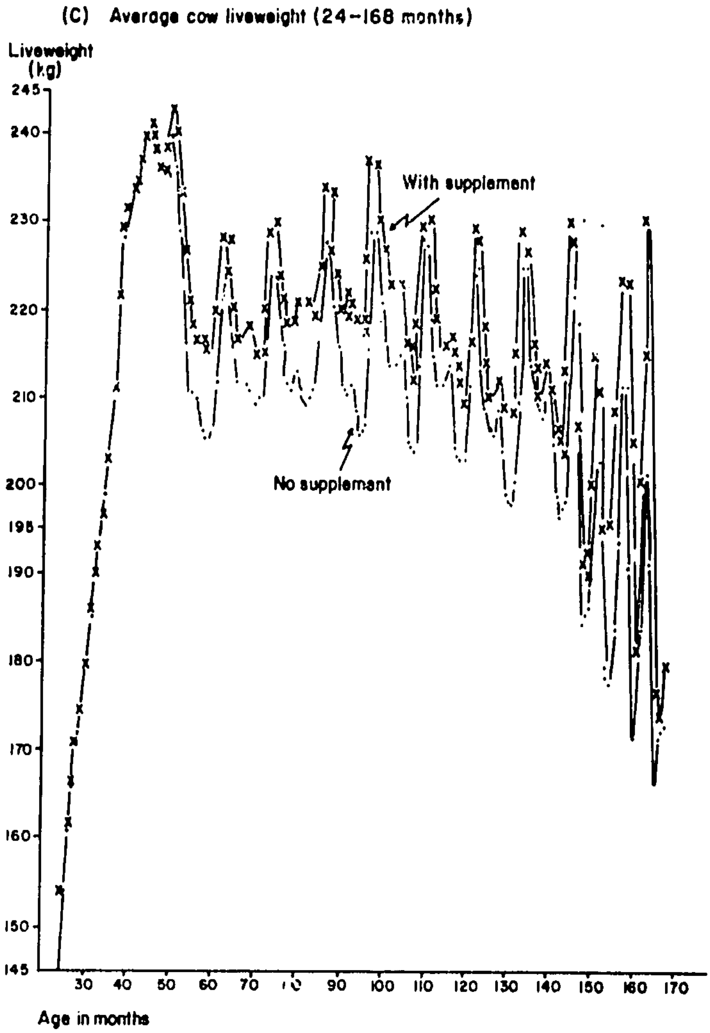
Figure 36. *Effects of supplementation (2 kg of cowpea hay) on lactating cows during March, April and May (computer simulation)*





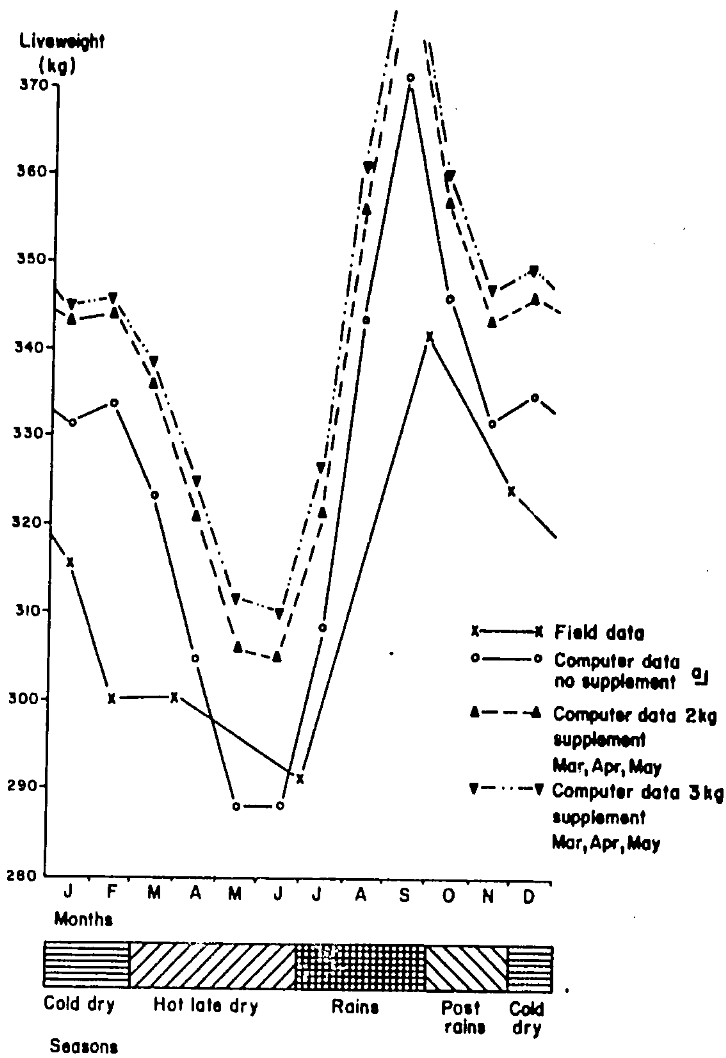
Source: Compiled by author.

Figure 36. (Continued).



Source: Compiled by author.

Figure 37. *Effects of two levels of supplementation on weights of work oxen in the agropastoral system (computer simulation).*



a/ The dry-season lay in weight loss is probably cuased by the lack of provision for energy expenditure in traction.

Source: Compiled by author.

limited effects on calf weaning weight and calf losses. Although with no supplementation calves do very poorly, it appears that nutrition *per se* is not the primary cause of death, and to prevent losses it will be necessary to isolate specific disease factors.

The computer-predicted increase in yield of about 100 kg of milk shows a financial deficit. The cost of cowpea hay at this period in Niono market averages 173 Malian francs (MF) per kg, which is twice the average for the post-rains and cold dry-season prices, while the price of milk at the point of production is MF 150/kg. Returns on milk are thus under MF 15,000, while the cost of hay (excluding transport) is almost MF 32,000. Better returns would be obtained if the hay were bought in October - November (average price of MF 82.5/kg) or even in December - February (MF 96.3/kg). If only increased human offtake of milk (and not total production) is considered, then the extra income generated is only around MF 10,000, so that it would be necessary to convince herd managers that returns other than purely monetary ones, such as better family nutrition, improved calf weaning weights, lower calf mortality rates and higher sales values of culled cows, justify the initial cash investment.

Interventions to maintain the weight of draft oxen at a minimum level of 320 kg throughout the dry season again used cowpea hay, for the same 3-month period of March, April and May. As for cows, it was assumed that the intake of superior quality roughage with a digestibility of 60% would depress intake of natural forage by half the amount offered. At the two levels of supplementation tested, 2 kg and 3 kg, of DM consumption of natural forage of 6.64 kg for a 320 kg reference ox was expected fall to 5.64 kg and 5.10 kg respectively. However, even at 3 kg per day, supplementation did not maintain oxen weights at the desired 320 kg level. At this level of supplementation a total of 5,912 kg of supplementary fodder would be required for a typical agropastoral herd of 100 head of cattle. Alternative intervention policies, still to be tested, might include a longer period of supplementation, say for a period of 5 months, or the addition of some concentrate feed such as cotton seed.

Interventions for work oxen are even more difficult to justify on financial grounds, as there are no direct cash benefits from feeding hay to oxen. It is generally true, however, that farmers appreciate the need for work oxen to be in better condition at the end of the dry season. The main problems are a lack of hay at this time of the year and the farmers' order of priorities in allocating what little feed he has: his transport donkey usually receives priority at this time. A more detailed multivariate analysis needs to be carried out, taking into account such factors as priority of feeding, supplementary feeding of oxen versus keeping extra oxen (at both village resource and individual resource level), extra millet yield generated from earlier planting and effects on labour use. Only then will the economic value of feeding oxen become clear.

In view of the longer calving intervals, lower milk production and lower liveweights of older cows, further possibilities for increasing production would probably arise from culling these animals, assuming overall reproduction rates are adequate. It is likely (based on figures for herd age analysis and for marketed offtake) that even under present management constraints herdowners are already applying this option. Where this is manifestly not the case, the practice should be encouraged.

The main production parameters for small ruminants in the two subsystems are shown in Table 41, together with their estimated development potential and the likely improvement paths. The higher indices in the rice system result from its better resources in terms of access to water and crop residues during the dry season. It is doubtful whether these advantages can be transferred to the millet system, at least in the short or medium term, so that improvements here will tend to be less marked. Within species, the gap between the two systems seems to be greater for goats, and more attention should therefore be given to this species. However, better opportunities seem to lie in the differences between flocks within a production system. The first needs are to identify the factors causing these differences, and study whether they can be generalized.

The biggest single factor affecting productivity is high mortality, caused by diseases, management factors (breeding practices) and, perhaps, nutritional constraints. It is therefore proposed to carry out a much more detailed study on the clinical causes of death, and to begin to introduce, for the flocks under study, vaccination schemes against the two main endemic diseases, pasteurellosis and *peste des petits ruminants* (PPR).

As regards reproductive performance, a number of points can be made. Males only slightly outnumber females, which is perhaps fortunate, as not much can be done about sex ratios. First parity is poor compared with all others and differences due to parity are probably highly significant. First

Table 41 . *Main production parameters for small ruminants in the rainfed millet and rice subsystems.*

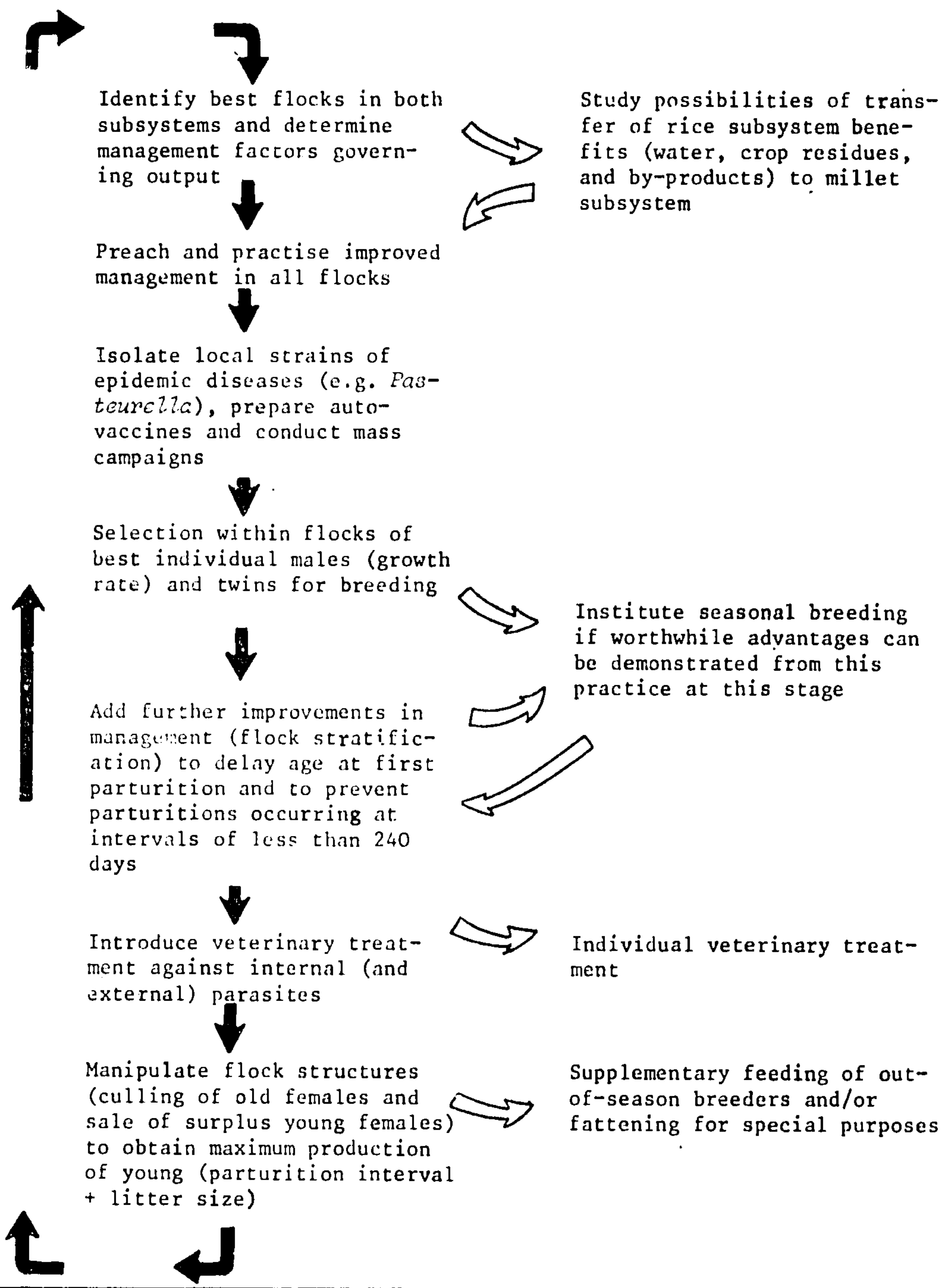
Parameters	Rainfed millet		Rice		Estimated potential		Improvement paths
	Sheep	Goats	Sheep	Goats	Sheep	Goats	
Average litter size	1.05	1.19	1.09	1.23	1.15	1.40	Selection
Parturition interval	242.4	262.6	227.6	247.7	240	240	Optimization
Age at first parturition	471	475	471	475	550	550	Optimization
Birth weight (kg)	2.60	1.84	2.60	1.84	3.0	2.2	Selection
Growth rate (0-150 days)	74	46	104	76	125	110	Selection
Mortality (%)							Diagnosis,
0-weaning	34.8	39.1	25.8	30.1	15	20	cure and
Index I	24	13	35	24.1	45	40	management

Source: Compiled by author.

parity is, of course, a fact of flock demography, but it might be possible to delay this to a later age and a heavier weight by improving management practices. In spite of higher mortality and slower growth rates the overall benefits of twins, when measured in terms of dam performance, are considerable: selection for twins could greatly increase output, particularly if the disease and nutritional problems leading to high lamb and kid losses can be overcome. Selection for twins in goats might well be highly successful and could significantly raise the overall productivity of this species in relation to sheep.

The effects of season, while very significant statistically, are in real terms of less importance than the other sources discussed. Animals born during the hot late dry season reflect the best performances in the records of their dams, a factor which can be attributed to the shorter parturition interval associated with this period, lower mortality of offspring in the 1- to 3-month bracket and possibly some marginally increased weight gain in the dam during the late rains and post-rains at about the time of weaning. Very short parturition intervals are usually associated with higher pre-weaning deaths, but for animals born during the hot late dry season such effects are probably overcome by nutritional advantages. With open management

Figure 38. *Intervention pathways for small ruminants in the agropastoral system.*



Source: Compiled by authors.

systems such as exist at present in central Mali, influencing the effect of season might be very difficult, and it is thus fortunate that these effects are not very great. Figure 38 attempts to summarize a feasible intervention pathway, building on the existing system without costly and technologically inappropriate inputs.

3.4 ANIMAL NUTRITION

3.4.1 Materials and methods

Since livestock productivity, as reported in the previous section, is directly related to nutrient intake, work started in 1978 to develop a methodology to quantify the intake of animals in the agropastoral system around Niono. This methodology was successfully applied during 1979 and 1980, when various aims were achieved, including quantification of animal nutrition levels by studies on voluntary intake, determination of correlations between intake and the various environmental and management factors influencing it, an understanding of seasonal variations in the plane of nutrition and an evaluation of productivity. It was felt that an approach of this kind would make it possible to identify the severity and duration of stress periods, as well as realistic interventions to improve animal nutrition within the system.

Voluntary intake is thought to be determined by several factors, most important of which are the environment, the management strategy of the herder, and the adaptation of the herd to this management strategy. While focusing mainly on voluntary intake itself, the study therefore also attempted to quantify some of the environmental and management factors involved.

The study was carried out on the same herds and flocks as served for the determination of livestock productivity. They are managed by traditional herdsmen who graze their animals during the rainy season (July - October) on natural Sahel vegetation, consisting largely of annuals such as *Schoenefeldia gracilis, Loudetia toguensis, Zornia glochidiata,* with *Pterecarpus lucens* and *Acacia* spp as the principal browse species. In November and December they graze the standing stalks and residues of the millet fields. From December until April they have access to irrigated rice fields belonging to the Office du Niger. When these rice fields become completely grazed out, the herds and flocks move back to the millet fields and fallows to await the rains in July.

The methods used are described in detail by Dicko (1980). The observations presented here were made over 1 complete year. For a 5-day period each month the grazing behaviour of four steers was recorded at 15 minute intervals, day and night, while the total faecal production of another four was measured with a bagging technique developed specially for free ranging animals (Dicko, 1980). During the same period samples of the various species and plant parts observed to have been grazed during the daily grazing orbit were taken, and their digestibility was determined in several ways:

(a) the relative time spent on each type of herbage was used to estimate the weighted average composition of the herbage grazed; the digestibility of each weighted fraction was then calculated from existing local measurements or was estimated by using coefficients from the literature;

(b) the faecal nitrogen index method was used, with the equations published by Lambourne and Reardon (1963);

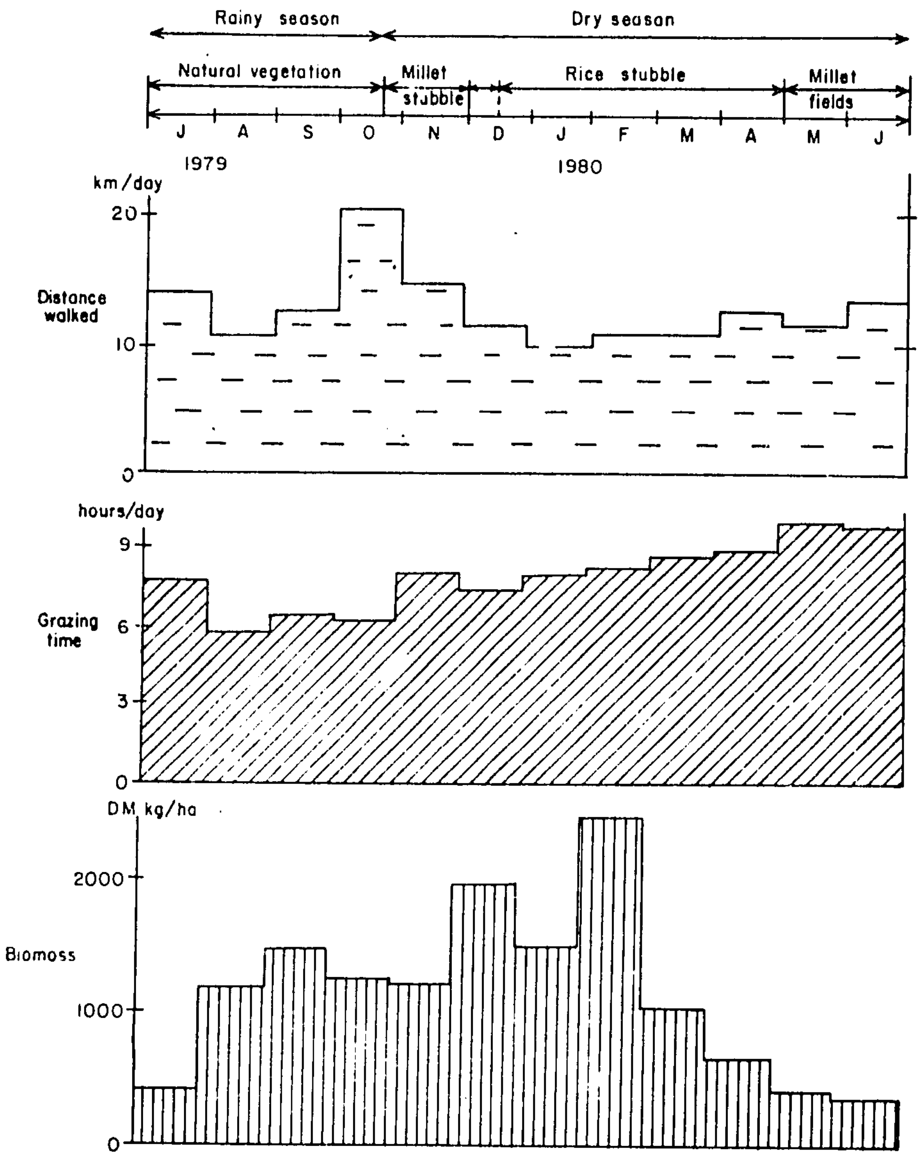
(c) the digestibility of hand-plucked "grab" samples of forage and of the rumen content of a fistulated animal was estimated, using the *in vitro* method of Tilly and Terry (1963) and the summative method of van Soest (1976) based on fibre analyses. The rumen was emptied manually before grazing began (Blancou et al 1977).

Weight measurement of the cattle under study were taken every 15 days, and less frequently on the whole herd. For small ruminants, the same number of animals were followed, and again total faecal output was determined. Digestibility was determined using the same methods except that no rumen sampling was carried out, and grab sampling for diet composition was much more difficult than for cattle because of erratic grazing behaviour.

3.4.2 Cattle

Figure 39 demonstrates the relationships between biomass availability and the grazing behaviour of cattle. Grazing time was lowest during and after the rainy season (July - October), when pasture is relatively abundant and quality high. On millet residues and rice straw from November onwards grazing time increased steadily until April - June, when biomass was much reduced. In both the rainy and dry seasons significant negative correlations (r = -0.85 and -0.82 respectively) were found between standing biomass

Figure 39. *Relation between biomass availability and grazing behaviour.*



Source: Compiled by authors.

and grazing time. Covariance analysis showed that grazing time was significantly lower for a given biomass in the July - October period, when forage quality was high.

Differences in grazing preference for cattle, sheep and goats are outlined in Table 42. The low amount of time spent on millet residues, in comparison with that on rice straw and regrowth in fields and fallows indicate the relative importance of these latter agricultural residues, particularly to cattle. Sheep and goats spent far more time on fallows and browse plants respectively.

Table 42. *Estimation of annual grazing time of ruminants on different types of forage.*

	Cattle		Sheep		Goats	
	Hours	%	Hours	%	Hours	%
Total time	2883	100	1948	100	2051	100
Spent on browse plants	115	4	669	34	1791	87
Spent on pasture or fallows	1519	53	1142	59	215	11
Spent on millet stems	179	6	135	7	45	2
Spent on rice straw and regrowth	1070	37	2	-	-	-

Source: Compiled by authors.

The digestibility figures (Table 43) and total faecal output figures were used to calculate total DM intake according to the following relationship:

$$\text{Dry matter intake (g/day)} = \frac{\text{Faecal output (g/day)}}{100 - \text{Digestibility coefficient}} \times 100,$$

and the results are shown in Table 44.

The distances walked (see Table 44) are largely determined by environmental factors, namely the availability of biomass and drinking water. When biomass availability is low, for instance from April until July, the distances covered are quite high (14 km/day). In October and November, when the surface water in ponds has dried up but the presence of millet and rice crops prevents access to the more permanent waterpoints, the main reason for trekking over longer distances is the search for water. During this period up to 20 km per day may be covered. Even in this system, a considerable amount of the total energy intake is therefore expended on walking.

Table 43. *Seasonal variation in digestibility coefficients of forage consumed, according to different techniques of estimation*

Month	Weighted average method (a)	Faecal nitrogen index (b)	Hand-plucked sample: Tilley and Terry (c)	Hand-plucked sample: Van Soest (d)	Rumen sample: Tilley and Terry (e)	Rumen sample: Van Soest (f)	Mean (a) to (d)
Aug	72	63	66	61	64	46	66
Sept	66	67	54	NS	51	NS	62
Oct	51	54	40	46	39	41	48
Nov	50	53	52	53	38	43	52
Dec	55	53	52	60	56	50	55
Jan	52	52	54	61	52	47	55
Feb	54	52	54	59	49	53	51
Mar	49	51	51	60	44	57	53
Apr	46	51	54	60	56	58	53
May	44	51	50	46	50	51	48
June	52	50	56	55	46	50	53
July	60	54	71	63	68	61	62
Average	54.2	54.2	54.5	56.7	51.1	50.6	54.8

Source: Compiled by authors.

Monthly digestibility values for cattle are given in Table 43 for the various methods of estimation. The digestion coefficients determined by rumen sampling were more erratic and were consistently lower than the others, and so were excluded from the overall mean used in the subsequent estimates of intake.

There was generally an inverse relationship between faecal output and forage digestibility. It should be noted that very acceptable coefficient of variation (c.v.) for faecal output were found (2 - 9%) in the periods when biomass availability was not a limiting factor. When biomass becomes limited, the c.v. increases considerably (9 - 18%). Obviously, the individual behaviour of the animal starts to play a bigger role.

Table 44. *Intake and performance measurements.*

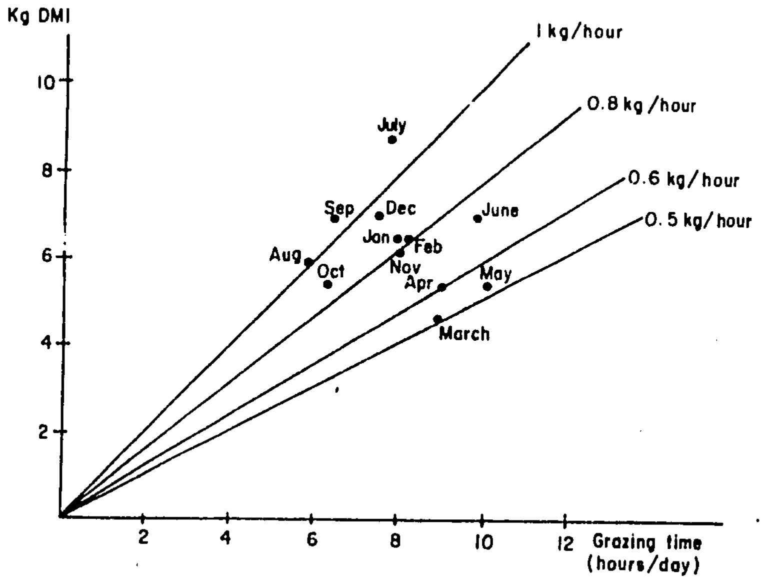
	Mean Lwt (kg)	Lwt change (kg/day)	DDMI (kg/day)	DCPI (kg/day)	MEI (MJ/day)	Distance grazing	Km/day walking
Aug	237	+0.75	3.91	0.747	57.09	6.01	4.83
Sept	258	+0.28	4.29	0.631	60.37	7.84	5.09
Oct	266	-0.14	2.62	0.213	35.81	7.28	13.07
Nov	261	-0.52	3.22	0.240	42.98	9.44	5.10
Dec	248	+0.13	3.83	0.176	49.17	7.39	3.90
Jan	251	-0.13	3.54	0.299	43.39	7.77	2.32
Feb	248	+0.08	3.28	0.390	44.92	7.64	3.28
Mar	242	-0.34	2.44	0.176	29.95	6.93	3.94
Apr	236	-0.32	2.87	0.127	35.46	7.85	4.84
May	228	-0.12	2.66	0.253	34.04	8.03	3.38
June	224	+0.15	3.74	0.348	48.30	8.62	4.64
July	230	+1.15	5.51	1.434	70.72	7.19	6.91

Source: Compiled by authors.

In Figure 40 the montly DM intake figures for cattle are related to the time spent grazing. In the rainy season, intake was approximately 1 kg of DM per hour, in the early dry season approximately 0.8 kg of DM per hour, whilst in the late dry season this was reduced to 0.5-0.6 kg of DM per hour. The slightly higher values found in December and June appear to be associated with the grazing of rice and millet fallows respectively.

Intake of DM averaged 6.32 kg, or 2.6% of the mean cow liveweight of 244 kg, as compared with 2.3 - 2.5% in Nigeria (Oyenuga and Olubayo, 1975), 1.5 - 1.9% in Rhodesia (Elliott and Fokkema, 1961) and 1.5 to 2.1% in Botswana (APRU, 1970). The higher figures found in this study apparently reflect the higher energy expenditure in grazing activities in this system. In this study there was also no significant relationship between liveweight and intake, and the intakes are therefore presented and analysed in absolute terms rather than expressed per kg liveweight. Linear and multiple regression analyses showed that the forage protein content (N x 6.25) has much more influence on DM intake (r = 0.68) than had forage digestibility alone (r = 0.48).

Figure 40. *Relation between voluntary intake and grazing time on different forages.*



Source: Compiled by authors.

The annual pattern of weight changes shown in Table 40 closely reflects the amount and quality of forage on offer. Cattle spent the dry months barely maintaining weight, lost weight quite rapidly in the late dry season and gained rapidly for only 3 months of the wet season, to show an annual gain of 30 kg.

Regression analysis of liveweight changes showed a correlation of 0.68 with DDM intake, 0.89 with CP intake, and 0.89 also as multiple correlation with DDMI and CPI, indicating the large contribution of CPI to the relationship. Metabolisable energy intakes were estimated from a formula proposed for tropical grasses (INRA, 1978) and assuming that the metabolisability of digested energy was 0.81 (MAFF, 1975). The linear regression of liveweight change on ME intake gave:

$$\text{Liveweight change (kg/d)} = 0.034\ \text{MEI (MJ/d)} - 1.513\ (r = 0.88)$$
$$= 0.034\ (\text{MEI} - 44.5)$$

indicating a total maintenance energy expenditure of 44.5 MJ/d. If the ME intakes are reduced by the estimated minimum maintenance requirements of about 112 kcal/kg 0.75 or about 30-32 MJ per day the regression becomes:

$$\text{Liveweight change (kg/d)} = 0.034\ (\text{available ME} - 13.2)\ (r = 0.91)$$

indicating that in this environment the additional energy expenditure for grazing activities and walking amounted to 13.2 MJ/d, or an additional 42% of the minimum maintenance requirement.

Multiple regression analysis was carried out to relate weight changes to DDMI, DCPI, metabolic weight, and liveweight times distance walked. Successive analyses used DDMI, DCPI, and DDMI + DCPI as the measure(s) of feed intake in the equation:

$$\text{Lwt change} = 0.264\ \text{DDMI} + 0.448\ \text{DCPI} + 0.0067\ \text{Lwt}\ 3/4 - 0.000750\ \text{Lwt} \times \text{km} - 0.0343$$

where liveweight change, DDMI and DCPI are expressed in kg/day, liveweight is in kg and km equals km/day walked during grazing.

The statistical analyses appear to indicate that DCP intake is more influential on animal performance than DDM intake. However, it is not the DCP content that is the restricting factor but rather the low DCP intake resulting from a low DDM intake. DCP content in the grazed diet calculated from the DCPI/DMI ratio is generally above 3.8% in all the months but December and April. This implied that the CP content in the grazed diet for 10 months is above 7%, which is only slightly lower than that of 8.5% recommended by NAS (1976) for 250 kg *Bos taurus* steers. It appears that liveweight losses occur when DCP intake is below 200 - 250 g/head/day and DDM intake less than 3.0 kg/head/day.

Although it is generally accepted that Zebus need less protein than *Bos taurus* breeds, it is unlikely that 200 g DCP/day will satisfy the requirements for maintenance and grazing activities. For the latter, 4 g of DCP/km of walking has been proposed (Boudet and Rivière, 1967), **thus adding** another 50 g/day.

Despite the fact that the multiple regression analysis showed a minor effect of grazing activities on liveweight change, this energy expenditure can take a large proportion of the ingested ME. For the period March to May, when weight losses are highest, average ingested ME is 33.2 MJ/day, while according to ILCA (1981 c) ME required for maintenance and activity is respectively 36.1 and 5.8 MJ/day, leaving a negative balance of 8.7 MJ/day with about 80% of these theoretical requirements covered.

The low growth rate of Zebu cattle in the agropastoral system therefore seems to be associated with their highly selective grazing habits. They ingest a relatively high-protein diet, but at the same time this continuous search for top quality fodder, involving much walking, reduces their grazing intensity and thus their DM intake.

In spite of these nutritional constraints - primarily a low level of ingested ME for about 5 months of the year (Table 44) - the agropastoral herds around Niono show a productivity level comparable to that of other systems. It may be postulated that this is mainly due to the grazing of rice fields from December to April which, at least in the beginning, provide good grazing and therefore a respite in the general downward trend of the nutritional plane.

3.4.3 Sheep and goats

The methodology followed to study the seasonal patterns in small ruminant nutrition in the agropastoral system around Niono was basically the same as that used for cattle, except that digestibility was determined only by estimating the ratio between browse and herbage intake as a function of grazing time. The monthly digestibility coefficients for herbage were derived from the cattle study, whereas for browse, literature sources were consulted together with data from a series of *in vivo* studies with caged sheep fed on browse carried out by ILCA in Niono.

The flock under study consisted of sheep and goats, which were herded together throughout the year and based in a village close to Niono.

The type of sheep and goats as well as their management was similar to that described previously (see Section 3.3).

The grazing orbit of the flock differed from that of cattle in that it relied very little on irrigated rice fields and fallows and spent almost all its time on the upland Sahel. This difference is reflected in the composition of the diet, which shows that apart from a high proportion of browse it contained little crop-related herbage (Table 42). The differential preference between sheep and goats is striking, in that the latter survive almost entirely on browse (87%), while sheep depend on rangeland herbage for 59% of their diet. This difference in grazing diet is largely responsible for variation in diet digestibility between the two species, which is higher for sheep during the rainy season when herbage quality is high, but higher for goats when browse quality exceeds that of dried herbage during the dry season (see Table 46).

It is clear that the monthly fluctuations in flock behaviour parameters are much less pronounced than those measured for the cattle herd (Table 45). Total hours in the field ranged from 6.2 to 7.5 hours and therefore fail to show adaptation to environmental conditions as was apparent in the cattle herd. It is likely that the hired herdsman had little incentive to prolong grazing hours when conditions became harsh, since his income, unlike that of the hired cattle herder, did not directly depend on flock output. As a consequence, the time spend grazing fluctuates little over the year and it appears that small ruminants, once they are released into the bush, spend most of their time (70-93%) grazing and browsing. It is curious to note that walking time is shortest from April to July (0.8 hours) while distance covered during the day is above average (13.8 km). This period coincides with the time when shrubs begin to flush, but grazable biomass is so low that the goats lead the sheep, rushing from shrub to shrub so as to obtain sufficient intake. During the rainy season the reverse is true: average distance covered is only 6.3 km, while time spent without grazing amounts to 1.7 hours, which may indicate that the sheep are forcing the goats to adopt a leisurely behaviour pattern, herbage being plentiful, or that the shepherd deliberately selects sites high in grass cover and low in shrubs.

Dry matter intake shows large fluctuations over time, ranging from 1,7 - 3,2% of liveweight for sheep and 1.6 - 3.2% for goats, with mean values of 2,6% respectively. Seasonal trends are difficult to detect: for all animals the period from October to January shows low intake, while goats

Table 45. *Grazing behaviour of a small ruminant flock.*

	Time in field (hrs)	Grazing (hrs)	Distance walking (km)		Time in field (hrs)	Grazing (hrs)	Distance walking (km)
Aug	6.5	5.3	8.0	Feb	7.5	5.8	12.5
Sept	6.2	4.0	5.5	March	7.2	5.2	13.0
Oct	6.3	4.[illegible]	6.5	April	6.5	5.5	13.5
Nov	6.5	5.0	10.5	May	6.8	6.3	14.0
Dec	6.0	5.0	8.5	June	7.0	6.0	13.5
Jan	7.3	5.5	14.0	July	6.8	6.0	14.5

Source: Compiled by authors.

eat much less during the height of the rainy season than do sheep. Digestible DM intake follows the same trends as DM intake, but variations are attenuated by inverse trends in digestibility. On average, sheep and goats ingest 0.70 MJ and 0.53 MJ/day, and in spite of the relatively high diet digestibility during the rainy season goat DDMI averages only 0.45 MJ/day (Table 46).

Table 46. *Performance, digestibility and feed intake of sheep and goats.*

	Liveweight (kg)		Digestibility (%)		DDMI (MJ/day)	
	Sheep	Goats	Sheep	Goats	Sheep	Goats
Aug	47	40	71	62	1.00	0.53
Sept	48	40	66	57	0.75	0.37
Oct	50	40	52	54	0.42	0.44
Nov	51	41	53	54	0.60	0.58
Dec	51	41	53	54	0.72	0.60
Jan	50	36	55	55	0.56	0.41
Feb	52	37	53	55	0.80	0.65
March	51	38	50	55	0.84	0.60
April	49	37	50	53	0.73	0.64
May	48	36	50	54	0.65	0.42
June	46	37	52	55	0.69	0.52
July	46	38	65	60	0.60	0.55
Means	49.1	35.4	55.8	55.7	0.70	0.53

Source: Compiled by authors.

Because the study involved mature animals, weight changes are minor, being 6 kg for sheep and 5 kg for goats It appears that, unlike cattle, small ruminants gain little during the rainy season, and their weight gain, if any, is put on after the rainy season. As a result, the close relationship between monthly trends in nutrition level and liveweight performance in cattle is not found in small ruminants.

It has been difficult to apply the accepted feeding standards for sheep (NAS, 1975) to a system of management that is entirely different. If the maintenance requirement of a 50 kg non-pregnant ewe is taken, then the average DDM intake of 0.70 MJ/day is 12% above requirements, but if the same is taken for a 50 kg yearling ram, the average intake is 12% below the level recommended by NAS (1975). Considering that the maintenance requirements do not include the energy expenditure for grazing activities, it seems reasonable to conclude that little extra energy is available for growth, which is in line with the weight performance throughout the year of the experimental animals.

3.4.4 Agro-industrial by-products

As very little information on the agro-industrial by-products is available in central Mali, a preliminary survey at producer level was made to assess the situation and identify possible constraints. Table 47 gives the results of this survey, showing the availability in DM and FU of rice and sugar cane by-products, as well as various kinds of oilseed and carcass products. The year of study was 1979, but an assessment of potential availability in the future is also given. Roughly 116,000 tonnes of DM of the products investigated were available in 1979, a total which represents about 58% of potential availability, estimated at 200,000 tonnes.

If these totals are compared with the livestock population of Mali, approximately 4.5 million TLU, then only about 3-6 kg of DCP per head per year would be available, even assuming that all output could be used locally. The real and potential contribution of by-products to animal feeds in Mali thus appears rather insignificant.

Supplies of the major products, shown in Table 48, appear erratic. The table, which gives details of yearly output for the period 1974-1979, indicates that although cottonseed and molasses supplies have been fairly stable and have been even shown a slight increase, rice residues and groundnut cake have fluctuated sharply, while the available amounts of cottonseed cake and

Table 47. *Real and potential availability and feed value of agro-industrial by-products in Mali.*

Product	1979			Potential		
	DM (t)	FU (000)	DCP (t)	DM (t)	FU (000)	DCP (t)
1. Rice:						
Bran and chaff	2,323	627	77	8,043	2,172	260
Meal	3,405	3,405	319	8,256	8,256	776
2. Sugar cane:						
Tops	23,700	13,035	497	26,958	14,827	566
Molasses	6,225	6,474	56	7,080	7,364	64
3. Oilseeds:						
Cottonseed	60,888	63,932	5,845	109,504	114,979	10,512
Cottonseed cake	3,000[a/]	2,526	1,152	6,918	5,811	2,650
Groundnuts cake	15,974	15,175	5,925	33,084	31,429	12,274
4. Carcass wastes:[a/]						
Meat meal	23	26	12	56	62	29
Blood meal	0.8	0.9	0.6	70	78	57
Bone meal	20	-	-	295	-	-
Total	115,556.8	105,200.9	13,883.6	200,264	184,978	27,124

[a/] 1978 figures; figures for 1979 were not available at the time of survey.

Source: Compiled by authors.

abbatoir wastes have fallen year by year. The main reasons for these fluctuations are the variations in the amounts of raw materials processed, linked with the vagaries of climate and the existence of an unofficial market which pays a better price to the peasant farmer, and the operating problems experienced by some factories.

In view of past performance, predicting the long-term output of by-products is thus problematic. Frequent assessments of the available amounts will be necessary, together with the alternative uses, other than in animal feeds, to which they could be put. In some cases, for example, export, the manufacture of alcohol and vinegar or burning as fuel might prove more profitable.

Table 4 8. *Fluctuations in the output of by-products (% in relation to output for a standard year).*

By-product	1974	1975	1976	1977	1978	1979
Cotton seed	100	60	105	116	115	126
Rice residues	-	100	83	115	93	113
Abbatoir wastes	-	100	97	86	83	-
Molasses	-	-	100	145	157	144
Groundnut cake	-	-	100	129	78	115
Cottonseed cake	-	-	100	85	45	-

Source: Compiled by authors.

The present uses of individual products are many and varied, although there is much wastage. By-products from rice processing plants and abbatoirs are almost entirely consumed by the country's livestock, and supply lags far behind demand. Sugar by-products, in contrast, are usually wasted: the green tops are burnt to make harvesting easier, while 90% of molasses is either thrown away or used to make reads, with only 8% reaching livestock and 2% used for the manufacture of alcohol. The low level of commercialization for molasses is caused by lack of storage facilities and packing and transport problems. In the case of cottonseed, however, 23% of output either reaches livestock or is sown, while 48% and 18% are exported by state and privately owned concerns respectively, and the remaining 11% is used for oil manufacture. Over 90% of groundnut and cottonseed cake is exported.

The low amounts available, the erratic supplies and many other uses to which by-products can be put, combined with the logistical difficulties in transporting them to livestock owners, make the chances of improving animal nutrition by the means rather slim. As a result, more attention will have to be given to the second of the two alternatives previously mentioned, namely the introduction of legumes and browse plants. This topic is dealt with in the section which follows.

3.5 CROP AGRONOMY AND IMPROVEMENT

3.5.1 Introduction

Figure 41 summarizes intervention possibilities in the farming components of the agropastoral system. More grain can be produced through higher yields per hectare and by increasing the area under cultivation. The soil nitrogen and phosphor deficiency is a major constraint in increasing the grain yields per hectare, while expansion of cropping depends largely on the availability of work oxen and their efficiency, which is a function of their size and nutritional status.

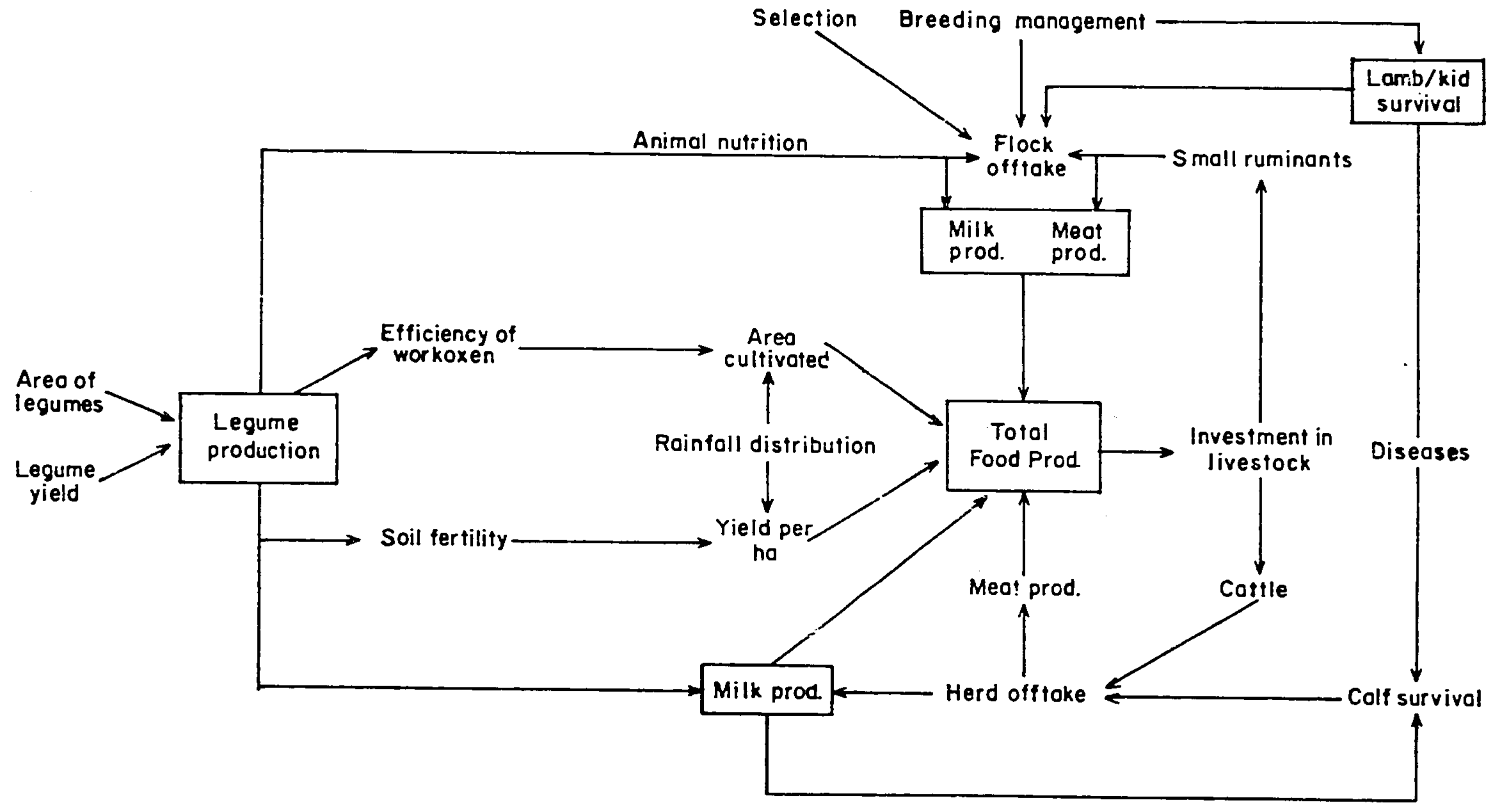
The productivity of small ruminants is affected by disease, management and nutrition. Although disease and management innovations are reasonably neutral to the total system as far as their introduction is concerned, their effect will be to increase the animal population, so that still higher feed production will be required within the system. The same applies to cattle, the milk and meat production of which can be increased by improved nutrition, again with the emphasis on introducing more nitrogen into the system, either through increases in forage production or by feeding high-protein concentrates directly to livestock.

The increase in the N supply has to be brought about within the socio-economic context in which the system operates. It has already been explained that direct animal feeding with agricultural by-products as an N source has a very limited applicability. Moreover the very low availability of cash in the rural economy, where millet is still the main medium of exchange, also places severe limitations on the purchase of nitrogen fertilizer. Hence the most obvious way for improvement seems to be through the introduction of legumes, planted either on natural rangeland and fallows, or as a forage crop in rotation with food crops.

The labour constraints identified previously make the sowing of legumes in natural vegetation a doubtful proposition. In the survival strategy of the arable farmer highest priority is always accorded to the cultivation of food crops. The main emphasis has therefore been on intercropping, an already existing local practice which would have a high acceptibility and transferability.

Closely associated with legume introduction is the problem of soil fertility. Most soils in Mali are deficient in both phosphorus and nitrogen, especially the sandy soils where millet is cultivated, but they are generally

Figure 41. *Intervention possibilities in the agropastoral system.*



Source: Compiled by authors.

adequate in potassium and sulphur. Increased cropping leading to reduced or to absent fallow periods is aggravating existing soil nutrient deficiencies as well as harming its physical properties.

There are serious constraints to the introduction of fertilizers. Their cost in Mali, when set against the prices obtained for farm produce, are not conducive to their use. According to Poulain (1976), an innovation is only attractive if it produces surplus income to a level two or three times higher than it costs to introduce. The logistical difficulties of fertilizer supply are a further drawback. Peasants are widely dispersed and virtually inaccessible to the official supply and extension services network. A farmer who wants to apply 50 kg P_2O_5/ha in the form of single superphosphate over 5 ha has to transport 1200 kg of fertilizer by donkey-drawn cart, carrying 400 to 500 kg per trip, over a distance which may be as much as 100 km.

It was against this background that ILCA began a series of experiments aimed at improving the nitrogen supply and hence the crop yields of the existing system. The trials concerned plant introduction, cowpea agronomy and millet fertilization.

3.5.2 Plant introduction

Trials on the introduction of various exotic and indigenous herbaceous and browse plants were carried out from 1977 to 1980 on a site with sandy soils 7 km east of the Sahel Station at Niono. Rainfall during the trial period was generally low, often concentrated over a small number of days in the year (see Chapter 2 for details). Sowing by hand took place in the second fortnight of July, after ridge cultivation with an ox-drawn plough, and was followed by hoeing and reseeding. Farm-level conditions were thus simulated as closely as possible. Harvesting generally began in the third week of October.[2/]

The seeding of forage species in natural vegetation had very disappointing results. When the 1978 rains finished, towards the end of September, the legumes lost their leaves and the grasses dried out, showing very stunted growth. Amongst the legumes, only *Alysicarpus ovalifolius*, *A. vaginalis*,

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2/ For comparison with the timetable of cropping operations in the traditional system, see Figure 23.

Macroptilium atropurpureum (Siratro), *Stylosanthes fructicosa, S. hamata* (Verano), all the varieties of *S. humilis, S. suburicea* and *S. viscosa* survived the first dry season, and amongst the grasses, only *Cenchrus ciliaris* (four varieties), *C. setigerus* and *Urochloa mozambiensis*. All the species regrew poorly during the next rainy season and were unable to compete with the natural annual vegetation. As in 1978, the grasses dried up and the legumes lost their leaves as soon as the rains stopped. At the end of the first growing season, *Stylosanthes hamata* and *Stylosanthes humilis* had produced seeds which germinated with the first rainfall in June 1979 but most seedlings died because of the severe drought during the rest of June and early July. Twenty-six species which had shown some promise in 1978 were sown again at the start of the 1979 rains, using direct sowing in natural vegetation with or without phosphate fertilizer, but they suffered the same fate as those sown in 1978.

Of the browse plants tried, only local special showed promise (Table 49). The young plants were raised in plastic containers in the nursery, before planting out. However, this method is very expensive and laborious, and therefore a direct sowing trial was also carried out. Again, the results were very disappointing, as not one single plant survived the dry season. These disappointing results have been confirmed by similar trials on the same site in 1980. It is therefore questionable whether further research on introducing forage and browse species will be fruitful in this difficult environment. As a result attention has since been concentrated on cowpea agronomy as the main strategy for improving the rainfed millet production system.

3.5.3 Cowpea agronomy

Trials to test the performance of cowpea varieties began in 1979. The varieties were grown on ridges which alternated with rows of millet, so as to imitate current peasant practices. For the 1979 trials a total population density at planting of 7900 plants/ha was used, which was increased to 10,050/ha in 1980. In 1980, 22 varieties were selected which in in 1979 had combined high forage production with adequate seed yield so as to provide the farmer the opportunity to rely on his own seed. Figure 42 shows that as regards haulm yield creeping varieties were on average the best, while semi-erect types yielded more than erect varieties. The majority of the varieties yielded between 500 and 1500 kg of forage.

Table 49. *Strike rate (%) of potted seedlings of browse species at three observation dates planted on the Niono ranch.*[a/]

Sample date: species	27 Oct 1978	Strike rate (%) 27 June 1979	13 Dec 1979
Bauhinia rufescens (L)	92	75	67
Acacia tortilis (L)	89	78	44
A. nilotica (L) (L)	89	33	0
A. salicina (e) (e)	67	33	0
Piliostigma reticulata (L)	80	60	53
Dalbergia sissoo (e)	80	40	20
Combretum aculeatum (L)	75	75	19
Prosopis cineraria (e)	76	17	9

[a/] Species which showed a fair survival rate (11-69%) at the end of the first growing season, but low rate in the subsequent seasons (0-9% in 1979) are the following: *A. albida (L), A. victoriae (e), A. malanoxylon (e), A. cyanophylla (e), A. horrida (e), A. kampsana (e), P. juliflora (e), Leucaena leucocephala (e), L. leucocephalo* Var. Hawai giant K18, *L. leucocephala* Var. Peru, *L. leucocephala* Var. Cumminghan. The following species did not survive the first rainy season: *Acacia aneura (e), A. brachystachya (e), A. ligulata (e), A. senegal (L), A. seyal (L), Atriplex nummularia (e)* and *Ziziphus nummularia.*

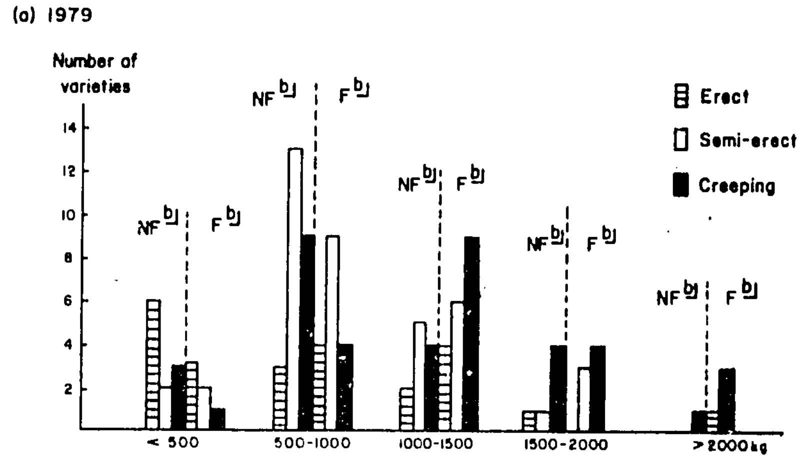
e = exotic species and *L* = local species.

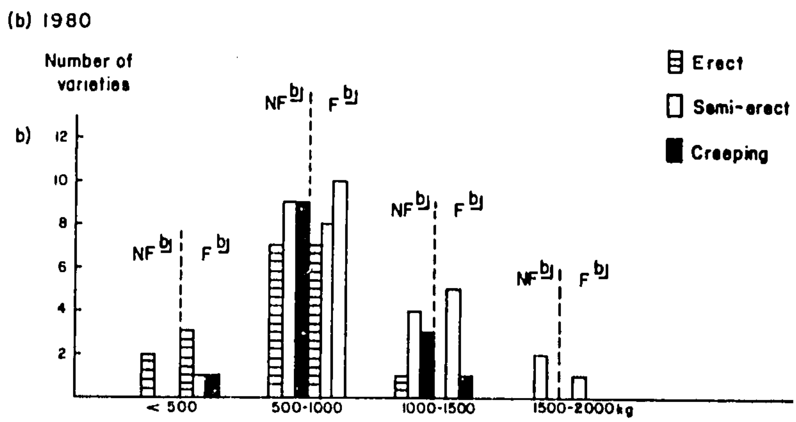
Source: Compiled by authors.

Thus for forage production creeping varieties are preferred, as they yield more and their haulms can be rolled into a ball, avoiding leaf loss and facilitating storage. Although grain production in 1979 was generally low, the erect and semi-erect varieties showed the best results (Table 50). In 1980, none of the tested varieties produced seed, although they formed flowering buds, which did not develop further because of the early cessation of the rains.

The next step was to examine the agronomy of cowpea-millet intercropping. The traditional practice is to sow a mixture of millet and cowpea seed in the same hole. As a result, millet and cowpea plants are distributed haphazardly throughout the field. During sowing the cowpea/millet seed ratio is usually about 10% and at harvest cowpea stands constitute some 4% of the plant population, but these proportions vary according to the producer. The haulms are mainly fed to horses, *moutons de case* and donkeys, while the grain is used as human food. In one of the villages studied a specialized cropping

Figure 42. *Productivity of cowpea varieties by class and growth according to habit, with and without fertilizer in 1979 and 1980.*[a]





[a] In 1979 54 varieties were tested: 12 erect, 21 semi-erect and 21 creeping; in 1980 37 varieties were tested: 10 erect, 15 semi-erect and 12 creeping.

[b] NF: no fertilizer; F; fertilization with 2 tonnes of dry dung/ha and 30 kg supersimple P_2O_5.

Source: Compiled by authors.

practice has developed: the cowpeas grown in the bush fields are sown early and are meant for grain, while the crop in the village fields is sown late, mainly to produce haulms. Cowpeas nonetheless always remain secondary to millet, and labour is preferably invested in cereal crops.

Table 50. *Average seed yield in 1979 of 54 cowpea varieties tested with and without fertilizer.*

Type	Number of varieties	Productivity (kg/ha)	
		Without fertilizer	With fertilizer[a]
Erect	12	65	96
Semi-erect	21	41	51
Creeping	21	30	35

[a] Fertilization of 30 kg of single super P_2O_5/ha and 2 t of dry cow manure.

Source: Compiled by authors.

Sowing cowpea together with millet does not affect labour time, but harvesting the haulms of randomly distributed plants is time consuming. If cultivated in pure ridges at regular intervals amongst the millet ridges, sowing is more laborious but harvesting becomes much easier. Both methods nevertheless create competition for minerals and water between the two crops. Cowpea has to withstand shading by millet, but at the same time should be competitive enough to produce haulms and grain without being so aggressive as to cause a reduced millet harvest. A third method, cultivating cowpeas alone in rotation with millet alone, would avoid all problems of water, light and nutrient competition but would also reduce the area under millet and is thus not generally acceptable within the socio-economic context.

The low seed rate used and the agronomic practices associated with cowpea growing indicate that this crop is of minor importance within the setting of a survival strategy that is focused entirely on producing millet. Innovative practices involving cowpea cropping that go against this strategy therefore have little chance of being adopted. Thus, altering the intercropping system so as to produce more haulms should not markedly add to the labour inputs nor should there be a risk that millet yields are adversely affected.

Figure 43 shows the yield of millet ears and straw as a function of cowpea percentage in the intercrop, with and without fertilizer while Table 51 shows millet grain and dry cowpea haulm yields at different fertilization levels with varying percentages of cowpea. Two major conclusions can be drawn: that in a year in which rainfall is well distributed, cowpeas appear not to influence millet yields below a rate of 30%, and that in a year where rainfall distribution is less favourable and/or cropping is less successful, cowpeas are more competitive than millet and respond better to phosphate fertilizer. It has been possible to calculate the percentage increase or decrease of millet and cowpeas when superphosphate and manure are used, as shown in Table 52.

Table 51. *Millet grain and dry cowpea haulm yields at different fertilization levels with increasing proportion of cowpea in the crop mixture.*

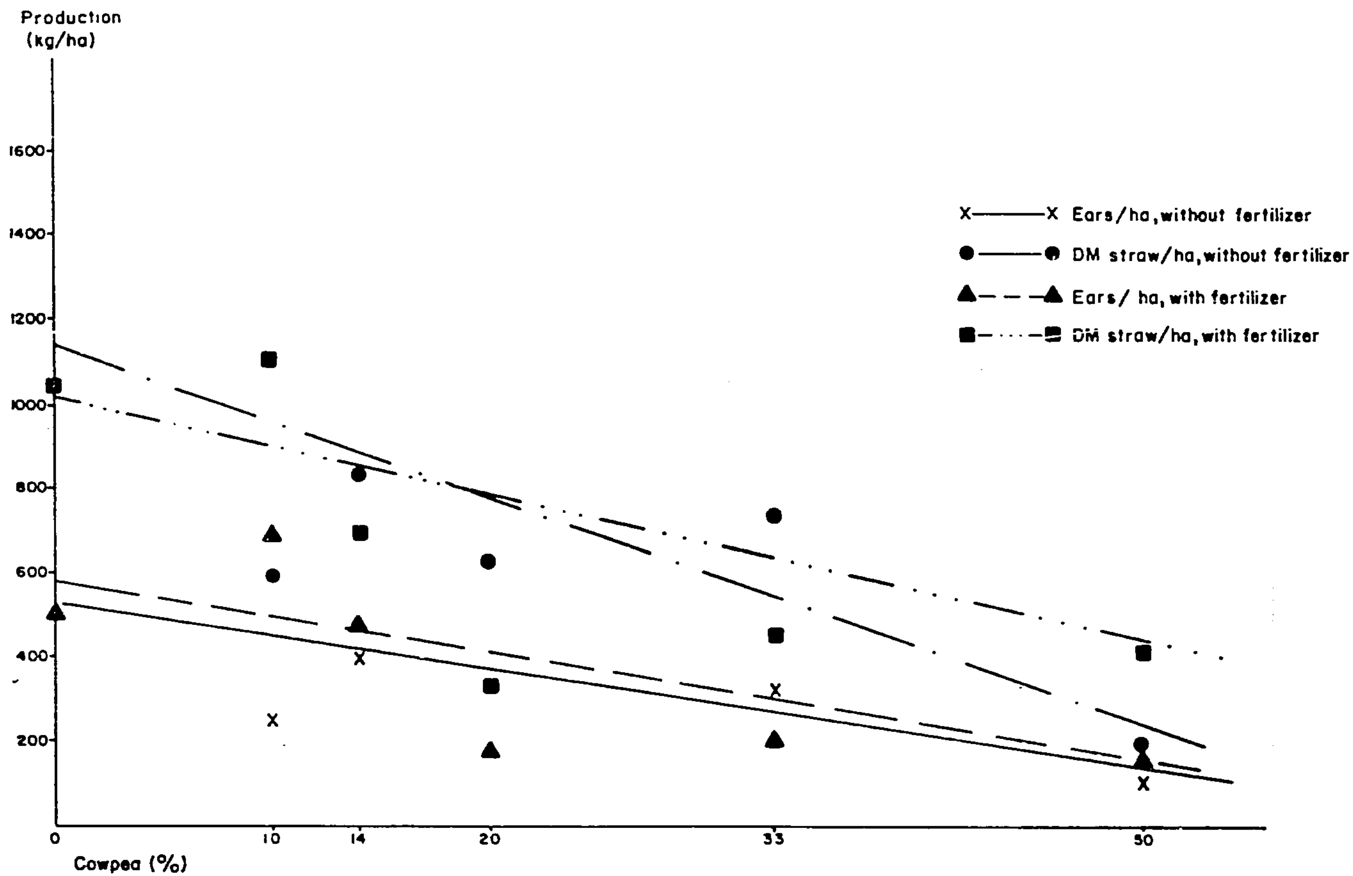
		Fertilization level				
N (urea) (kg/ha)		0	50	0	50	
P_2O_5 (kg/ha)		0	0	50	50	
Cowpea %		Yields (kg/ha)				Mean
0%:	Millet grain	454	715	1110	[illegible]28	777
	Cowpea haulms	0	0	0	0	0
20%:	Millet grain	614	836	502	1177	782
	Cowpea haulms	512	722	484	349	517
33%:	Millet grain	446	285	947	1276	739
	Cowpea haulms	775	590	306	356	507
50%:	Millet grain	546	327	845	970	672
	Cowpea haulms	1452	1036	356	435	820
Mean:	Millet grain	515	540	851	1063	742
	Cowpea haulms[a]	913	782	382	380	614

[a] Average for 20%, 33% and 50% rates only.

Source: Compiled by authors.

Although the pure millet crop produced about 1100 kg of straw and almost 600 kg of ears, grain-filling was very poor, resulting in a low grain yield (Figure 43). The grain/ears ratio is 0.2 as against a norm of

Figure 43. *Production of millet ears and straw with and without fertilizer as a function of cowpea percentage.*



Source: Compiled by authors.

Table 52. *Effect of single superphosphate fertilizer and manure on relative yields (in %) of millet grain and cowpea haulms.*

P_2O_5 (kg/ha)	10	30	50
Without manure			
Millet grain	-3	+64	+147
Cowpea haulms	+88	+121	+54
With manure:			
Millet grain	+50	+64	+178
Cowpea haulms	+43	+59	+54

Source: Compiled by authors.

0.6, and the ears/straw ratio is 0.4, compared to a norm of 0.7, indicating that the crop was arrested in its growth. Thus, the success of millet cropping in marginal areas is strongly dependent on available soil moisture in September and October, and a healthy looking crop in August can easily turn into a field of straw without any grain, if rains stop early

The forage trials in the villages indicated that when cowpeas were grown on pure ridges losses caused by stray animals are much higher, whereas scattered plants are more difficult to detect and thus less prone to be grazed before harvest. Hence, if cowpeas are grown on pure ridges, or as a pure crop livestock have to be well controlled.

The present work on the intercropping of cowpeas with millet indicates that with greater soil fertility millet competes better with cowpea, while the same is true when soil moisture is not deficient. Thus, in good years, millet yields are not likely to be depressed when cowpea is intercropped, provided it is grown in a proportion to millet of less than around 30%. However, when the water balance is negative or fertility is low, or when crops are poorly managed or other unfavourable factors for millet intervene, cowpea becomes too competitive and this may result in much lower millet yields.

There appears to be little information on the longer-term effect of cowpea on millet crop yields. Steel (in Jones and Wild, 1975) concludes that cowpeas cultivated in millet increase the production of the latter. In addition, Wetselaar (1967) found in Australia that cowpeas fixed 136 kg of

N/ha after one growing season, and 269 kg of N per ha after three seasons. However, Jones and Wild (1975) concluded from their work on residual effects from various crops on maize, that cowpea has no positive effect on subsequent crops and that its N fixing ability has not yet been clearly proven.

3.5.4 Millet fertilization

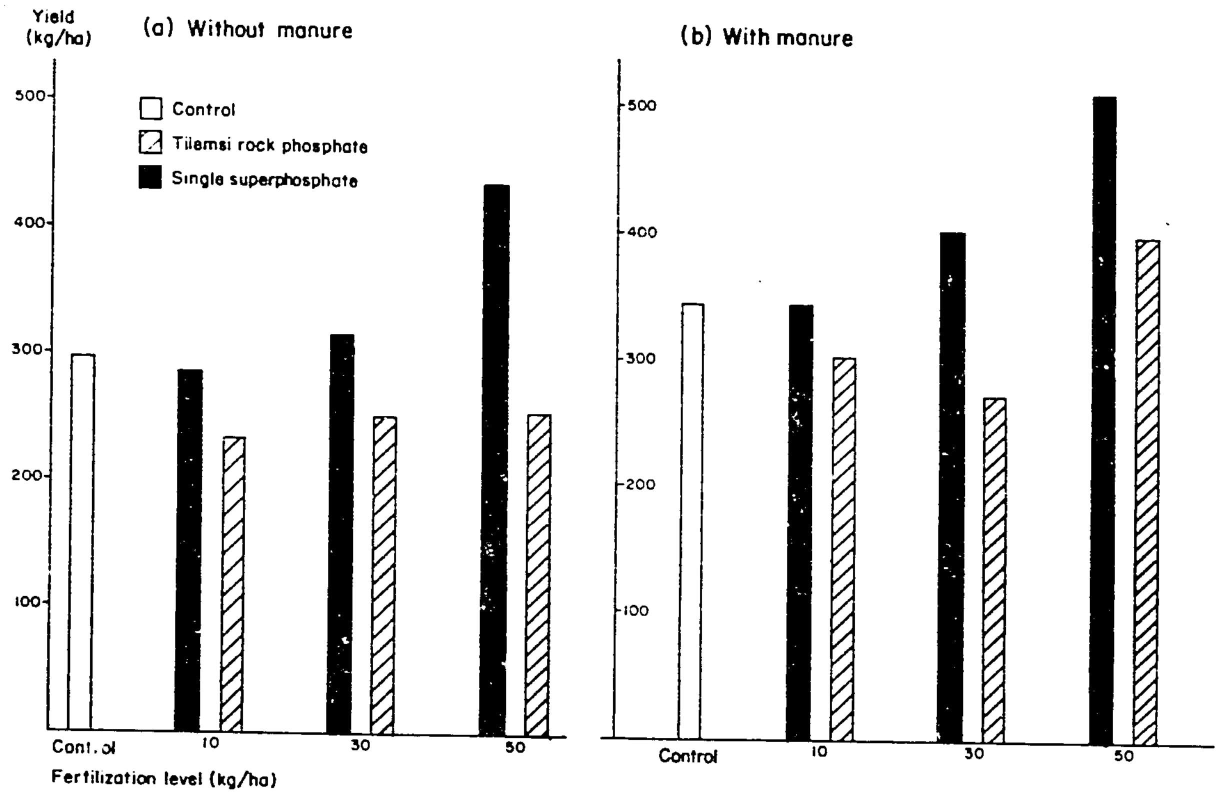
Research has shown that phosphorus application increases millet yield. For instance, in ILCA trials phosphor applied as soluble monocalcium increases yields by an average of 5 kg of millet grain per kg of P_2O_5 during the first year, although the response is extremely variable with rainfall, site and planting date. Djiteye and de Vries (1980) confirmed that this P-fertilizer is highly soluble and has a 50-70% recovery rate during the first year when applied to natural pasture.

In contrast, phosphorus applied as much less soluble tricalcium phosphate (rock phosphate from Tilemsi in Mali) is believed to be ineffective under low rainfall regimes. ILCA results showed a drop in production following application of rock phosphate (by 6 kg of grain per kg of P_2O_5 during the first year). These conclusions are in line with those of Djiteye and de Vries (1980), who state that Tilemsi rock phosphate is recovered at a rate of only 2% during the first year on natural pasture. Boyer (1970) and Pierri (1971) also advised against the use of insoluble phosphates at rainfall levels below 700-800 mm. However, SAFGRAD (1979) used Tilemsi phosphate at 90 kg of P_2O_5/ha and produced an extra yield of 4 kg of millet grain per kg of P_2O_5 with rainfall at around 430 mm.

The residual effects of soluble P were tested and showed that the average yield response in one trial over 3 years per 1 kg of P_2O_5 was 14 kg of millet grain. For the trial represented in Figure 44, the yield over 2 years, was 6 kg of millet/kg P_2O_5, at an application of 50 kg of P_2O_5, but only 1 kg of millet on application of 30 kg of soluble P_2O_5.

Trials with N fertilizer showed increased millet yield at a rate of 1 kg of grain for each kg of N applied, but as with P, responses are very variable. SAFGRAD (1979), at rainfall of 400 mm, obtained similar results. In northeast Mali, on similar soils and rainfall as the ILCA trials, Poulain et al (1976) obtained an increase of 2.4 kg of millet grain/kg of N, and estimated that for Mali as a whole 1 kg of N applied produced 8 kg of millet or sorghum grain. The same authors reported a linear, albeit low, response of millet to increasing applications of N. Pierri (1971) specified that

Figure 44. *Average annual millet yields over 2 years with two different fertilizers at various levels, with and without manure.*



nitrogen is effective only if other nutrient deficiencies, particularly P, are eliminated, and recommended a 25-45-0 fertilizer Table 53 shows the interacting effects of NP application. Nitrogen alone leads to a drop of 5% of grain, while phosphorus alone increases output by 18%, while an NP dressing leads to an increase of 67% over the control.

Table 53. *Production of millet grain and straw (DM) at various fertilization levels.*

	Fertilization (kg/ha)				
Nitrogen (urea)	0	50	0	50	Average
Single super P_2O_5	0	0	50	50	
Grain (kg/ha)	705	673	829	1178	846
Straw (kg/ha)	1277	1382	1572	2051	1571

Source: Compiled by authors.

Djiteye and de Vries (1980) estimate a nitrogen recovery on natural pasture of 30 to 80%, losses with urea being the lowest. These authors indicate that large doses of nitrogen alone can increase productivity three times, phosphorus alone two times, and the combination N + P eight times, while residual effects of the nitrogen during the second year were also demonstrated, in contrast to Poulain et al (1976) and Pierri (1971), who indicated that no residual effect occurs during the second year.

Figure 44 showed that the spreading of manure had only a moderate effect on yields: namely a 29% increase over the control when manure was applied with fertilizer and 18% without. This response is low because, as Djiteye and de Vries (1980) found, over 2 years only 10% of the manure N is used, this low recovery being due to the high C/N ratio (about 50) and the low N content (about 1%). According to Pierri (1971) the high organic matter content of manure seems to reduce the short-term effect of mineral fertilizers, but over the long term the combination of manure and fertilizer is more attractive than fertilizer alone, which itself is superior to manure alone.

Increase in millet grain production are matched by those for ears and stubble. When P or NP fertilizers applied, grain/ear and ear/straw ratios increase, while with nitrogen, whether applied as manure or as urea, these ratios do not appear to change.

It should be noted that the effect of organic and mineral fertilizers is influenced by the many other variables affecting crop yields. They are only efficient if other conditions, such as early planting in moist soil and early and frequent weeding, are optimal. The fertilizer trials done in the three villages are summarized in Table 54. The increase due to fertilizer treatments ranged from 13% in village A to 130% in village C. Fields in village A received large amounts of organic manure, and here NP fertilizer was not tested since, according to the farmers, fertilizers, and especially nitrogen, make plants more sensitive to drought. A preliminary economic evaluation of these trials shows that these fertilizer rates give marginal yield increases after 1 year of cropping on village fields, and indicates that frequently fertilizers do not pay in the first year, but that during the second year applying single superphosphate becomes economically worthwhile with a marginal yield of approximately 1.5 kg. As 1 kg of P_2O_5 as single superphosphate costs MF 357 and MF 304 as ammonium phosphate, profitab..ity will be enhanced by using the latter. These low marginal yields achieved on peasant farms nonetheless demonstrate the high help element of risk in using fertilizers.

Table 54. *Average millet grain yield (souna variety) for three villages receiving fertilization of village fields.*

Yield (kg/ha)	Village fields		
	Tilemsi	Single super P_2O_5	N-P
Village A	139.7	1585	-
Village B	637	782	990
Village C	405	833	929

Source: Compiled by authors.

4. PASTORALISM ASSOCIATED WITH FLOODPLAIN FARMING

4.1 GENERAL DESCRIPTION

The subsystem identified in Chapeter 1 as pastoralism associated with floodplain farming is found in the inner Niger delta of central Mali and is characterized by transhumant livestock production and extensive rice cultivation. For a period going from late July to November - December, the delta pastures are flooded each year. The transhumant and semi-sedentary pasteralists have priority rights to the *bourgoutières* or flood-retreat pastures, where their animals spend up to 6 months annually, the other half being spent on the rainfed Sahel rangeland in the areas surrounding the delta. The main ethnic group within the system is the Fulani, although other groups entrust their animals to Fulani herdsmen.

The basic production unit is the nuclear or extended family, inhabiting a village base where most of the family remains for the whole year. Animals belong to individual family members but are herded together in extended family herds. Because women own many cattle, herds often contain animals belonging to owners related through matrilineal kinship ties, for example, cousins whose mothers are sisters, rather than cousins whose fathers are brothers, as is almost invariably the case in other production systems.

Household herds are built up by a combination of inheritance, gifts and loans, investment of agricultural profits in animals. Women constitute their herds mainly by inheritance, as a dowry, and with the profits from the sale of milk. Cattle are the main animals herded, together with large numbers of sheep, including the Macina wool breed, in some groups. Smaller numbers of goats may also be herded.

Men perform the main pastoral and agricultural tasks. Some agricultural work is still done for the Fulani by their former agricultural dependents, the Rimaibe, who are paid in kind. The herdsmen during transhumance away from the base villages are yound unmarried boys and men (from about 10 years upwards) under the supervision of a senior herdowner, known as the *jowro*. Households cultivate rice or have rice cultivated on their behalf using the natural flood and increasingly also semi-controlled irrigation in the inner Niger delta flood zone. However, only a few male cattle, less than 10%, are used as draught oxen.

There is a precisely determined annual migration in several stages. The main herds or *garti* leave the delta as the flood rises in July, and follow the traditional transhumance routes, known as the *burti*, to the Mauritanian Sahel in the northwest and Mema in the north, where they spend the rainy season. They start to return towards the delta by the same routes in October, spend most of November in a transitional zone along the edge of the delta, and enter the delta flood pastures in early December. Once within the delta, they follow the retreat of the flood in a generally northeastern direction towards Lake Debo. Towards the end of the dry season, many of the herds return south towards their h-me villages ready for departure towards the Sahel once the floods begin to rise again (figure 7).

Two small groups within the herds do not follow this overall pattern. The first is the *dumti*, a small number of milk cows for household nutrition, which remain in the village throughout the rainy season where they are often stall-fed. The second is the *bendi*, the main body of milk cows and their calves, which remains around the villages as long as possible. The number of animals remaining in the delta during the flood period appears to be rising, perhaps as a result of increasing demand for milk.

The delta resources are subject to a complex system of grazing management dating from the nineteenth century. Delta pastures are divided into about 35 traditional grazing units (*leydi*) of varying size, in each of which a traditional social organization governs who holds pasture rights, which herds have access to the pasture and on what conditions, what grazing fees are paid and to whom, and the dates and order in which herds are allowed access to the pastures. A special status governs village pastures reserved for the *dunti* and *bendi* herds, and the tracks and resting places used by transhumant herds passing through the *leydi*. The Malian Government now recognises the *leydi* system of territorial organisation *de facto*, and the regional authorities enforce decisions on range use made jointly by herders' representatives and the local administration. Outside the delta, the upland Sahel pastures are not allocated, but the major transhumance tracks are recognized and in theory are protected from agricultural encroachment.

Because of extensive rice cultivation and trading activities, the share of household income from pastoral activities is less than in the other pastoral systems, and livestock products play a less important part in household nutrition. Domestic rice production is largely consumed within the household, so that the marketed output of this crop is also smaller than would be expected in a pastoral economy closely associated with trading activities. The proportion of overall production marketed has been estimated at 44% among the Niger delta Fulani.

Although occupying a relatively small area, the floodplain production system is of major importance within the Malian livestock sector. It accounts for about 25% of the national cattle herd and also contains an estimated 18% of Mali's sheep and goats. As indicated previously, the system is not widespread, but comparable production systems are found on a smaller scale in other parts of the Sahel, for example around the shores of Lake Chad.

4.2 FEED RESOURCES

4.2.1 Introduction

Pastoral systems take very different forms but all have one feature in common in the way in which they use rangeland, namely the considerable spatial mobility of herds. The aim of herd movement, which may follow more or less regular patterns, is to compensate the substantial seasonal variations in available feed supplies by aiming to occupy the part of the rangeland considered most advantageous at each season, taking into account the quality and availability of feed but also health and watering conditions, although the latter are often subject to the limitations set by the social status of the individual herdsman.

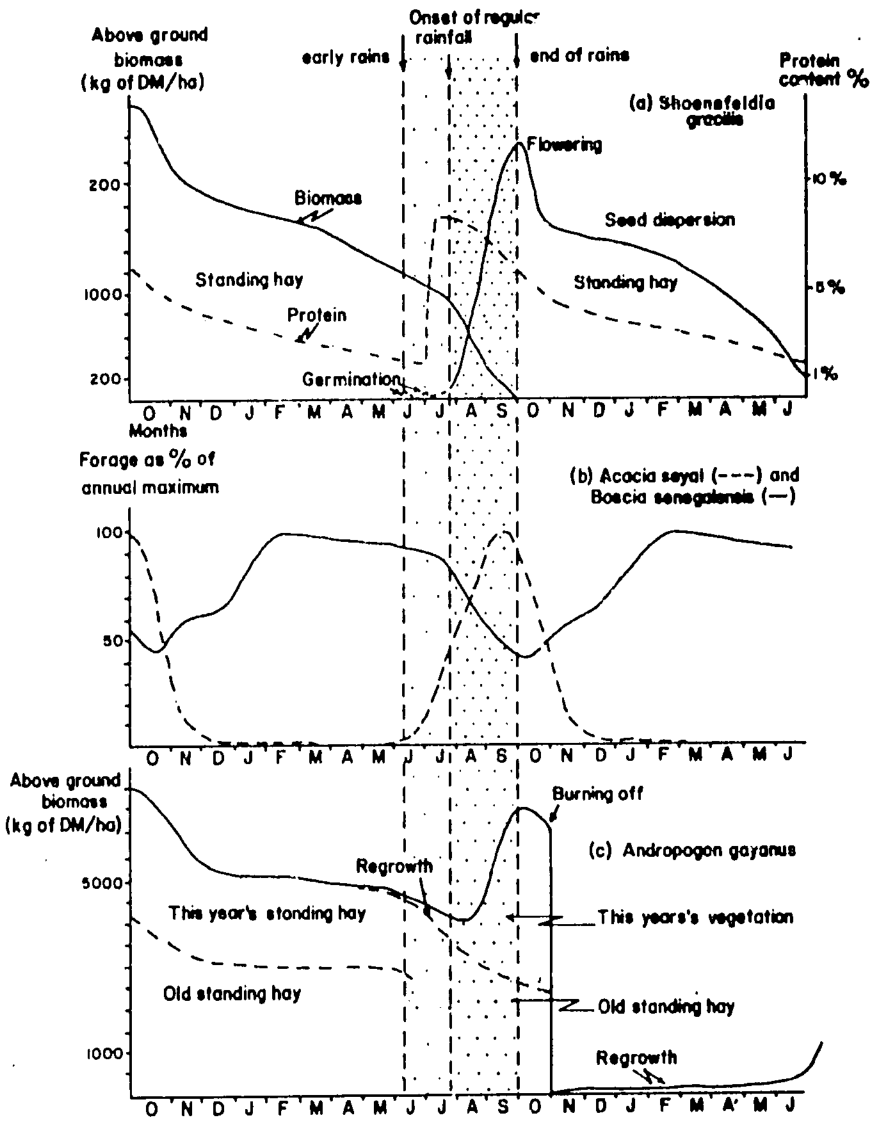
Pasture utilization in pastoral systems thus tends to develop not around a point, as in agropastoral systems, but along an axis linking different areas of rangeland. In the case of the nomadic subsystems of the northern Sahel, the pastures grazed thus consist both of Saharan rangeland to the north and of Sahelian rangeland to the south. In the transhumant subsystems the Sahelian rangelands are used either in conjunction with Sudanian savanna or with higher potential grazing land, such as the delta of the Niger in Mali. In the case of the Niger delta system studied by ILCA, the floodplain pastuers are used as the floods retreat during the dry season. As the rains begin and the floods start to rise again, the herds migrate northwards to use the upland Sahel rangeland. The feed resources of these two contrasting environments differ considerably. In the section which follows they are described in greater detail.

4.2.2 Upland Sahel rangeland

The upland Sahel rangeland consists of two major components, each distinct in terms of its biology and structure, as well as the quantity and quality of feed it produces. These two components are the grass cover, dominated mostly by annual *gramineae* but containing a few perennial species, and a cover of varying density consisting of trees and shrubs. These different strata have quite different utilization rates by the various ruminant species.

The climate, with its sharp contrasts caused by a single rainy season of 2 to 4 months, leads to large seasonal variations in the quality and quantity of available range resources. The trends for biomass and protein content on *Shoenefeldia gracilis* rangeland (Figure 45) show this clearly. The natural degradation rate of the standing hay in this species is modest in comparison with others: 59% from September to June, as against 76% for *Loudetia togoensis* and 63% for *Diheteropogon hagerupii* in the same year (Hiernaux et al, 1979). Biomass trends measured on one of the rare *Andropogon gayanus* formation show a longer growth period and higher production than annual grasses. For browse plants, the examples of *Acacia seyal* *Boscia senegalensis* show that there is considerable difference between species, and measurements have revealed secondary fluctuations resulting from environment, the age of the plant and other factors. In general the leaf production curve of browse plants reaches its maximum during the rainy season, with the well known exceptions of *Acacia albida* and a few *Capparidacae* species. It starts well before the onset of the rains and often continues long after the rains have stopped and the grasses have dried out. This time lag explains the special part played by browse plants in overall feed resources (Cisse, 1981).

Figure 45. *Biomass and protein content for various plants on Sahel rangelands.*



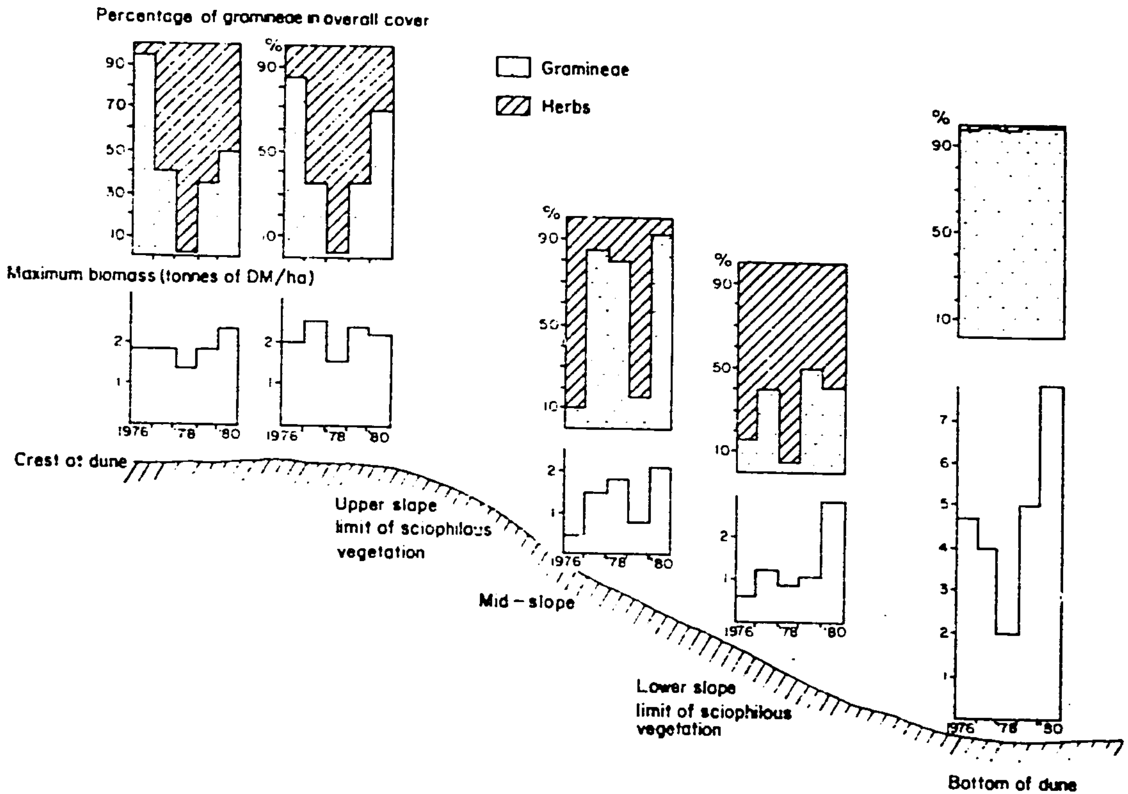
Source: Compiled by authors.

As regards the annual grass cover, observations for 60 sites near Niono over 4 years showed considerable interannual variability. The variations involved not only the floristic but also the biomorphological composition, as well as production. Over 3 years only 57% of flora repeated from one year to the next, the *gramineae* cover varied by 41% and maximum biomass by 39% on average. Figure 46 illustrates biomass fluctuations and changes in the floristic composition for five sites distributed in a catena over a transect several hundred metres long and monitored over 5 years. The location of the transect was a sloping dune on the Niono ranch, including a variety of ecological niches. The figure confirms the magnitude of the variations and also shows the asynchronized nature of trends for the different niches.

When these niches are considered separately, the role of rainfall regime and its influence on biomass and floristic composition are seen to be crucial. The distribution of rain, in particular, appears more important than total rainfall. Early rain, length of the rainy season and especially the onset of the rains (whether they come gradually, suddenly or with one or more interruptions) have considerable effects. The timing, distribution and volume of the first rainfall determine the floristic composition by triggering off seed germination, while the greater or lesser resistance of young plants to the irregular rainfall so often occurring during their early growth period is a further factor. In addition to rainfall regime, edaphic environment, topography, soil texture and the ligneous plant cover are secondary factors influencing the water regime. As a result, the density of young plants, their floristic variety and their development stage can differ enormously from year to year for one and the same site by the time rainfall becomes more regular and triggers off the herbage growth period proper.

Growth is limited by soil fertility (Djiteye and de Vries, 1980), especially by the levels of nitrogen and phosphorus which can be assimilated. Daily growth rates range from 20 to 50 kg of DM/ha. If rainfall is not a limiting factor, growth continues until flowering, which occurs independently of rainfall in early to mid-September, depending on species. Seed production enables the seed stock to be replenished, thereby influencing the grass cover

Figure 46 *Interannual variations in biomass and biomorphological composition for five sites in a catena on a sloping [illegible] transect [illegible] (1976 - 1980).*



Source: Compiled by author

of the following year. This influence emerges clearly when the species lists for the five sites in Figure 46 are compared from one year to the next (Table 55). The coefficient of similarity is always higher when two consecutive years are compared (on average 64%) than when they are not (58, 56 and 56%). Dependence on climate at each phase of the phenological cycle makes the Sahelian grass stratum highly vulnerable to freak variations in rainfall. Nevertheless this statement should be qualified: when the trends for fiora at each site taken separately are compared with those for all the sites together, the variability of the transect as a whole is seen to be distinctly less than that of each of the sites. This can be explained by the lateral mobility of species affected by climate fluctuations. Sahelian grasses have a low ecological specialization, often noted in phyto-ecological studies, which may be regarded as a form of adaptation to an unpredictable environment.

Perennial grasses play a very minor part in the floristic composition of Sahel rangeland compared with their importance further south. The few species found do not prosper under such low rainfall conditions. A past description of the Niono rangeland (Boudet and Leclerq, 1970) compared with its condition at present, suggests that *Andropogon gayanus* for example, regressed considerably during the drought years of 1972 to 1975 (Cisse, 1976). The periodicity and vigour of regrowth are both highly variable from one year to the next, probably in relation to residual soil moisture. In any case, only under privileged soil and topographical conditions will soil moisture in the Sahel climate last long enough to cover the *Andropogon gayanus* cycle (see Figure 38), where early growth in May or June is combined with late fruiting in October. The regeneration of populations is made even more hazardous by the fact that the seeds germinate with the very first rains, since the young plants resist subsequent droughts poorly. Thus on a 25 m^2 plot covered with 31 tufts, 125 seedling developed in 1976, none in 1977, 46 in 1978, 1 in 1979 and 3 in 1980. By 1980 there were only 7 left (4%) of the plants started over the 4 previous years. Nonetheless, mortality affects the older tufts much less (only 2 out of 31).

The longevity of browse trees and shrubs does not allow diachronic observations over a period of only 5 years. The demographic conclusions to be drawn from the structure of woody population (Hiernaux, 1981) are risky, for want of a sure method for estimating ages. Generally speaking, however, populations appear stable even if a series of deficit years from

Table 55. *Sorensen coefficients of similarity between years for species lists compiled for the five sloping dune transect sites on the Niono ranch.*

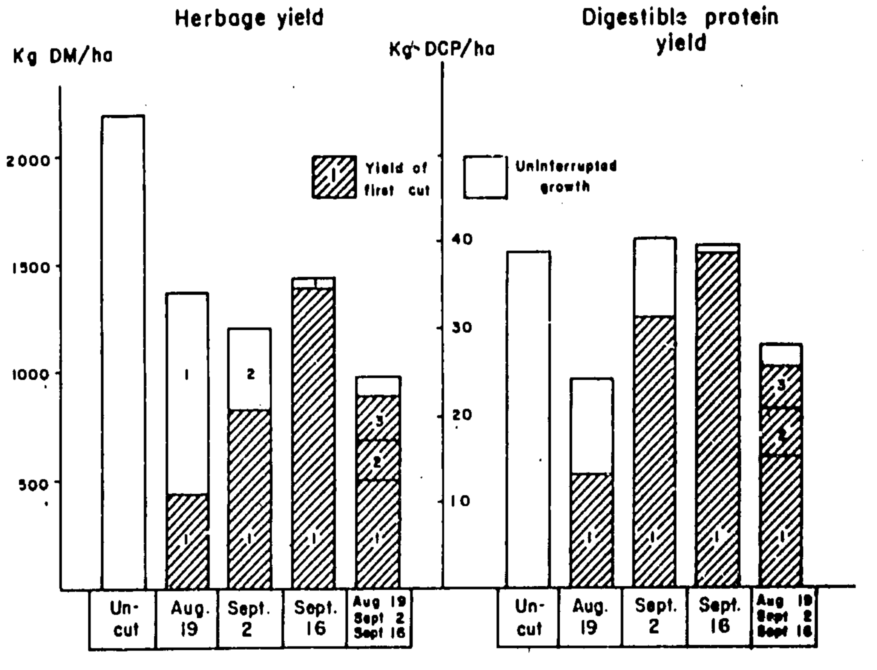
		Pairs of years compared									
		76-77	77-78	78-79	79-80	76-78	77-79	78-80	76-79	77-80	76-80
Coefficient of Similarity	Site: Crest of dune	67	68	63	73	52	64	68	57	66	56
	Upper slope	78	73	61	64	63	64	66	51	68	66
	Mid-slope	46	70	67	80	47	55	79	40	68	49
	Lower slope	57	72	56	59	48	67	62	45	56	56
	Bottom of dune	51	62	50	61	45	57	39	51	55	52
	Catena average	60	69	59	67	51	61	68	49	62	56
	Average	64				58			56		56
Whole transect		90	71	72	79	68	73	68	75	73	76
	Average	78				70			74		76

1970 to 1975 led to high mortality in some species, such as *Terminalia avicennoides*, *Bombax costatum* or *Grewia bicolor*. Population levels do not appear to be as sensitive to climatic variations as for example, leaf production. Their regeneration can nontheless appear problematic. Some populations of *Pterocarpus lucens*, for example, show no regeneration apart from a few non-viable seedlings. Their origin therefore, has to be attributed to a series of exceptionally favourable years, which might explain the existence of populations in which the individuals are almost all of the same age.

The impact of pastoral utilization on the production and dynamics of Sahelian rangeland varies according to the component concerned, the season and periodicity of grazing, and the management methods of the herdsmen. For annual grasses, the consequences of grazing differ mainly according to season. If grazing occurs outside the growth season it has the immediate effect of accelerating the degradation of standing hay, reflected in a level of apparent consumption 50 to 100% higher than real intake. The apparent rate of consumption varies according to species and period in the dry season, but averages around 10 to 15 kg of DM/TLU per day (Hiernaux et al, 1977 - 1979). Over the longer term, however, dry-season grazing seems to have only very limited effects on subsequent production and flora. After 3 years of controlled grazing during the dry season there was only a slight extension of bare soil patches on grazing land with heavy soils, and a slight increase in germination and plant cover on sandy soils was even noted (cf. Breman and Cisse, 1977).

When annual grasses are grazed during the growth season, in addition to the actual removal of plant material there is also an effect on subsequent growth. Cutting trials at different stages in the development of the grass stratum show that this effect is very variable. For *Schoenefeldia gracilis* (Figure 47) the earlier the cutting the more active the regrowth, such that when cutting occurs during tillering it even stimulates growth, whereas growth is checked if the grass is cut after stem elongation. Repeated cutting, however, very soon has an impact on the vigour of regrowth. Herd management therefore has important implications for subsequent protein availability which differ according to whether a pasture is grazed early in the growing season or continously throughout is. In annual grasses, such as *Schoenefeldia gracilis*, however, the effect on protein content is not as pronounced as in perennials.

Figure 4.7. *Effect of cutting date and repeated cuts on herbage yield and quality of Schoenefeldia gracilis rangeland on the Niono ranch (1977).*



Source: Compiled by authors.

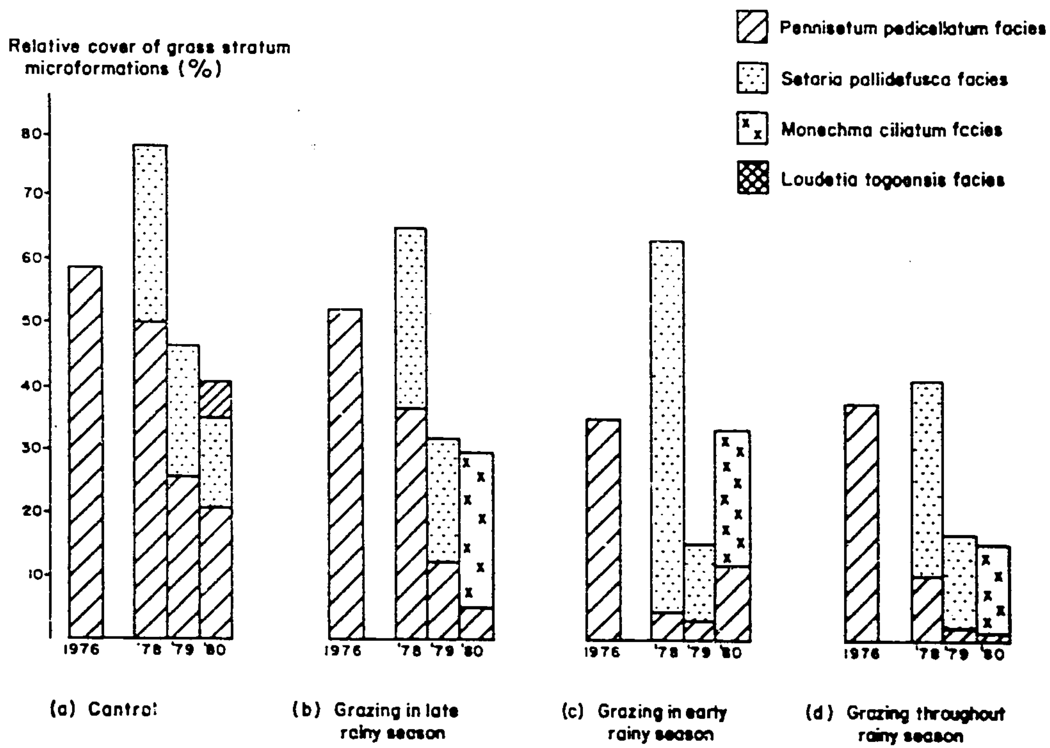
The longer term effects on rangeland trends are highly variable, depending on the type of rangeland as well as on management. Trials at the Niono ranch showed that rangeland on heavy soils is more sensitive than rangeland on sandy soils. The most marked effects were obtained when stocking levels were maintained throughout the growth season, preventing the most palatable species from completing their cycle, thereby reducing their chances of being present the following year. In the case of flat rangeland, with *Pterocarpus lucens*, in which the grass stratum was dominated by *Pennisetum pedicellatum* (Figure 48), 3 years of extended grazing throughout the rainy season was almost enough to eliminate the *Pennisetum*. It was only partially replaced by two facies, a very open one with *Setaria pallidefusca* and *Borreria chaetocephala*, and one with *Monechma ciliatum*, a species which at least when green, is left untouched by cattle. When grazing is limited to only part of the growth season (Figure 48) the effect is less pronounced (cf. Breman and Cisse, 1977).

The impact of pastoral utilization on perennial grasses can be subdivided into an effect on the vitality and production of individual tufts and an effect on the regeneration of the population. Observations at the Niono ranch showed a drop in the production of tufts of *Andropogon gayanus* var. *bisquamulatus* subjected to intense grazing during the wet season, but also their good resistance. On the other hand, the trampling and pulling up of young plants by animals completely prevented regeneration. The regular removal of regrowth during the dry season 3 years running did not eliminate the tufts which had been planted, although it did make production fall sharply (Cisse, 1976).

For browse plants a distinction must again be made between the impact of grazing on growth and production and the impact on population trends. There are very few general rules valid for all browse species and everything depends on the timing and form of grazing, which may use green foliage, fruit or dead foliage lying on the ground. The impact depends a great deal on the accessibility of the feed to animals, which is direct for bushes and young trees, whereas for older trees and shrubs it requires intervention by the herdsmen, who practise various forms of pruning which inevitably affect the growth of tree.

To measure the effect of browsing several ligneous species were subjected to repeated stripping (Cisse, 1981). As can be seen from

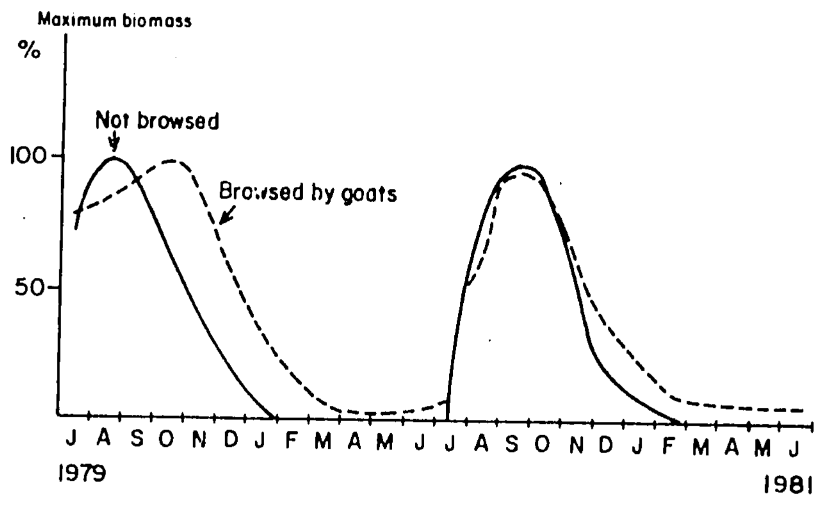
Figure 48 *Effect of grazing management on the composition of the grass stratum of Sahel rangeland.*



Source: Compiled by authors.

Figure 49 browsing increases the biomass production of *Pterocarpus lucens* during the dry season. Regrowth is better the earlier stripping takes place in the plant cycle, but recovery soon becomes weaker when stripping is repeated. Even in the case of repeated stripping, both total and partial, or in other words treatments which are much more severe than browsing by animals, very little mortality was recorded. The technique of pruning, lopping and cutting back were also tested for several species. In general it appears that the larger the branches cut or the closer they are to the base, the more difficult regrowth becomes. Cutting is always reflected in a drop in leaf production during the following year, but is often also accompanied by a lengthening of the plant cycle.

Figure 49. *Monthly development of foliage biomass in Pterocarpus lucens with and without browsing by goats.*



Source: Compiled by authors.

The longer term effects of browsing primarily depend on the specific composition of the population. Some browse populations experience a reduction in forage production, while in other cases the trend appears more favourable. For instance, the *Pterocarpus lucens* rangeland around the rice cultivation perimeter of the Office du Niger is losing its best species, *Pterocarpus lucens* and *Combretum aculeatum* which are gradually being replaced by unpalatable species such as *Combretum micranthum* and *Acacia ataxacantha*. A contrasting situation is provided by a population of *Balanites aegyptiaca*, *Acacia seyal* and *Ziziphus mauritiana*, which has replaced a population of *Combretum ghasalense* following browsing.

The upland Sahel rangeland may also be considered to include pockets of land previously cultivated but now lying fallow. This land consists of former bush fields used for shifting cultivation and, in contrast to village fields, will have received little if any manure. Although fallow periods are shortening further south, their average duration is still fairly long. When cultivation stops the field returns to rangeland, but with a vegetation fundamentally altered and giving rise to a plant successional development with greater or lesser rapidity before the next cropping cycle. A post-cropping pioneer cover often including *Cenchrus biflorus*, *Eragrostis tremula*, *Schizachyrium exile* and *Mitracarpus scaber* develops initially, but, surprisingly for soils depleted by cropping, production in the longer term is often about the same or higher than that of the original grass cover. Presumably the drop in fertility is compensated by the residual beneficial effects of ploughing on the physical properties of the soil.

The woody vegetation is drastically reduced by cultivation. Most of the trees and shrubs are cut down and only a few bushes, such as *Guiera senegalensis*, *Piliostigma reticulata*, *Ziziphus mauritiana* or *Combretum aculeatum*, continue to produce new shoots even after several years of regular cutting. Study of a 2-year fallow as compared with uncleared land illustrated the important effects of clearing, not only on numbers (295 stems per ha on fallow land, as against 1108 on uncleared land) but also on cover (2.5% as against 14.5%) and floristic and canopy composition. Traces of disruption on this kind of scale remain noticeable for a long time, and the fallow is often cultivated again before they have disappeared. Comparison of an older fallow with a similar field of uncleared land showed partial recovery (350 stems/ha as against 568 and 5.3% cover as against 9.4%), but the floristic composition and canopy structure nontheless remained severely affected.

4.2.3 Degradation and regeneration

In view of alarmist warnings about the rapid decline of the Sahelian environment and the need for quantified information on actual degradation levels, an assessment of degradation within the ILCA study zone in Mali was made, together with a quantification of land use. After comparing aerial photo covers of 1952 and 1975, Haywood (ILCA, 1980 a) concluded that while rainfed farming had risen by only 1.4% per year, land degradation was increasing at the alarming rate of 16.7% and now covered some 1.2 million ha or 25% of the area surveyed. However, further studies indicated that these conclusions should be treated with caution because:

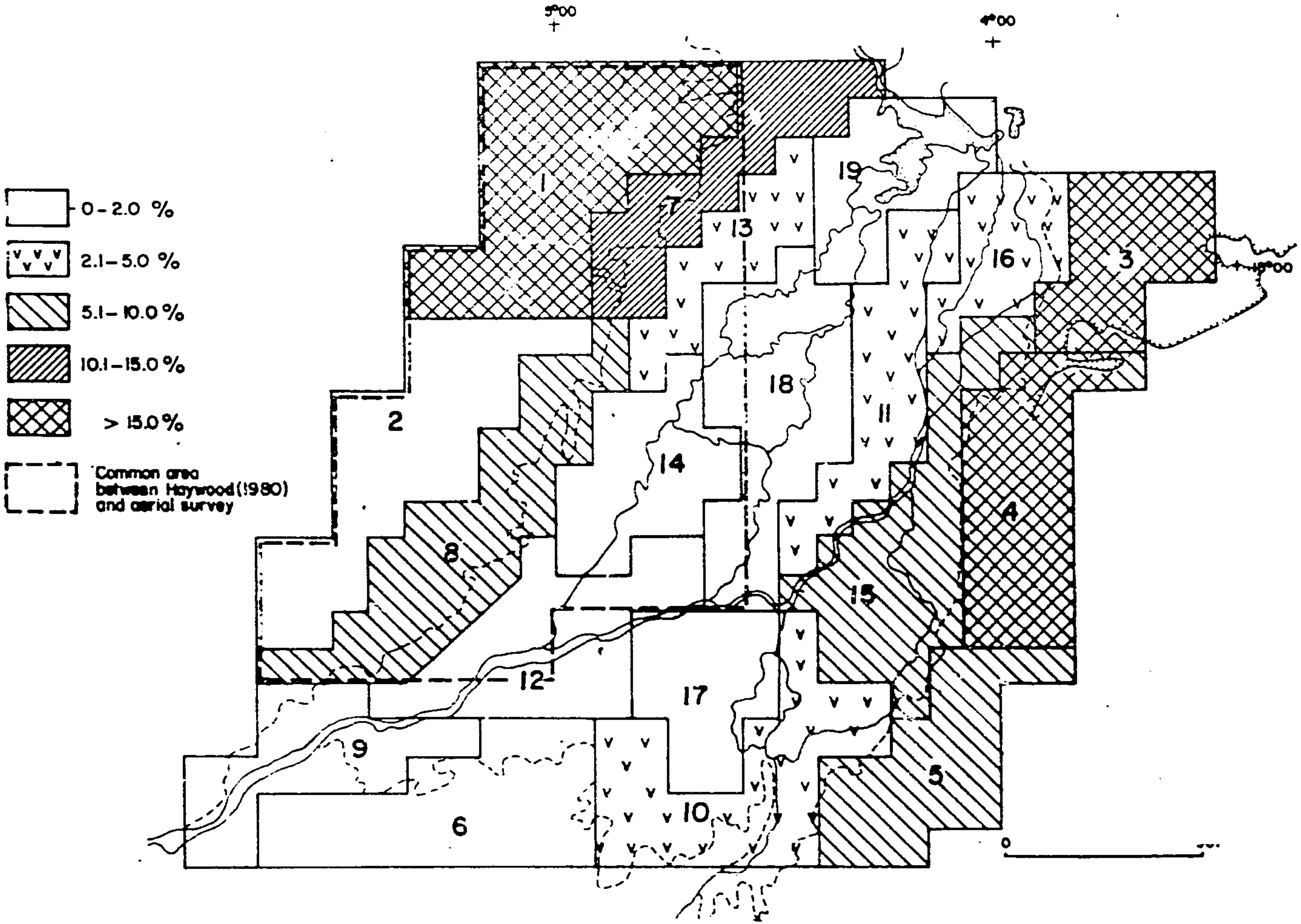
1. Degradation for the purposes of aerial photo-interpretation was defined as areas of high reflectivity but interpreted as "areas devoid of herbaceous, shrub and tree cover". While it is true that tree cover and to a lesser extent shrub density can be seen on photos, the grass cover cannot.

2. Even if high reflectivity in 1975 meant large areas of denuded soil, this should not be accepted as the permanent truth. That year can be more or less regarded as the end of the 1969-74 drought and the start of a period of regeneration, not only because over 1975-80 rainfall was more plentiful than before, but also because livestock populations had not yet regained per-drought levels.

Since 1975 much evidence has been brought together indicating that the plant cover has regenerated. Reconnaissance ground surveys (Hiernaux et al, 1977-79;Djiteye and de Vries, 1980) have shown good biomass production in areas previously mapped as degraded. Secondly, he ecological low-altitude reconnaissance done by ILCA in October 1980 confirmed the relatively high level of grass cover. During that survey, the proportion of bare ground was estimated in each grid square (86 km^2) as well as the level of inundated rice cropping and rainfed crops (Milligan and Keita, 1981).

Figure 50 confirms the high degree of bare ground in the eastern Mema (unit 1), which is characterized by a climatically determined (300 mm isohyet) open tree steppe with very little ground cover. Similarly, the plateaux, ridges and rock outcrops of the Bandiagara area (units 3, 4 and 5) account for much bare ground. In the remainder of the delta and its surroundings the proportion of bare ground was below 5% except in some parts of the transition zone (unit 8) and deltaic river terraces, levels and sandy ridges (unit 11,15 and 16;see also figure 14 in chapter 2).

Figure 50. *Proportion of bare ground (% of total land) for landscape units (1 - 19) in the Delta and its fringes*



Compiled by author.

Direct comparison with the 1975 photo-interpretation is unfortunately limited to that part of the transition zone covered by both surveys (figure 50). The low-altitude survey confirmed the sparse ground cover in the Mema, north of 15°00'N latitude, but showed a much higher plant density in the area south of that latitude. Table 56 shows comparative analysis of two data sets. This comparison leads to cautious optimism as to the level of degradation in an area known for its high degree of utilization by livestock.

Table 56 *Proportions (%) of survey units classified according to percentage of degraded land, 1975 and 1980.*

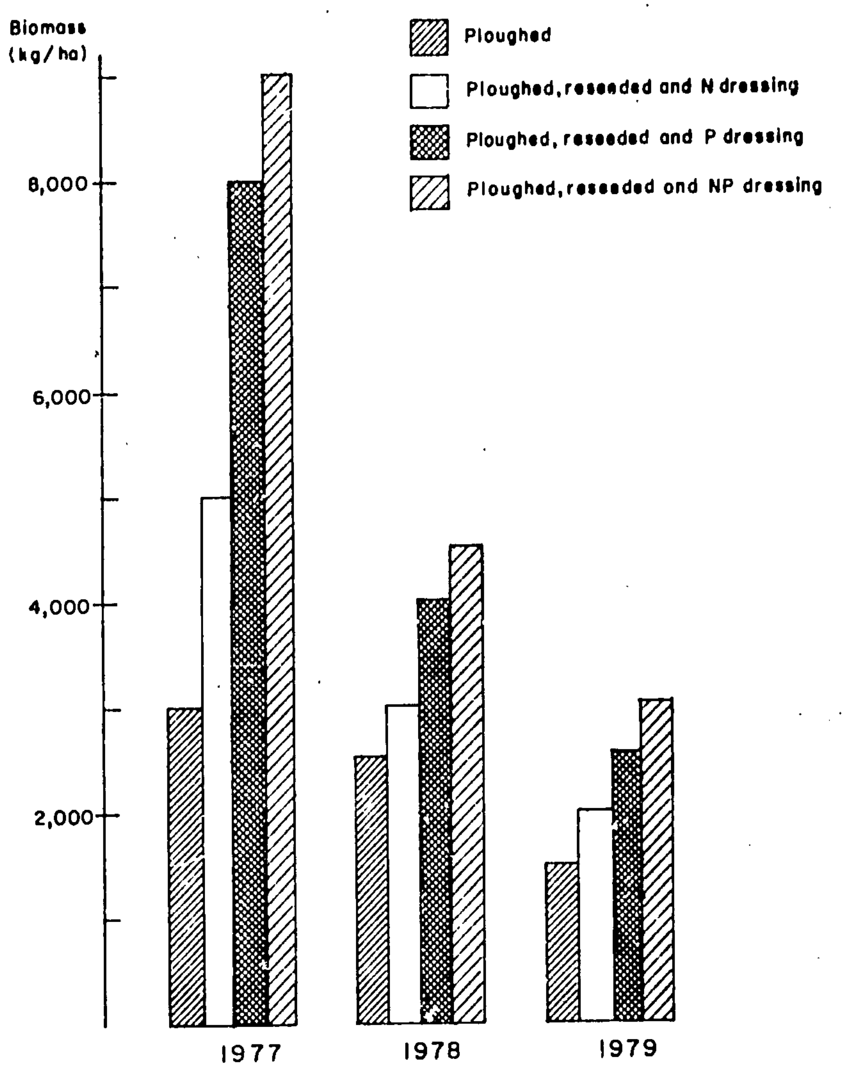
Degree of degradation in 1975	50% or more of land unit degraded		25-40% of land unit degraded		Less than 25% of land unit degraded	
% of Units:	1975	1980	1975	1980	1975	1980
North of 15° latitude	76	33	34	17	0	0
South of 15° latitude	67	8	34	8	6	5

Source: Adapted from ILCA (1980) and Miligan and Keita (1981).

Although fears of rapid overall degradation of the Sahelian rangelands may be somewhat exagerated, this does not imply that degradation on a localized scale is not a problem. Bare ground around villages and major water points, as well as along transhumance tracks, is widespread. There is also little doubt that around the Office du Niger land degradation is real, due to increased human pressure leading to excessive firewood cutting and overgrazing (Wilson, 1981). How to stop this process and, more specifically, how to convert bare ground into productive land through a combination of more balanced management and technological interventions are little known, although these aims figure high in proposed rehabilitation strategies. However, to determine adapted strategies, it is first necessary to define the degree of degradation, which for the sake of convenience can be divided in two major types: (i) land that is completely denuded, and (ii) land on which ground cover is sparse and of low productivity.

No work has been done by ILCA on the rehabilitation of completely denuded land, but fortunately reference can be made to a series of trials carried out by the PPS project in the vicinity of Niono (Djiteye and de Vries, 1980). Several techniques were tried, of which hoe cultivation of bare ground,

Figure 51. *Effect of reseeding and different fertiliser applications on the biomass yield of denuded terrain after ploughing over three years (1977 - 1979).*

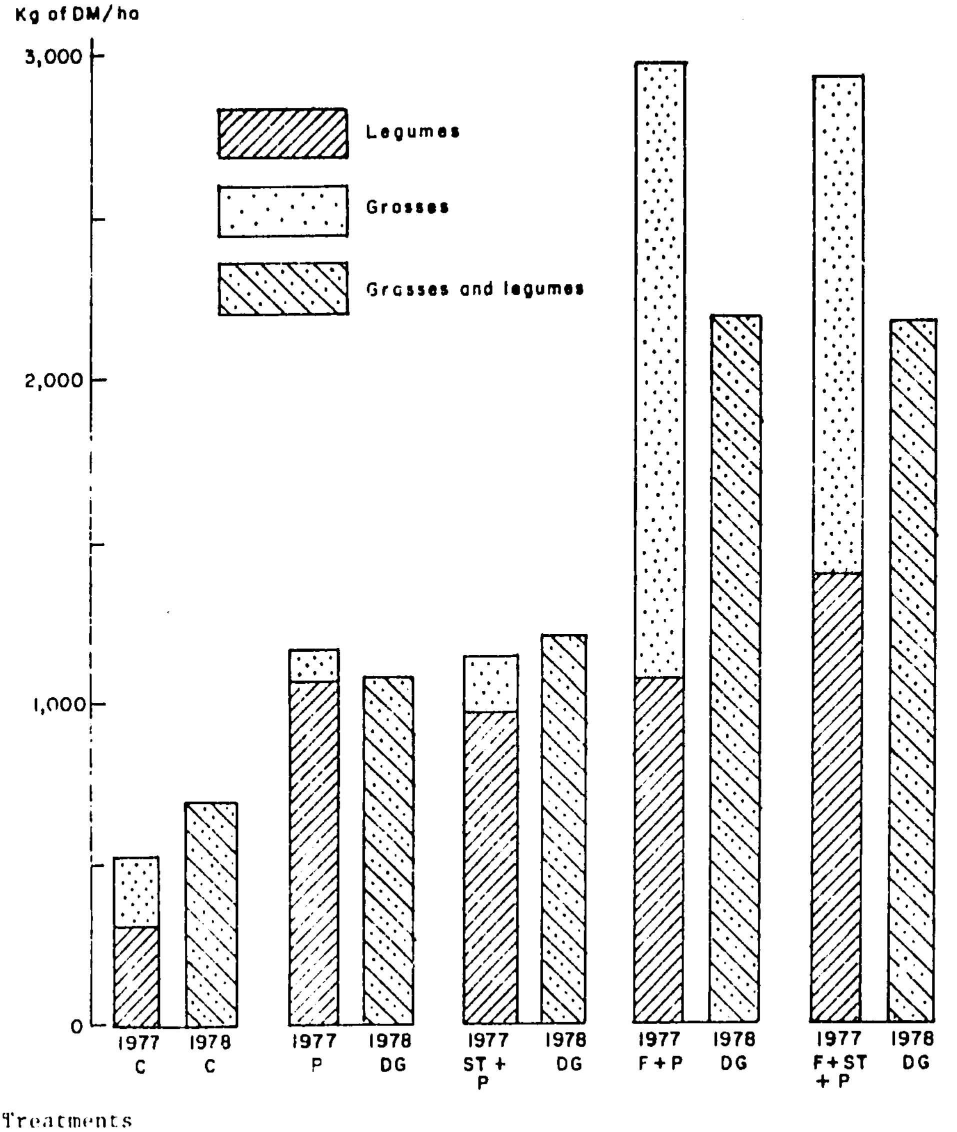


Source: Djiteye and de Vries (1980).

either without further treatment or followed by reseeding with local annual grass species (with different fertilizers) was successful in varying degrees in restoring a plant cover (Figure 51). Hoe tillage alone produced some 3 t of biomass in the first year, with reasonable though reduced yields in the second and third years. Very high yields resulted from fertilizer application, which appeared to level off in subsequent years. Labour investment was high, ranging from 145 man-hours when moist soil was cultivated to 450 man-hours when dry ground was tackled 3 months before the start of the rains, the later soil tillage being more productive than the earlier one. The initial high yields were attributed to the high availability of soil nitrogen built up during the period when the ground was bare. Its rapid use by the restored ground cover was doubtless the cause of reduced production in subsequent years. Although the high fertiliser dressings are no doubt uneconomical in the strict sense, the high potential productivity of Sahelian grasslands, even when fully degraded, has been amply demonstrated

The combined effects of farming and overgrazing have produced large areas of degraded land producing below average biomass, particularly on sandy soils farmed to millet, which have short fallow periods and are continuously grazed by sedentary livestock. Lack of grazable biomass has been identified as an important constraint to sustained productivity and may warrant investment for improvement. A trial was carried out to establish feasible alternative strategies, in which protection and grazing on shallow soil with and without low phosphate dressing were compared. The results are much less spectacular than those reported by Djiteye and de Vries (1980), but show that biomass doubles with simple protection, and about 3 t of growth follows to phosphate existing cover. Treatment effects continue in the second year, though yield increases are slightly less (ILCA, 1980 b, Figure 52).

Figure 52. *The two-year effects of four treatments applied to natural upland Sahel vegetation in June 1977 on the standing herbage biomass*



Treatments

C = control (grazed)

P = protected against grazing

DG = differed grazing

ST = shallow soil tillage

F = fertilizer application (50 kg P O as triple supperphosphate)

Source: Authors

4.2.4 Pastures of the inner Niger delta

The inner Niger delta pastures consist mostly of tall grass formations, with the exception of the rainfed shrubland found on the *toguérés* or knolls which rise above the floodplain, woody stands in the main river bed and deeper depressions, and the Farimaké plains, characterized by late and irregular flooding. These grass formations vary according to flood regime, the components of which have already been identified in Chapter 2 and form *bourgou* pastures and several other grassland types made up of perennial *Gramineae* of *Cyperaceae*, among which four biomorphological types can be distinguished. These types are cespitose grasses, floating grasses, turf grasses and rhizomatous geophytes. Some of the dominant species belonging to each type are listed in Table 57.

Table 57. *Biomorphological types of some dominant Gramieae and Cyperaceae found the inner Niger delta*[a/].

Hemicryptophytes			Geophytes
Cespilose grasses	Floating grasses	Turf grasses	Rhizomatous grasses
Vetiveria nigritiana	*Echinochloa colona*	*Cynodon dactylon*	*Oriza longistaminata*
Andropogon gayanus	*Vossia cuspidata*	*Sporobolus spicatus*	*Echinochloa pyramidalis*
Eragrostis barteri	*Brachiaria mutica*	*Sporobolus helvolus*	*Eleocharis dulcis*
Hyparrhenia rufa		*Brachiaria mutica*	*Scirpus brachyceras*
Panicum anabaptistum			*Cyperus maculatus*, *C. denudatus*

a/ For more details on the environment of the grasses, see Table 8.

Source: Compiled by authors.

Cespitose grasses respond in two different ways to flooding, sometimes found in one and the same species, as in the case of *Vetiveria nigritiana*. Either the tuft of grass is completely covered by the rapidly rising flood, in which case it will only develop after the flood has receded, or else it is left uncovered, so that the flood height reaches no more than 10 to 30 cm and the plant develops during the rainy season and the submersion period, which overlap to a greater or lesser extent.

The floating grasses from the pastures known as *bourgou*, while the plant formation itself is called *bourgoutière*, from the Fulani word for flooded grazing land. They are found on deeply submerged plains (up to 4 or 5 m). However, the pastures do not survive deep flooding unless the waters rise sufficiently gradually to allow simultaneous growth of the stems.

Characterized by their colonization of the soil through stolons, the turf grasses often form swards round the upper flood limit, where they undergo shallow submersion for short periods at irregular intervals. Owing to their morphology and mode of regeneration they are particularly resistant to intense pastoral utilization and are abundant around the *teguéré*, on slopes and in the neighbourhood of villages.

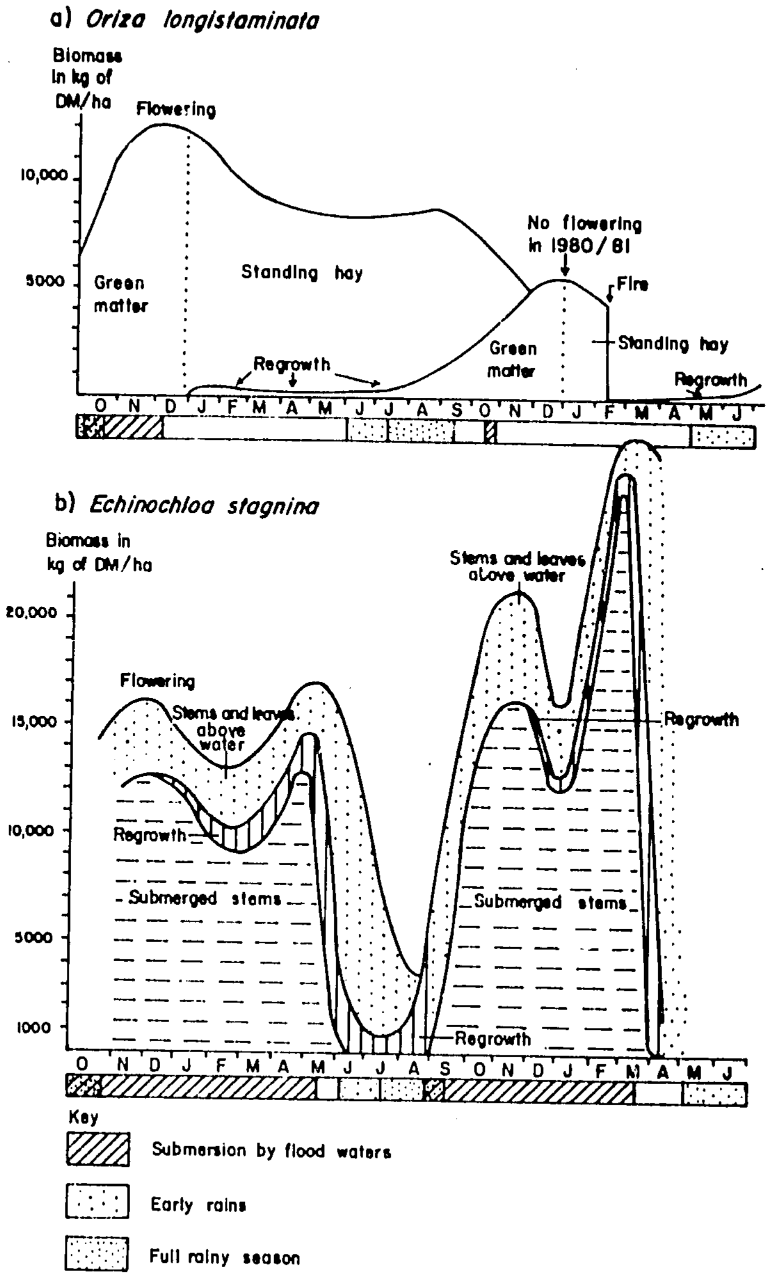
Rhizomatous geophytes may be covered by the flood, in which case they do not develop until it subsides (as in the case of *Cyperus maculatus* and *C. denudatus*). but usually they take advantage of the reserves stored in their rhizomes and develop rapidly, rising with the flood. They can survive fairly deep flooding (0.5 to 1.5 m) when the waters rise rapidly.

Figure 53 shows trends during the annual cycle of biomass production on two ungrazed areas of delta rangeland. The two examples illustrate that the level of production is very high but varies considerably from one pasture to another, and that growth periods are considerably extended over the annual cycle, contrasting with the rapid development of the Sahelian grass cover, which rises to a peak and then falls away sharply. However, here again difference between range types are very sharp and linked with differences in the flood regime[1/].

Growth generally takes place in two stages: first during the rainy season and/or flood period, ending with flowering between September and December; secondly after seed-setting and if soil moisture conditions allow, a regrowth period takes place, with important implications for forage supplies.

1/ Different kinds of pasture complement each other as a function of flood regime and season, thus determining herd mobility within the delta during the dry season.

Figure 53. *Annual biomass curves for two ungrazed pastures of the inner Niger delta*



Source: Compiled by authors.

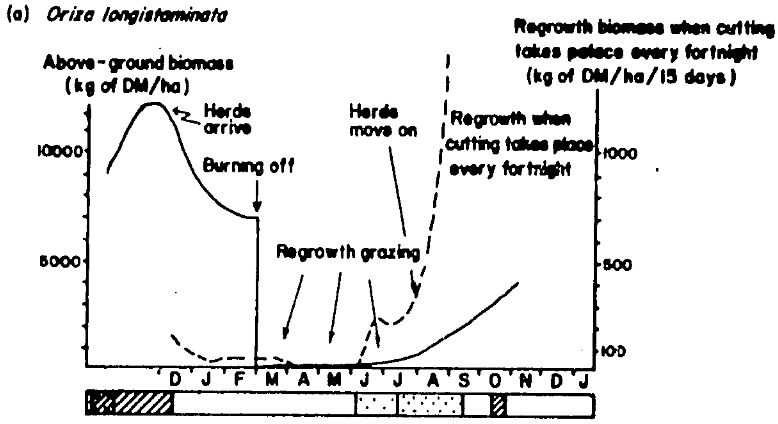
Consisting of grasses and often seasonally protected from grazing by the flood, many delta pastures appear floristically very stable. The combined interannual fluctuations of flood and rainfall regimes have a greater effect on production than on flora. Figure 53 gives an example of biomass curves for an *Oriza longistaminata* pasture over 2 consecutive years. In 1980 late and shallow flooding did not allow the complete development of *Oriza* which did not flower, and limited production to half the level of 1979. However, the interaction is complex, since for the same 2 years the neighbouring *Echinochloa stagnina* pastures shown in the same Figure exhibit the opposite trend, explained by the fact that the waters rose too rapidly in 1979, drowning some of the young plants and lowering production.

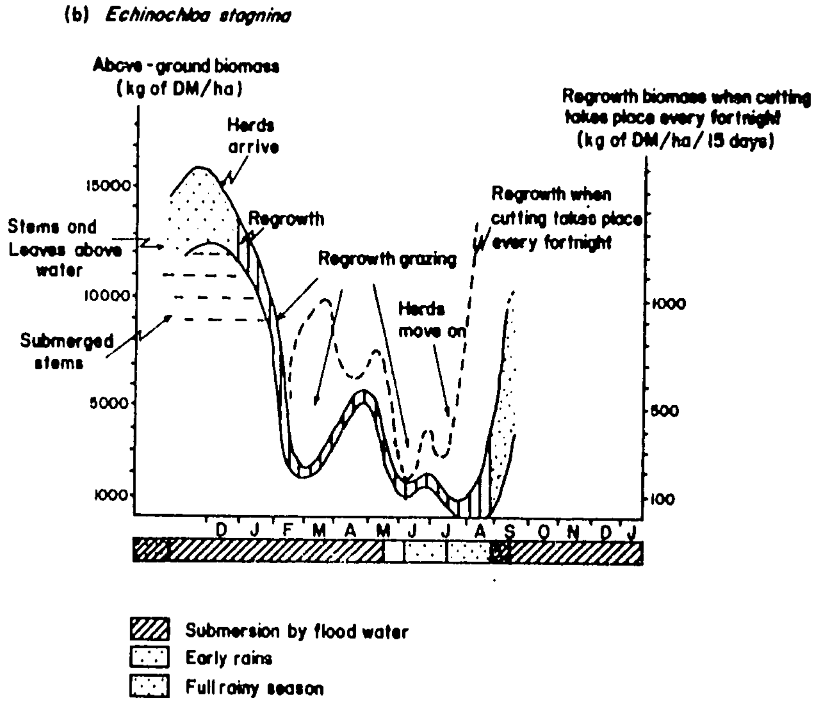
However, although in the short term fluctuations in flooding characterize primarily the level of production, it is certain that in the longer term the vegetation too can be modified. In areas such as the Farimaké and northwestern plains where flooding is marginal or irregular owing to their higher altitude and location in relation to water courses, *Vetiveria* savanna is rapidly giving way to Sahelian rangeland with *Acacia seyal*, *A. nilotica*, *Ziziphus mauritiana* and a thick grass cover consisting of *Sporobolus helvolus* and some annuals. It is worth noting that changes of this kind are likely to become more widespread and less easily reversible as water development projects in the delta or further upstream permanently alter the natural flood regime. The consequences for crop and forage production in the inner delta may well be far reaching.

Biomass curves for ungrazed pasture cannot be used to establish seasonal availability of the different types of grazing land, since these are all subject to intense seasonal grazing which modifies both available biomass and production. With very few exceptions (round villages, on *toguérés* and embankments) the delta pastures are not used during the rains and flood season. On entering the delta the herds thus find tall pastures, usually with a high biomass (5 to 20 t of DM/ha) but of average to mediocre quality and difficult of access, leading to enormous waste. After initial grazing regrowth occurs, which is grazed together with any remaining standing hay, if this has not been burnt off before.

To illustrate the impact of grazing on forage availability and production, Figure 54 gives biomass curves for the two types of pasture taken as an example above, recorded under traditional pastoral management, together with the production curve for regrowth obtained by cutting every

Figure 54. *Annual biomass curves for two grazed pastures of the inner Niger delta*





Source: Compiled by authors.

fortnight. When compared with the productivity of the ungrazed pastures it becomes clear that seasonal forage availability depends not only on type of pasture and flood regime, but also on pastoral management. Since grazing is not controlled it is very difficult to assess its impact, as well as that of burning or clearing, without relying on controlled experiments. Trials began at the end of 1979 on:

(a) a pond with *Echinochloa stagnina*;

(b) flat rangeland with *Oriza longistaminata*;

(c) a slope dominated by *Andropogon gayanus*;

(d) a slope dominated by *Vetiveria nigritiana*;

(e) flat rangeland with *Vossia cuspidata* and *Oriza longistaminata*.

These trials have been extended to include four other formations during 1981, namely *Cynodon dactylon*, *Panicum anabaptistum*, *Vetiveria nigritiana* (low) and *Eragrostis barteri* pastures. The treatments applied differ according to pasture, but involve one or more of the following: early and late cutting; cutting during flooding; repeated cutting every fortnight, every months, every 2 months and even everyweek for *Echinochloa stagnina* and *Cynodon dactylon*, early and late burning, grazing as currently practised.

The effects of the treatments on regrowth during the same year and on vegetation during the year following treatment are being analysed separately[2/]. It is still too early to draw any conclusions on the effect on production during the following years. Initial observations indicate, however, that this is low unless cutting occurs very late, after the end of June. At this stage the treatments have an obvious depressive effect on production. In the case of *bourgoutières*, early access to livestock while the pasture is still under water or at least while the soil is still moist has favourable effects despite the resulting wastage. It stimulates regrowth and makes tillering easier, thereby giving better chances of development during the following year.

The effects of cutting, burning and grazing often seem beneficial and are generally the more so the earlier treatment is applied, as the floods recede. Figure 55 clearly shows the stimulating effect of early cutting

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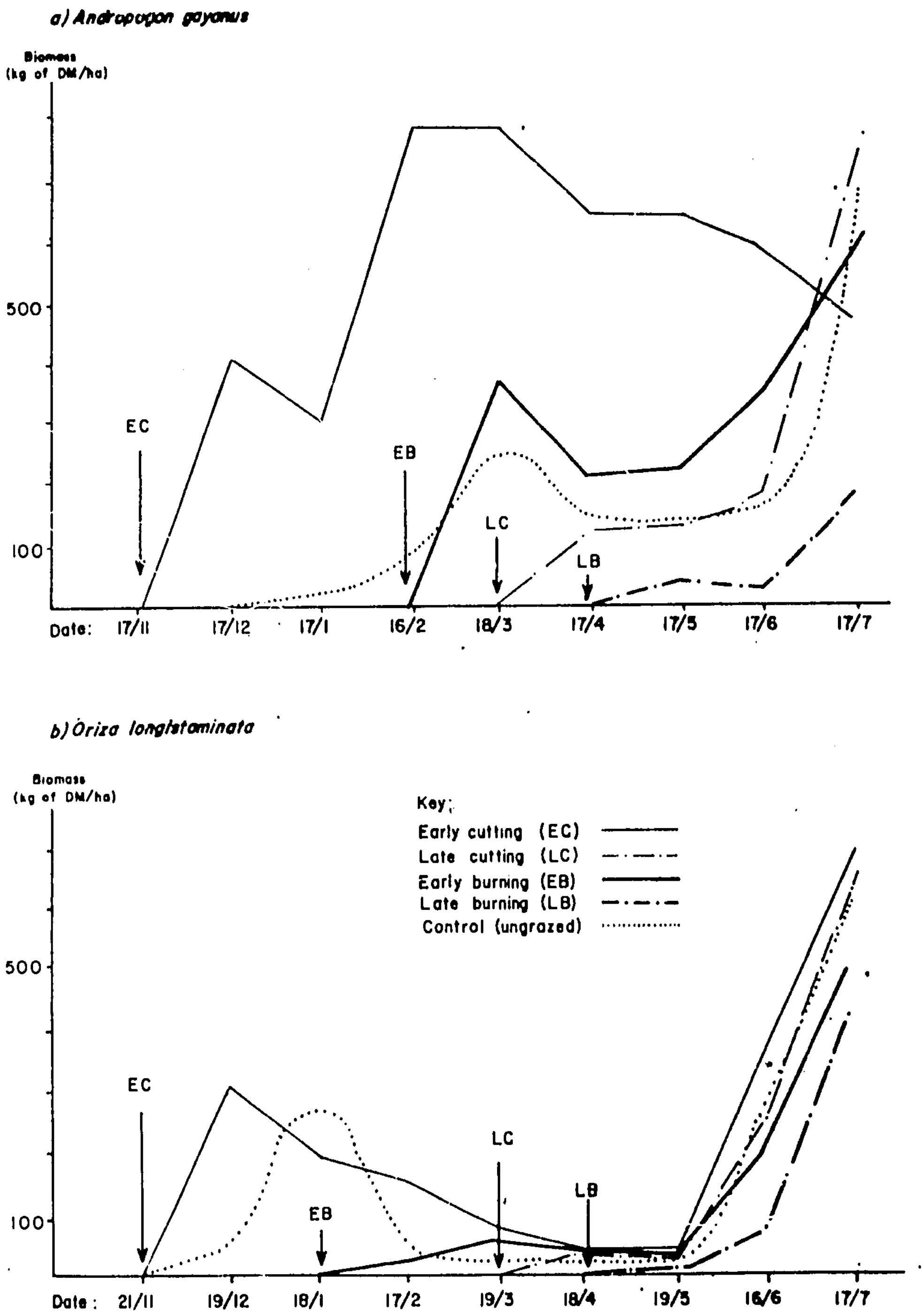
2/ No effect on flora has so far been detected since the observations at present are concerned only with biomass, which is measured by cutting, drying and weighing, with subsequent feed value analysis where appropriate.

Figure 55. *Effects of early cutting or burning on regrowth of two pastures of the inner Niger delta*



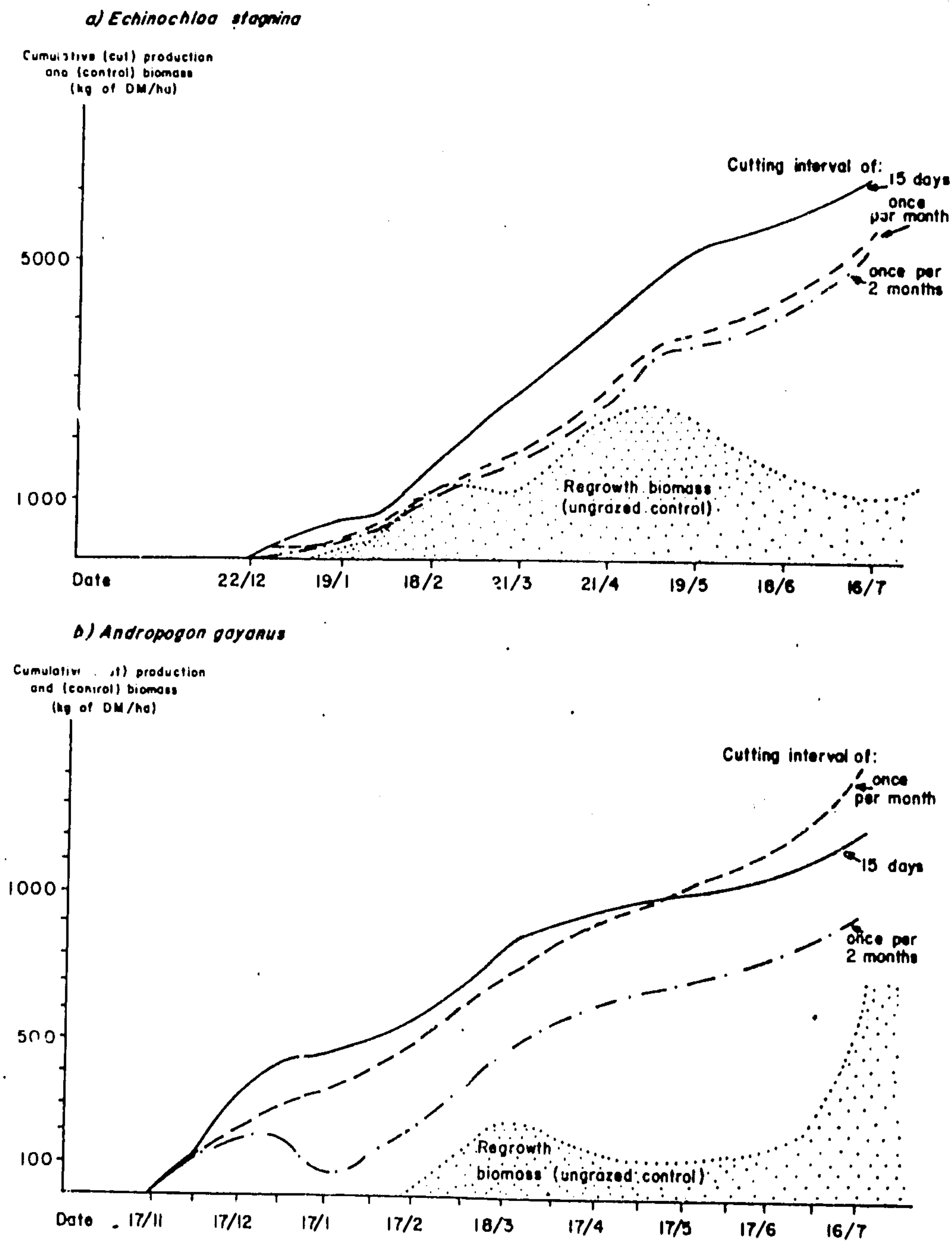
Source: Compiled by authors.

on the regrowth of *Andropogon gayanus*, but the effect is less pronounced for *Oriza longistaminata*. Burning does not appear to stimulate regrowth to any great extent, although it makes it more accessible to animals. However, it must be borne in mind that its first effects are the loss of large quantities of standing hay of poor quality. Late burning has a slightly depressive effect on regrowth. Figure 56 shows the stimulating effect of repeated cutting on the regrowth of *Echinochloa stagnina* and *Andropogon gayanus*. For *E. stagnina* the effect grows stronger as the cutting interval is shortened, but an additional experiment currently in progress is showing that this stimulus falls off when cutting is increased to once a week. The optimum interval is between 10 and 15 days. For *A. gayanus* the curves show an optimum interval of around 15 to 30 days. The existence of this optimum interval has important practical implications for range management.

Cropping in the delta is a further factor having an impact on grazing resources. The yearly cultivation of rice takes up a very variable proportion, but overall a large one, of the flood plain. This share has greatly increased with the spread of animal traction in recent years and may well increase still further since, given the range of rice varieties and cropping practices used - preliminary clearing, burning, repeated ploughing, partial control of flooding by dykes, etc - the potential cultivable area, without using sophisticated irrigation techniques, covers all rangeland with *Oriza longistaminata* and *Eragrostis barteri*, a large proportion of the *bourgoutière* and some of the *Vetiveria* formations. There is thus considerable potential competition for space between rice cropping and animal production. The impact of cultivation takes two forms: first there is the loss of available forage caused by planting rice on land previously used for grazing, and secondly, since shifting cultivation is often involved, there is a further effect caused by the increase of fallow land.

Since rice plots can be grazed after harvest, loss of fodder in the first instance depends partly on the success or failure (fairly frequent since flooding is not controlled) of the crop, but more especially on the original type of pasture. For *Oriza*, *Eragrostis* or *Vetiveria* pastures,

Figure 56. *Effect of three cutting regimes on regrowth of two pastures of the inner Niger delta*



Source: Djiteye and de Vries (1980).

substitution of a perennial cover with an annual one rules out dry season of regrowth, the importance of which has already been underlined. For *bourgoutières* the loss is considerable, estimated at maintenance rations for 6 TLU/ha for 6 months of the dry season at the minimum[3/] No experiments have been made by ILCA to asses the productivity of fallow land, but initial observations indicate the rapid restarting of previous formations, especially in the case of *Oriza* (2 to 3 years). *Bourgoutières* also restart rapidly (3 to 5 years), but the pace is much more variable for less regularly flooded formations, especially *Vetiveria*.

A secondary impact of cultivation arises from the extended use of burning initially so as to rid a plot of stubble before ploughing. Finally, an important indirect impact lies in delayed access of livestock to some rangeland areas, when access has to wait until harvesting is over.

4.3. LIVESTOCK PRODUCTIVITY AND NUTRITION

4.3.1. Introduction

The aims of the livestock productivity study were to monitor the cattle production parameters and population dynamics of a limited number of herds in the transhumant delta system. It should be realised from the outset that a 2-year study (December 1978 - March 1981) is too short to quantify with confidence all parameters that determine the development of herds and their productivity in such a variable and often harsh environment.

The herds under study belong to a fairly homogenous pastoral group with grazing rights in the *leydi* of Diafarabé located on the southwestern edge of the inner Niger delta (Figure 7). The group is a geographic and administrative entity collectively known as the *Diafaradji*. Its members own some 14,000 cattle, whose grazing orbit extends from the northeastern fringes of the delta to the Mauritanian Hod Harki (Figure 7). When the first rains fall in July the herds leave the delta floodplains for the Sahelian uplands to the northwest, where they remain from August to October. They return to the delta in November and continue their transhumance within the confines of the delta until the next rains (Breman et al, 1978).

These movements play a decisive part in the herd dynamics and

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3/ A calculation of the carrying capacity of *bourgou* dominated grassland is given below; see 4.3.5.

management, and have given rise to complex relationships between the various management groups within herds and between the owners of individual animals within these groups.

The methodology of the study was broadly the same as used for the agropastoral system, but owing to the very different features of the pastoral system several modifications in the timing of operations were necessary. In addition, as herd mobility was much greater and exchange of animals between herds and management groups was frequent, data analysis and processing were much more difficult than for the agropastoral herds.

As ownership is likely to have a bearing on management strategies and thus on productivity, it seems appropriate to begin by defining the different categories of owners of the study herds. First there is the cattle herder, who has his own animals in the herd in addition to those of his immediate and often his extended family, and can manage and exploit these animals as he thinks fit. Secondly there are cattle owners, who entrust their animals to one or more kinsmen and good friends and are therefore not directly involved in day-to-day management, although they have a strong say in overall herd management strategy. Thirdly there are farmers, fishermen, civil servants and traders who own cattle, which they place in herds against renumeration in kind or cash. Their involvement in management is much less and they could be termed absentee-owners investors.

To illustrate the complicated ownership pattern of transhumant herds, the composition of owners of two sample herds has been shown (Table 58) The data indicate that there are 77 owners, who collectively own a total of over 500 cattle. Although the information for these herds is believed reliable, herders are often reluctant to identify owners. Some 50 - 60% of the herd belong to 'real' cattle producers, of which 14-33% originate from 'absentee' owners. The 'unknown' group is likely to contain further absentee owners as well as less closely related members of the extended family.

Another characteristic of transhumant herds, leading to complications in herd monitoring, is the existence of different groups of animals within the herd. These groups are herded separately during certain periods in the general transhumance cycle, and each is managed differently.

The core of the herd, known as the *garti*, consists of the majority of dry and pregnant cows, most or all young bulls and heifers, some older steers and a few breeding bulls. Only about 20% of the cows in milk plus their calves are found in the *garti*, their main purpose being to provide the herders with

Table 58. *Distribution of ownership in two sample herds.*

Type of stock owner	Herd R		Herd S		Total	
	N	(%)	N	(%)	N	(%)
Herders	51	(23)	47	(18)	98	(20)
Non-herding pastoralists	82	(37)	84	(32)	166	(34)
Farmers	5	(2)	9	(3)	14	(3)
Investors	27	(12)	79	(30)	106	(22)
Unknown	55	(25)	44	(17)	99	(21)
Total	220	(99)	263	(100)	483	(100)
Total number of owners	48		29			

Source: Compiled by Authors.

milk for direct consumption or barter against foodgrains and other necessities while on transhumance. The *garti* is the only management unit to participate fully in the transhumance orbit (Figures 57 and 58) and is therefore believed to derive full benefit from its great mobility and consequently from the skillful exploitation of grazing resources within the totality of the transhumance orbit.

The majority of lactating cows, their calves, a few heifers and steers and breeding bulls form the portion of the herd known as the *bendi*. These animals produce milk for home consumption and sale, and are managed in accordance with these aims. From December to the end of July or early August, the *bendi* remains in the vicinity of the home villages, leaving in August on a short transhumant journey (100 - 150 km) northwestwards into the upland Sahel. It returns home together with the *garti* in November, and it is during this period that the herds join together to await the great event of the crossing of the river Diaka[4/]. To maintain the productive capacity of the *bendi*,

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4/ Each year the animals returning from the major transhumant journey cross the Diaka River at Diafarabé to gain access to the delta pastures, an event which is the occasion of local festivities.

Figure 57. *Delta movements (November-July) of the Diafarabé herds*

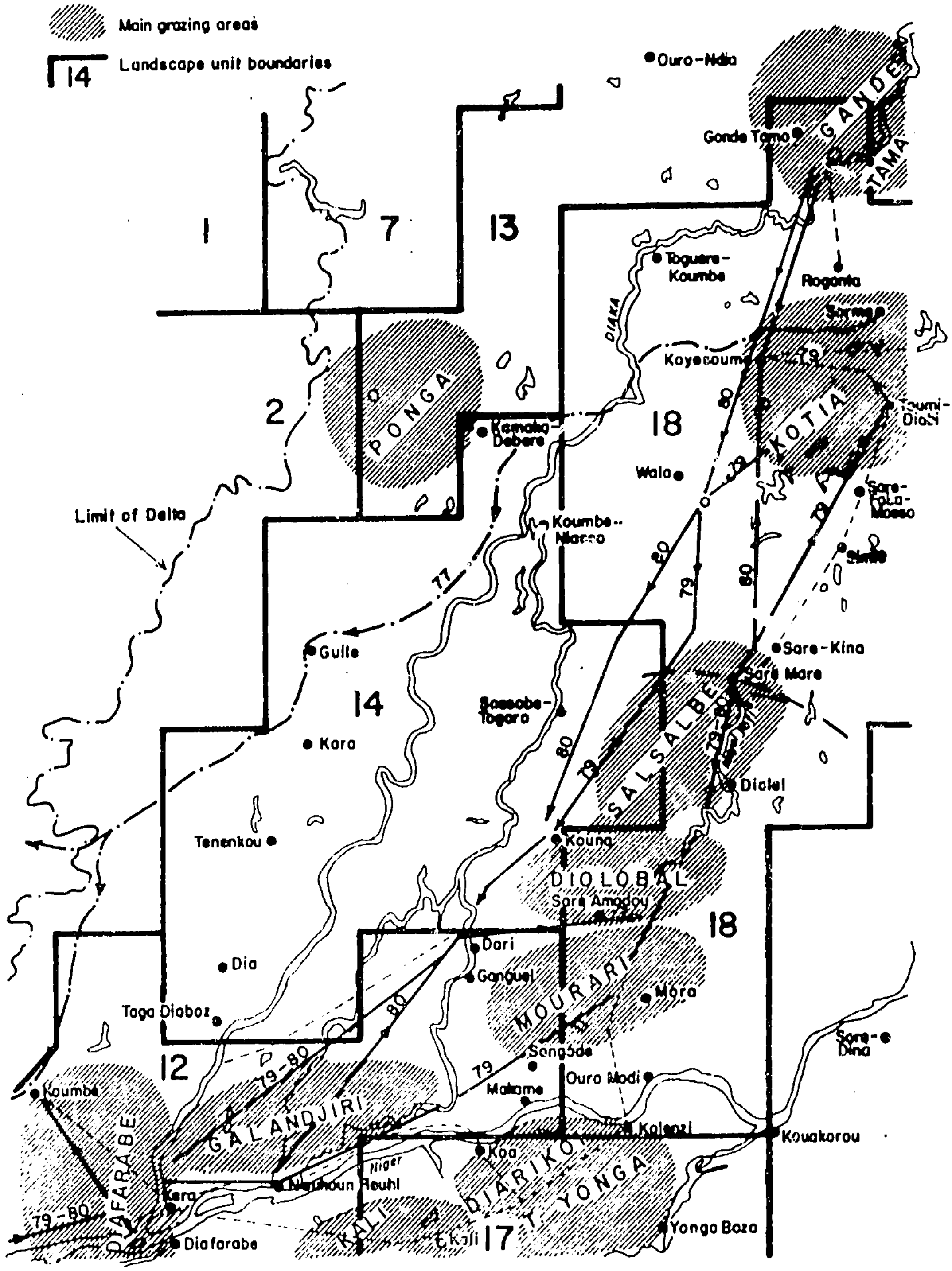
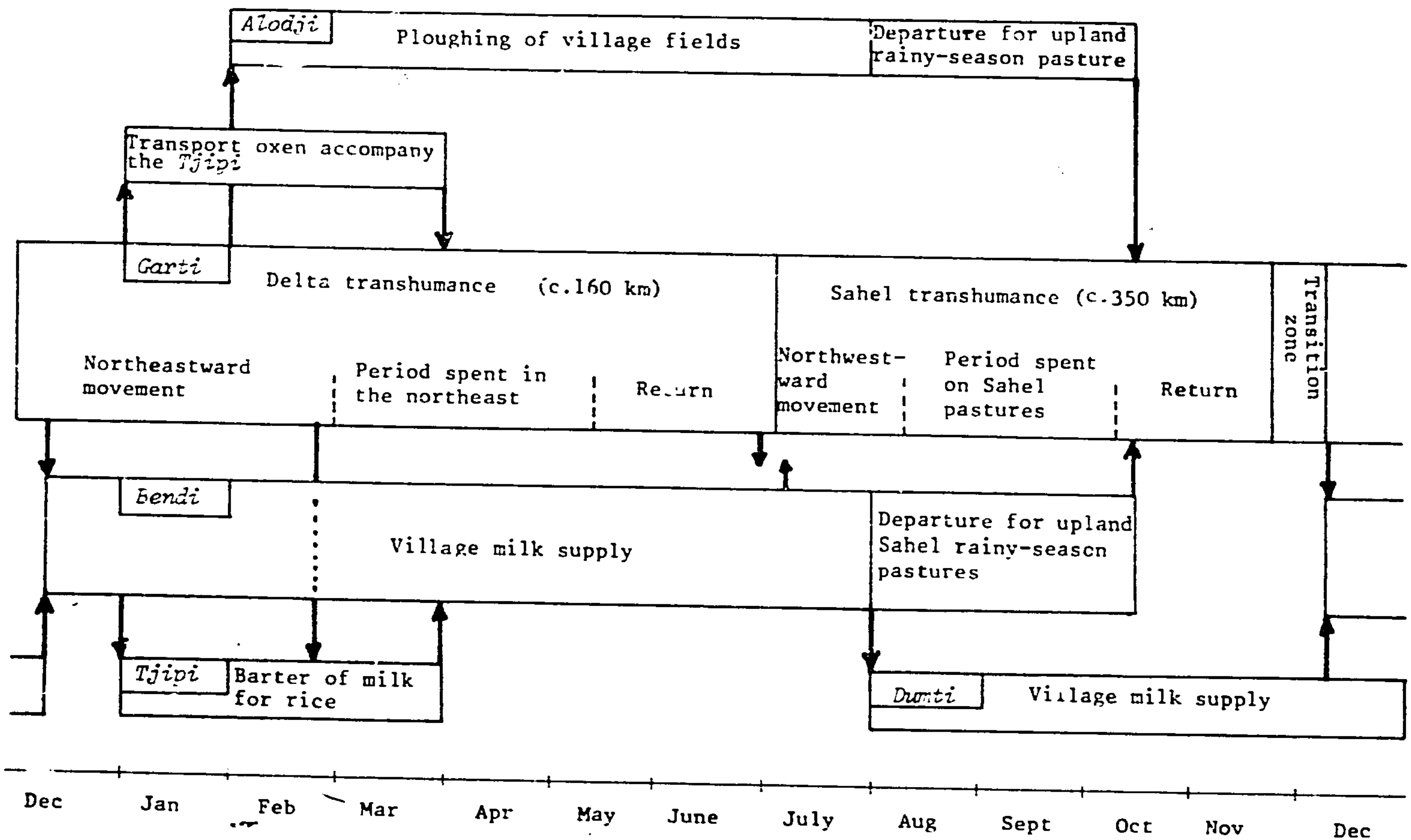


Figure 58. *Herd fractions and their movements*



lactating cows are repeatedly transferred from the *garti* in exchange for dry cows. These exchanges are most frequent in December at the time of 'crossing', but continue while the *garti* is on transhumance in the delta, when the distances between the two herd portions are not too great.

In order to reach the potential market for milk beyond the home villages, a herd fraction called the *tjipi* is separated from the *bendi* and taken to various villages in the delta to exchange milk for rice during the January - March period. Often, as much as half the *bendi* is used for this purpose and the different *tjipi* units are accompanied by a few pack oxen to transport rice back to the home village.

A fourth fraction, known as the *dumti*, consists of two or three lactating cows per family. These animals are separated from the rest of the *bendi* only during the rainy period from August to October, and replace the function of the *bendi* when it migrates towards the Sahel grazing land. Their fairly low numbers allow supplementation with millet bran and salt. Cows allocated to the *dumti* are usually of quiet disposition and among the best milkers in the herd, having calved recently. They are kept away from breeding bulls to prevent conception.

Two further management units exploiting the male portion of the herd can be identified. First there are the transport oxen which accompany the *tjipi* on its trading missions or are sent on transhumance with the *garti* and *bendi*. Secondly the herd contains a small group of plough oxen, usually belonging to absentee farmers or Fulani cattle owners who also engage in rice farming. For most of the dry season they are kept near settlements so as to plough the rice fields immediately after the harvest (February - March) and again during the first rains (May - July). They join the *garti* either when it departs for the upland Sahel or at a later date.

These exchange patterns between management units in the herd are of course much influenced by environmental and other external conditions. For instance, the composition of the *tjipi* fraction of the herd depends largely on whether or not the rice harvest is plentiful. In bad years, milking cows are concentrated only in the larger villages and milk sales are low, since the main customers are the rice farmers. A bad harvest results in high prices for rice, leading to the sale of young animals (1 - 2 years) so that subsistence grain stocks can be built up and taxes paid. In addition, greater numbers of animals in milk are withdrawn by many individual owners, with the result that the economic situation of the owner/

herder can become very critical, since his herd is no longer large enough to support him and his family.

It is also clear that the constant and complex movement of animals in order to optimize exploitation of the various herd fractions means that each herd is managed differently, so that an average herd with an average set of management fractions cannot be said to exist. The herder guarantees proper care of the animals entrusted to him in return for benefits from the sale or consumption of milk. According to the terms of this contract, the herder is entitled to the milk of first-calf cows for at least 1 month, and for 2 weeks in the case of all other cows. This traditional sharing of the milk offtake results in interminable and highly complex movements between management units. Some milking animals, for example, are given back to their proper owners and return to the herd only after six months or more.

Annual exchanges between the *garti, bendi* and *tjipi* are related to similar complexities. Throughout the dry season, movements between herd fractions are by no means rare. In one fraction newly born calves or pregnant animals will be taken away, while in another dry or sick cows are grouped. The various types of movement and the activities of the animals involved are indicated in Figure 58.

4.3.2 Herd composition and age structure

The Diafarabé cattle are kept in large herds, 78% of the cattle belonging to herds larger than 200 head, which form 44% of all herds. These proportions are much larger than for the delta as a whole, where these fractions were 38% and 18% respectively (Table 59). Admittedly, data for Diafarabé were based on counts at various water points in November 1977, when the herds had returned from their Sahel transhumance and herd size was at its maximum. Thirty-nine herds were counted out of an aggregate total of 48 herds, which constitutes the accumulated cattle wealth of the Diafarabé *leydi*. The largest herds included 700 - 1000 head of cattle, whereas the smallest contained 50 - 75 head. The frequency distribution in the whole delta was derived from counts made during the low-altitude aerial survey in late October 1980, during which 609 herds were recorded (Milligan and Keita, 1981).

In January 1979, the four sample herds included about 1400 head: two herds of 220 and 260 head (R and S), one herd of intermediate size with

Table 59. *Herd size frequency distribution of the Diafarabe herds as compared to that of the whole delta.*

Herd size	< 100	100-200	200-300	300-400	400-500	> 500
Diafarabé						
Number sampled	15	7	6	5	3	3
% of total herds	38	18	15	13	8	8
% of total cattle	9	13	18	21	17	22
Whole delta						
% of total herds	57	25	11	4	1	2
% of total cattle	39	24	18	9	3	8

Sources: Authors, and Milligan and Keita (1981).

Table 60. *Cattle herd structure of four transhumant herds*

Age in months[1/]	Males		Females	Total
	Entires	Castrates		
1 - 24	13.9	-	18.2	32.1
21 - 30	2.9	-	5.9	8.8
30 - 39	3.2	0.2	5.9	9.3
39 - 48	1.2	1.2	6.1	8.5
>48	2.0	6.5	32.8	41.3
Total	31.1		68.9	100.0

Source: Authors; age classes based on teeth eruption derived from Wilson and Clarke (1976).

450 head (A/V) and the large herd (P) numbering 650 head. This means that the sample herds had a definite bias towards the larger sized herds.

At the start of the study age structure was determined on the basis of teeth eruption (Table 60). More detailed but probably less reliable data on age were also obtained from the herders themselves during interviews about the reproductive history of their herd. The data in Tables 60 and 61 reveal:

(a) that there is a rapid reduction in the male component of the herd with age so that in the age groups over 3 years 70-75% of all animals are females, a composition consistent with a management strategy aimed primarily at milk production;

(b) that there is a much higher proportion of young stock in the largest herd (61%) in comparison with the smaller herds, indicating a much higher reproductive rate over recent years in the former.

Table 61. *Average cattle herd structure of three smaller herds combined and one large herd (% of all animals).*

Age in years	Herds R, S and A/V		Herd P	
	Males	Females	Males	Females
1	6.0	7.3	10.4	11.7
1 - 3	14.0	17.6	14.3	24.5
3 - 5	7.0	14.1	4.4	11.4
- 5	6.6	27.4	7.4	15.9
Total	33.6	66.4	36.5	63.5

Source: Authors; Age class based on herder information.

Similar conclusions can be derived from the population pyramids (Figures 59 and 60), which show anomalies in the normal shape, such as a rather low number in the 6 - 9 year age class, which may be related to the drought in the early 1970s.

There are considerable fluctuations in the herd structures that are not related to natural growth processes, but rather to the addition or removal of animals to and from the herd. Therefore, estimates of the natural

Figure 59. *General structure of herds R, S and A/V in December 1980.*

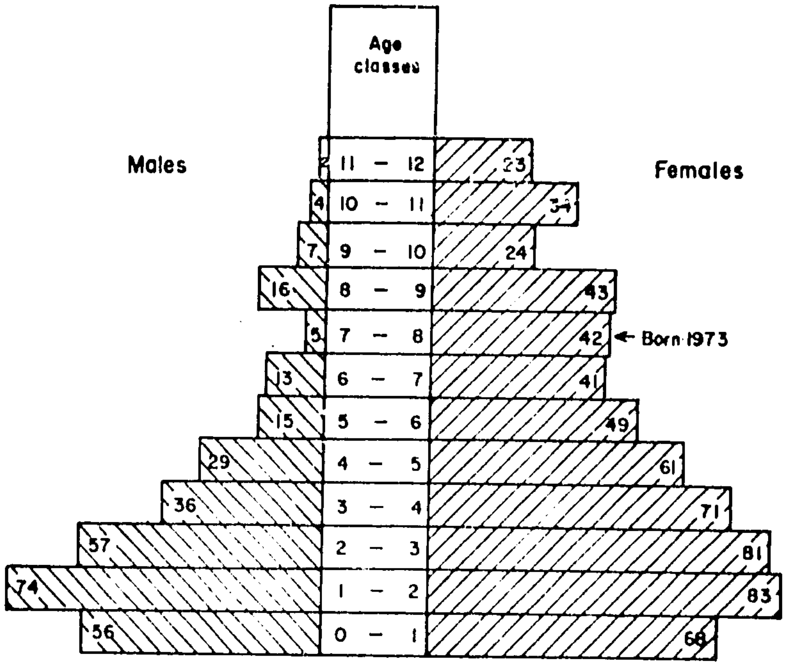
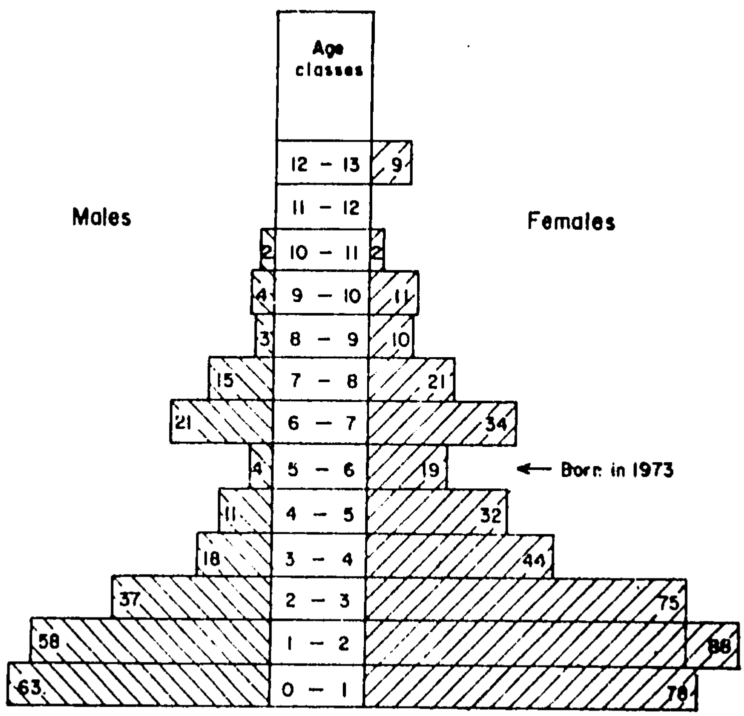


Figure 60 *Structure of herd P in December 1978.*



Source: Compiled by authors

increment of herds are difficult to calculate, since apart from births, deaths and direct sales, there are other transactions which cause changes in structure. In Table 62 the average numerical and proportional increases of the different age/sex groups have been tabulated. These show that, although the overall structure and composition of the herds does not change dramatically when expressed as a percentage, there is a large increase in male animals, a moderate increase in female stock and no increase or even losses in calves below 1 year. The total aggregate annual increment for the three herds studied is 11.8% in 1979 and 11.0% in 1980.

Table 62 *Average age/sex group increases in herds R,S and A/V over 2 years.*

	1-1-1979		31-12-1980		Annual increment
	N	%	N	%	%
Female calves	69	9.6	67	7.2	- 1.4
Male calves	69	9.6	57	6.	- 8.7
Female, 1 - 3 yrs	119	16.6	149	16.0	+12.6
Cows, > 3 yrs	303	42.1	388	41.5	+14.0
Bulls, 1 - 3 yrs	67	9.3	138	14.8	+53.0
Adult males	92	12.8	134	14.4	+22.8

Source: Authors.

To try to elucidate how much of this increase reflects the normal growth of the herd, a balance has been made of herd entries and exits (Table 63). It seems that changes are largely accounted for by the ratio of births to deaths followed by that of owners placing animals in herds to those taking them out, while sales are very low when taken as percentage of total stock (2.9% in 1979 and 4.0% in 1980). It may therefore be assumed that the increase in heifers, young bulls and cows (Table 62) is mostly due to natural changes in age classes over two years, with the possible exception of heifers, some of which are bought. The rise in adult males may be due to entries by absentee owners, such as farmers who entrust their oxen to the herders during the dry season. The reduction of calf numbers can be explained by the lower calving percentage in 1980 as compared with that in 1979 (see Table 64).

Table 63. *Balance of entries and exits for 3 herds (R,S and A/V between 1-1-79 and 31-12-80.*

Entries	N	%	Exits	N	%
Births	385	78.6	Deaths	152	55.3
Bought	19	3.9	Sales	55	20.0
Gifts & loans	11	2.2	Gifts & loans	9	3.3
Owner entries	61	12.4	Owner exits	34	12.3
Unknown	14	2.9	Unknown/losses	25	9.1
Total	490	100.0		275	100.0

Source: Compiled by authors.

4.3.3 Reproduction, mortality and growth

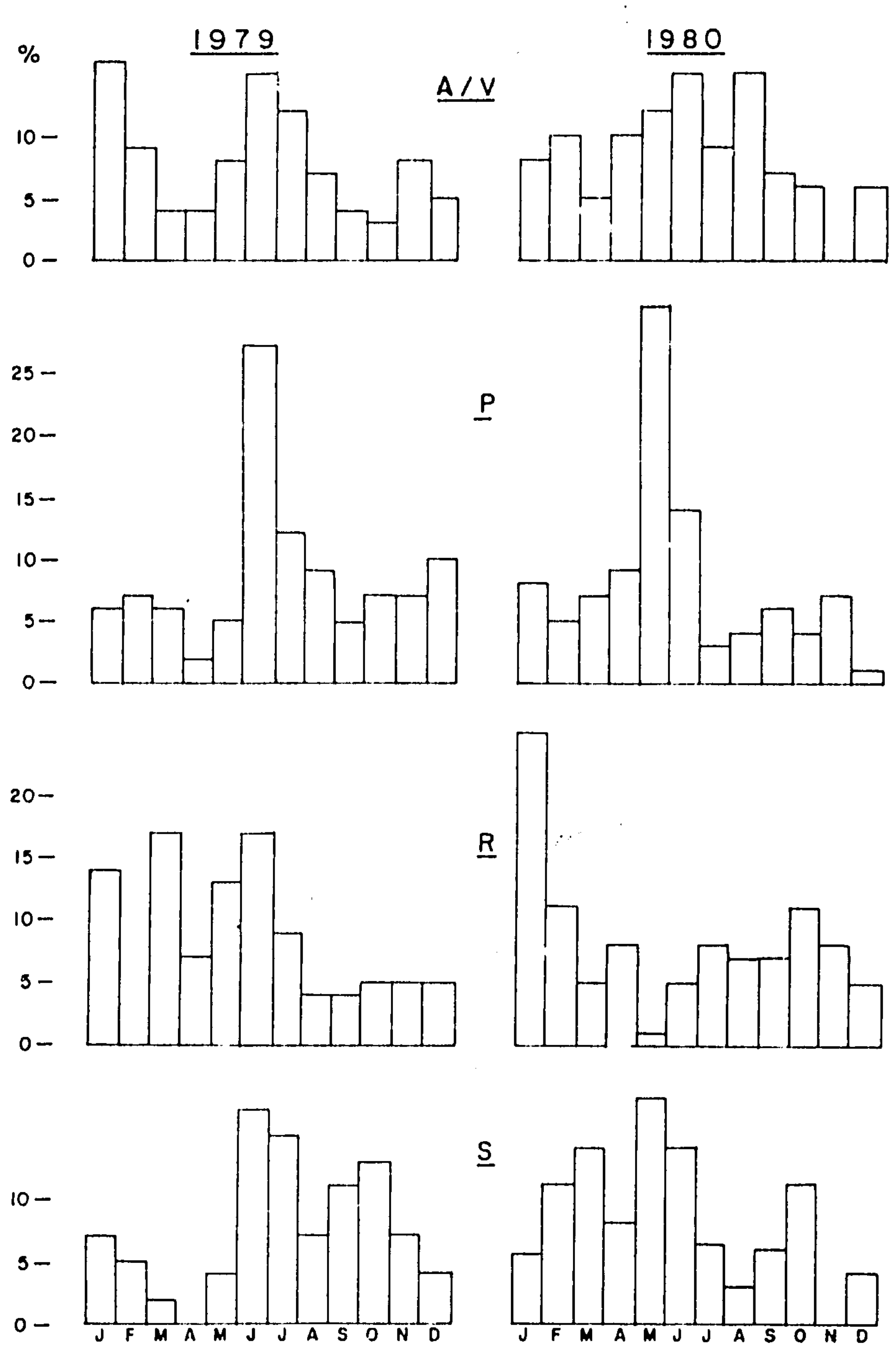
Apart from an average drop in calving percentages in 1980, table 64 shows considerable differences between herds. While the lower 1980 rate can be explained by the unfavourable rangeland and watering conditions in 1979, which induced lower conception rates, differences between herds are less easy to account for. There may be differences in management skills and variations in the transhumance orbits, but no clear reasons can be put forward.

The monthly distribution of births also shows large between-year and between-herd differences, although on the whole no distinct seasonal pattern can be detected (Figure 61). In herd P there is a pronounced peak in May - June indicating high conception rates during the rainy season, whereas minor peaks occur in January (herds A/V in 1979 and R in 1980).

The average age at first calving of 3.75 years was estimated from 70 observations and no significant effects of season of birth of the dam were found. Calving interval, calculated from 247 known cases, was 19 months. Only the best cases may have been recorded, i.e. those within the limits of the study period, and thus cows with a longer calving interval were excluded. Year of birth and number of parturitions of the cow had no significant effect on calving interval.

Table 64 shows that weaning occurs on average at 11.3 months. However, it appears that there is large variation between herds, indicating highly significant differences in weaning strategy ($P < 0,001$).

Figure 61. *Birth distribution histogrammes (relative frequency in % per herd).*



Source: Compiled by authors

Table 64. *Average calving percentage and weaning age in three sample herds.*

Herd	Calving %		Weaning age	
	1979	1980	Month	N
R	68	76	11.2	12
S	69	39	12.1	39
A/V	50	50	12.3	16
P	-	-	9.4	29
Mean/total	59	53	11.3	101

Source: Authors

Table 65. *Effect of parity on weaning age.*

Number of observations (N)	Parity	Average weaning age (months)
24	1	14.1
17	2	11.5
28	3	11.8
9	4	10.4
11	> 5	10.4

Source: Authors

The influence of parity on age at weaning (Table 65) showed a longer period for first parity, which thereafter gradually diminished with subsequent parturitions ($P < 0.05$). Apparently age of weaning does not greatly influence growth performance, since it always occurs at a time when the calves are able to fend for themselves.

The components of calf mortality for 2 years and three herds are shown in Table 66. These data demonstrate that in 1980 calf deaths were higher than in 1979, due to the high rates in herd R (36.4%) caused by a peak in stillbirths and in herd S (40.2%) by the high degree of abortions. Death in living calves up to 1 year of age averaged 17.5%, ranging from a low in herd A/V in 1979 of 12% to a peak in herd S of 21%, but it appears that this mortality component showed less variation than the others. However, least squares analysis demonstrated that sex, herd and season of birth had no significant effect on mortality and, unexpectedly, neither had season. The only significant effect was from birth weight.

Table 66. *Annual mortality (%) of calves below 1 year for 2 years and 3 herds.*

Herd and year	No. of calves born[a)]	Mortality percent			
		Abortions	Stillbriths	1-365 days	Total
R					
1979	55	1.8	9.1	16.3	27.2
1980	66	1.5	15.2	19.7	36.4
S					
1979	63	4.7	3.0	12.8	20.5
1980	42	14.3	4.5	21.4	40.2
A/V					
1979	75	4.0	5.3	12.0	21.3
1980	84	1.2	4.7	22.6	28.5
Means for years:					
1979	193	3.6	5.7	13.6	22.9
1980	192	4.2	8.3	21.3	33.8
Overall means	385	3.9	7.0	17.5	28.3

a) including abortions.

Source: Compiled by authors.

Mortality in older age classes is much lower than for calves, amounting to 4.2% and 5.5% for young stock (1 - 3 years) and older stock (over 3 years) respecively. Effect of herd and year on mortality is shown in Table 67 and that of season in Table 68. As for calves, mortality in 1980 was higher than in 1979, while herd S had the lowest mortality. As for seasonal influence, mortality was high in all animals during the period from April to September. However, since no detailed information was collected on the causes of mortality, these observed differences are difficult to explain.

Table 67. *Mortality of the older age class animals for three herds over 1979 and 1980.*

Age class and year	Herd R	Herd S	Herd A/V	Mean (N)
1 - 3 yr 1979	8.5	1.8	7.9	6.1 (11)
1980	4.7	0.0	2.5	2.4 (5)
> 3 yr 1979	4.0	2.9	7.7	4.9 (22)
1980	10.5	2.6	5.5	6.2 (30)

Source: Compiled by authors.

Table 68. *Seasonal distribution (%) of mortality in three age classes.*

Age class	< 1 year	1 - 3 yr	> 3 yr
Season:			
Jan - March	17	17	11
April - June	24	33	33
July - Sept	25	39	31
Oct - Dec	27	11	25
Mean	23.6	4.2	5.5

Source: Compiled by authors

Performance and growth

The average birth weight measured on 416 calves born alive over the 2 year recording period was 17.6 kg for males and 16.3 kg for female calves. Least squares analysis demonstrated significant effects on birth weight by months and year of birth as well as by sex (Table 69).

Month of birth continued to exert a significant influence on growth up to 9 months of age, but at 1 year this effect was negligible as all calves had gone through the same sequence of nutritional concitions. Up to 3 months calves born in the rainy season grew much faster than those born in other seasons, while at 1 year of age, calves born immediately after the rainy season (October - December) were heaviest, since they profited at 9-12 months of age from rainy season grazing and grew 0.19 kg/day as compared to almost no growth at all for calves 9-12 months during the October to March period (Table 70). For all ages growth was best in the rainy season followed by that during the late dry season (April - June).

Table 69. *Environmental effects on animal growth up to 6 years of age.*

Age	N	mean	Month of birth	Year of birth	Herd	sex	Number of calvings
Birth	416	17	xx	xx	NS	xxx	NS
1 m	359	25	xx	NS	NS	xx	x
3 m	259	38	xx	xx	NS	xx	x
6 m	226	61	xx	xx	xx	xx	x
9 m	205	73	NS	xx	x	x	NS
1 yr	178	81	NS	NS	NS	NS	xx
2 yr	103	121	NS	NS	NS	x	NS
3 yr	141	173	--	--	--	xx	--
4 yr	109	222	--	--	--	xx	--
5 yr	83	224	--	--	--	xxx	--
6 yr	72	241	--	--	--	xxx	--

x = P < 0.05; xx = P < 0.01; xxx = P < 0.001; NS = not significant.

Table 70. *Daily growth rates (kg) per quarter of calves born in different seasons.*

Age in mo. / Season of birth	0 - 3	3 - 6	6 - 9	9 - 12	Annual daily gain	LW at 1 yr
Jan-March	0.17	0.16	0.08	0.01	0.165	77.1
April-June	0.21	0.16	0.20	0.10	0.177	81.7
July-Sept	0.33	0.38	0.28	0.19	0.180	82.5
Oct-Dec	0.23	0.22	0.12	0.06	0.192	87.1
Mean	0.23	0.23	0.17	0.09	0.178	82.1

Source : Compiled by authors.

Growth of calves raised in different herds was identical up to about 4 months of age, diverged between 4 - 9 months and converged again at 1 year of age except for herd P, which showed higher calf weights strengthening the impression that this herd is differently and somewhat better managed than the others (Figure 62).

The growth performance from 1 to 6 years demonstrates the difference between males and females, which becomes increasingly greater, from 14 kg at two years reaching 25 kg at 3 years. Females grow very slowly from 4 years onwards, reaching average adult weight of about 200 kg while males at six years weigh on average 265 kg. Since the age of the first calving is 4 years, conception occurs at around 3 years, when the liveweight of females is only 160 - 170 kg.

4.3. 4 Milk production

The main management objective of animal production in the pastoral system is milk. In the opinion of the herdsmen themselves, "a good herd of milk cows is worth more than a large herd of bulls and oxen". When asked why, they reply quite simply, that "we prefer to eat a little every day rather than a lot on some days". This caution lies behind the whole management strategy for the pastoral herds. How is this attitude put into practice? First, milk cows are allocated to different herd fraction (*bendi, tjipi etc.*). Secondly, these fractions are subject to particular management care, for instance, around the village there are reserved pastures, known as *harima*. Lastly, the fairly even distribution of births throughout the year can be seen within the same context. However, since average milk yield per cow is low the number of breeding females is maximised, resulting in increased pressure on the *harima* pastures.

Milking is done in the evening, when the animals return from grazing. After milking the calves remain with their dams throughout the night, but are separated the following morning, when the cows leaves for grazing.

Milk offtake curve is given in Figure 63. It shows minimum and maximum average production levels of 0.35 and 0.95 litre/cow/day. However, season of calving affects the shape of the curves markedly. All curves show peak offtake during the favourable pasture conditions of the rainy season. Thus, for cows calving during the rainy season milk offtake descends from a maximum of 0.9 litre at calving to 0.4 litre 8 months thereafter, but rises

Figure 62. *Calf growth in different herds*

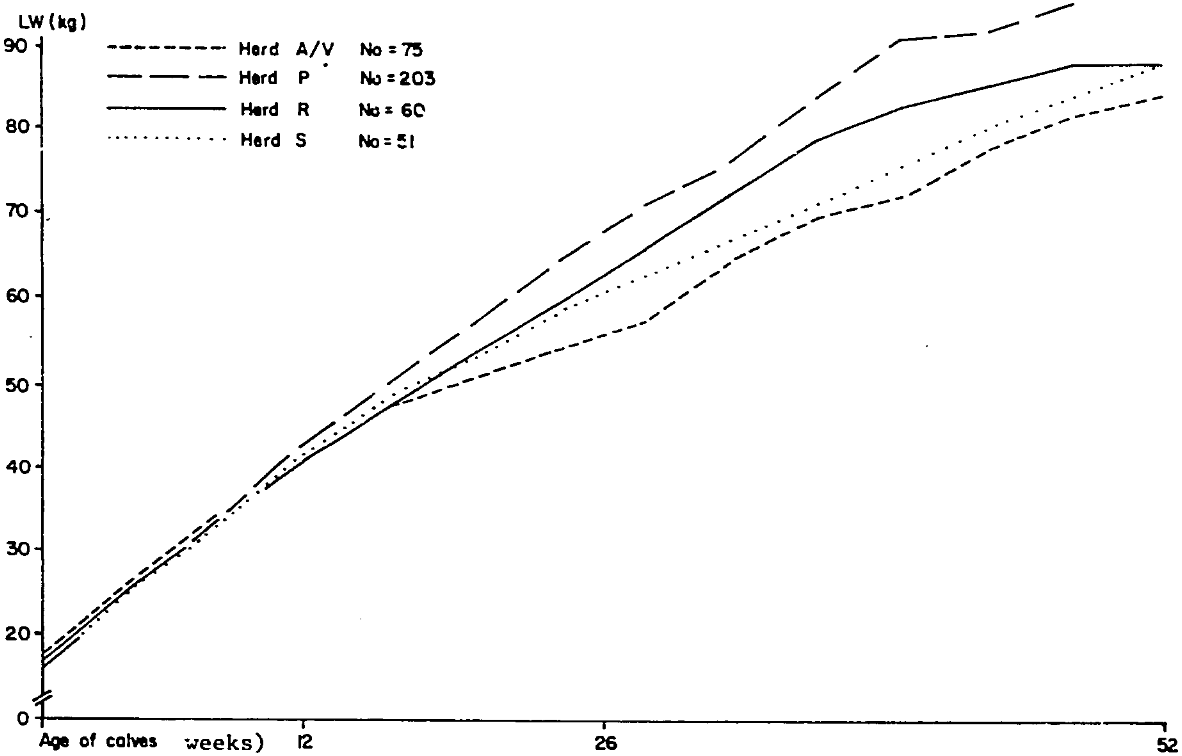
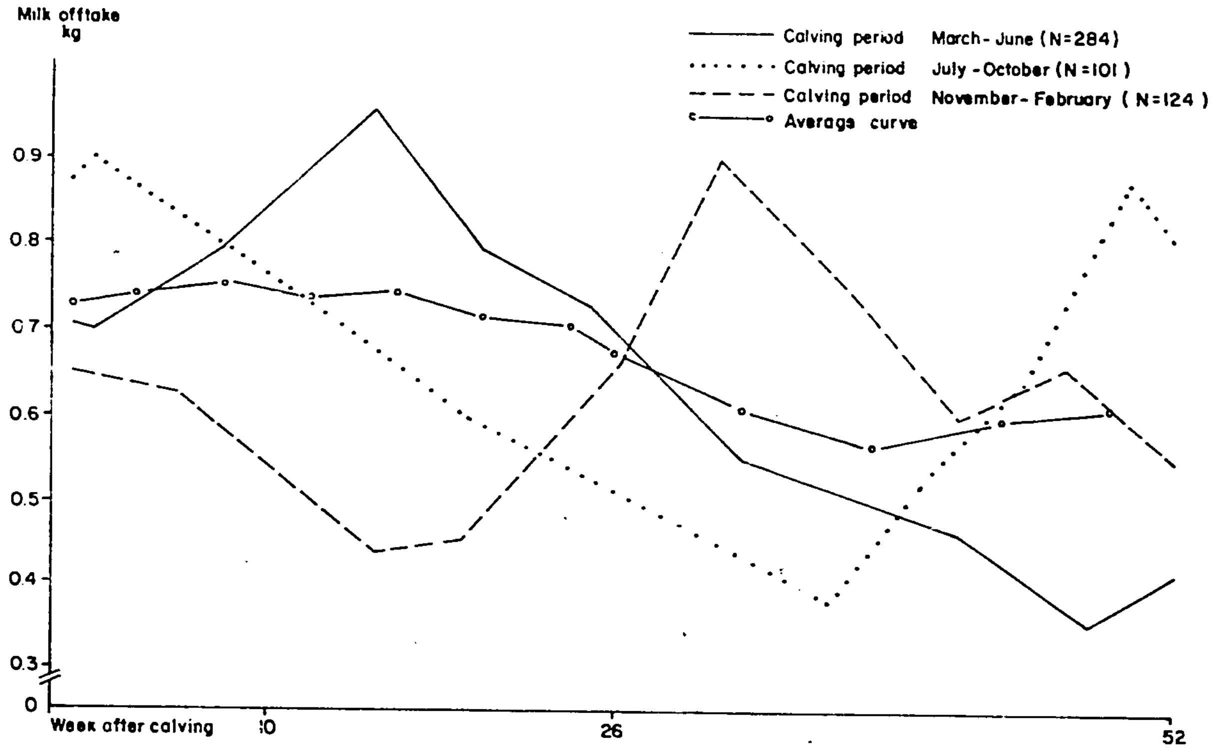


Figure 63. *Seasonal effects on milk offtake curves*



Source: Compiled by author

to a second peak of 0.9 kg at 11 months after calving. Cows calving during November - February show a peak about 6 months after calving, while those giving birth just before the rainy season show one 3 months after calving. Due to these interactive effects, the average offtake curve is a slightly descending straight line.

At weaning, after 11.3 months, the average milk offtake is 235 kg based on 509 lactations. Average offtake is significantly influenced by season of birth ($P < 0.001$) and sometimes by year of birth, by the interaction of year with season of birth and by herd. The owner, the sex of the calf and the parity have no significant effect.

The milk consumed by the calves during the first 6 months of lactation has been estimated on the basis of calf growth, using conversion coefficients of litres of milk/kg of calf growth determined by Montsma (1962) in his study on the Sokoto Zebu in Ghana as follows: 0-8 weeks 8.0; 0-13 weeks 8.1; 0-26 weeks 6.3 litre/kg growth. Using the conversion coefficient of 6.3 for 0-26 weeks, total yield of milk amounted to 428 kg, of which the calf got 296 kg or 69%, leaving 132 kg for human consumption.

The relationship between the milk offtake for individual cows and their calves indicated that during the first 8 weeks of the lactation, milk offtake was positively correlated ($R = 0.42$) with calf growth, leading to the conclusion that good cows producing most milk for consumption, had more milk available for their calves than poor producers. At the same time, herders in knowing the productive capacity of their cows may conscientiously partition their total milk yield between calf and consumption. Later in the lactation these trends are less clear, because the calf relies progressively more on herbage and its growth becomes dependent on its genetic potential and overall calf management rather than on the milk output of the dam.

4.3.5 Grazing conditions and nutrition

Characteristics of the deltaic grazing orbit

The transhumance routes followed by the Diafrabe herds during 1977-80 are shown on figure 47. Allowing for diversional grazing away from the traject, the schematised grazing orbit encompasses an area of about 4200 km^2, stretching along a SW-NE axis some 160-180 km in length.

To simplify the characterisation of the environmental conditions along the traject in time and space, two major periods have been distinguished: December to February and March to June, which correspond to an early - and a late dry season grazing area.

Distribution of rangeland types and proportion of land flooded and cultivated to rice for the two zones (Table 71), demonstrate that movements are largely governed by flood retreat, which progressively opens up new grazing resources along the traject axis. While before March, the orbit consists mostly of dry or only partially inundated land (70%), entry into the heavily flooded back-swamps (96%) of units 14 and 18 becomes possible only later in the dry season (see Figure 15 , on p. 4).

In view of the close linkage between flooding parameters and rangeland types, it is clear that grazing resources and their utilisation change continuously in time and space along this axial gradient.

To indicate the degree of resource utilisation within the two orbit areas, its sequential cattle population based on the aerial census have been tabulated (Table 72). It is seen that the "early" zone is intensively used during at least 5 months (November-March) at stocking rates increasing with time from 0.3 to 0.8 head/ha (or 4.5 - 1.8 ha/TLU). In the northeast, grazing pressure is even higher at 0.6 to 0.9 head ha (2.5 - 1.6 ha/TLU) over the 5 months period (February to June).

It is evident that this high grazing pressure has far-reaching implications for the nutrition and health of the transhumant herds resulting in seasonal variation of productivity parameters.

Grazing resources

Given the wide variations in vegetation types all differing in growth characteristics in relation to the flooding regime, the prediction of the composition and nutritive value of transhumant cattle rations is a difficult task. There is such a choice of grazable resources, that diet

Table 71. *Ecological characteristics of grazing orbit of Diafarabe herds over 1979-1980 (in % of area).*

Transhumance area during period	December-February	March-June
Type of rangeland[1/]		
Deep-flooded grassland with dense grass cover; high proportion of "*Bourgou*"	8	41
Shallow-flooded grassland of mixed composition; little "*Bourgou*"	22	55
Plains, partially and shortly inondated, with *Vetiveria* and associated species	48	4
Levees, ridges and terraces, often well-wooded	22	-
Total	100	100
General level of flooding[2/]	51	81
Land cultivated to rice[2/]	17	12

a/ Based on an aerial sample survey in late October 1980; proportions are calculated from 440 observations.

b/ Based on a global estimation for each grid-square of 86 km^2 (Total orbit 49 squares - 4200 km^2; for details see Milligan and Keita, 1981).

Table 72. *Population density and grazing pressure in the transhumance orbit of the Diafarabé herds.*

Transhumance area	Dec. Febr.	March-June	Dec. Febr.	March-June
Census period ('000)	Cattle population 000		Grazing pressure head/km^2	
October 1980	72.9	2.2	31.5	1.1
February 1980	133.9	162.7	57.8	86.1
March 1981	188.4	123.5	81.4	65.4

quantity and quality are dependent both on the day-to-day management of the herds and on the grazing behaviour of the herds themselves.

The distinction in two zones, sequential in time, makes sense on two counts: first, because within the overall traject there is an increasing contribution of *bourgou* pastures with time, and second, because there is an increasing impact of fire resulting in the destruction of tall standing biomass and the emergence of after-fire regrowth. These two factors have a pronounced influence on fodder on offer and its quality.

It is thought that during the December to February period neither water nor overall rangeland resources are in short supply, although inter-annual variations in the supply situation of both resources depend primarily on the degree of annual flooding and the time and speed of its retreat.

A study by Traore (1978) has demonstrated the range in productivity (2 to 8 t DM/ha) of rangeland types within the delta. This range is confirmed by average values of 4.3-4.6 t reported by Breman (pers. comm.) and also by the detailed growth curve measurements, which showed a total standing biomass of *bourgou* of 15 t in 1980 and 30 t in 1981, from 12 to 5 t of biomass for wild rice (*Oryza longistaminata*) and some 5 t for *Andropogon gayanus* stands and similar tall-grass rangeland types (Figure 53). However, much of this standing biomass consists of mature herbage low in leave: stem ratio and consequently low in digestibility and crude protein content. Estimates of average digestibility and crude protein content in the grazed ration over this period are 50-55% and 5.5-7.0% respectively (Figure 64), while good quality herbage containing more than 60% digestible energy constitutes some 10-30% of the grazed biomass (Figure 65). A similar range of values is shown in Table 73 and 74, which highlights the low digestibility of *Vetiveria nigritana*, one of the commonest components in the "drier" deltaic rangelands.

Therefore, it is not surprising that Diallo (1978) concluded that in spite of the high standing biomass, the supply of nutritious fodder containing over 7.4% CP rarely exceeds 400 kg DM/ha. Assuming that this good quality herbage consists mainly of regrowth, further estimates can be obtained from measured growth curves. These data, obtained from controlled cutting and burning experiments in natural deltaic rangeland types, show an early growth of *Andropogon gayanus* of 5-9 kg DM/day/ha, providing a total biomass of 150-300 kg/ha if a grazing rotation of 30 days is practiced (Figure 55).

Table 73. *Digestibility coefficients (D%) of perennial grass species and their components in the Delta,*

Component	Species	Period	Number	D%	SE
Straw	Several	Jan-May	9	48.0	3.0
Leaves	Several	Jan-Febr.	4	49.2	-
Regrowth after fire	Several	March-June	11	58.4	2.4
Regrowth after rain	Several	May-June	6	62.6	-
Leaves/regrowth	*E. stagnina*	April-May	6	74.2	1.0
Unburned regrowth	*V. nigritana*	Jan.	4	35.2	-
Regrowth after burning	*V. nigritana*	June	6	39.3	-

Adapted from Diallo (1978); SE: standard error.

Table 74. *Crude protein content (% DM) of grazed grass components in the Delta.*

Component	Period	Number	CP %	SE %
Whole plants	Dec-Febr.	16	6.8	0.8
Leaves	Dec-March	24	7.6	0.8
Straw	Febr.-May	10	3.2	0.3
Regrowth (mainly after fire)	March-May	26	10.5	0.6
Regrowth after rain	May-June	8	11.8	1.3

Adapted from Diallo (unpubl. data).

For wild rice, regrowth is much lower, while in contrast, new growth in defoliated *bourgou* stands is much higher rainging from 600-1000 kg DM/ha/month in a monthly or 15 day rotation (Table 75 and figures 55 and 56).

Table 75. *Average growth rate in kg DM/ha/day of different rangeland types in relation to defoliation regimes*[a/].

Rangeland type	*Andropogon gayanus*		*Oryza longistaminata*		*Echinocloa stagnina*	
Sampling period	Early	Late	Early	Late	Early	Late
Defoliation regime						
Single early cut (17/11)	8-9	nil	2	nil	-	-
Single late cut (18/3)	-	1	-	1	-	-
After fire[b/]	-	2	1	nil	-	-
Repeated cuts (every 15 days)	6	5	-	-	35	30
Repeated cuts (every 30 days)	5	5	-	-	20	25

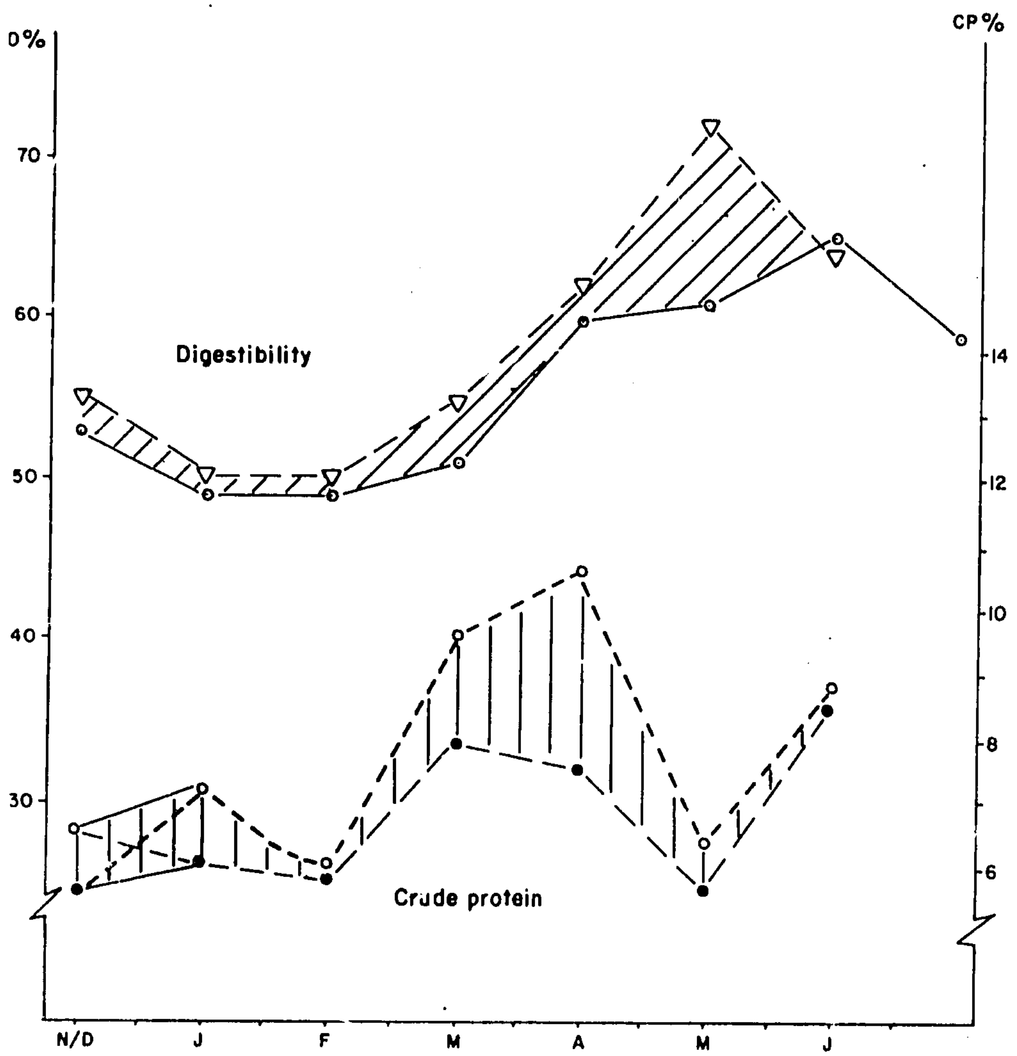
a/ Adapted from growth curves (cf. 4.2.4); average daily growth rates are calculated over 90 day period. More reliable estimates covering more rangeland types will become available once data over two years (1980-81) have been analysed.

b/ Dates of burning for *Oryza* and *Andropogon* were on 18/1 and 16/1 respectively.

Applying short-term high grazing pressure may be a management strategy to improve access to standing biomass and provoke more regrowth, in particular during the start of the dry season, when herbage is not sufficiently dry for efficient burning. High herd concentrations in early November (some 240,000 head within 140,000 ha or a pressure of 1.22 TLU/ha) are usually explained by the scheduled mass entries into the delta, but rangeland management considerations may well play an important role.

From March onwards, due to the marked change in species composition along the transhumance route combined with the rising spread of burned rangeland, there is a rapid drop in total biomass accompanied with a rise in herbage quality (Figure 64 and 65). Thus, provided grazing pressure is not excessively leading to fodder supply constraints, the nutritional plane of transhumant herds should improve from March onwards. However, later on, in May and June, continued grazing accompanied by lower growth rates of after-fire regrowth, may provoke a decline of available biomass, followed by a rise again when rainfall-induced regrowth commences.

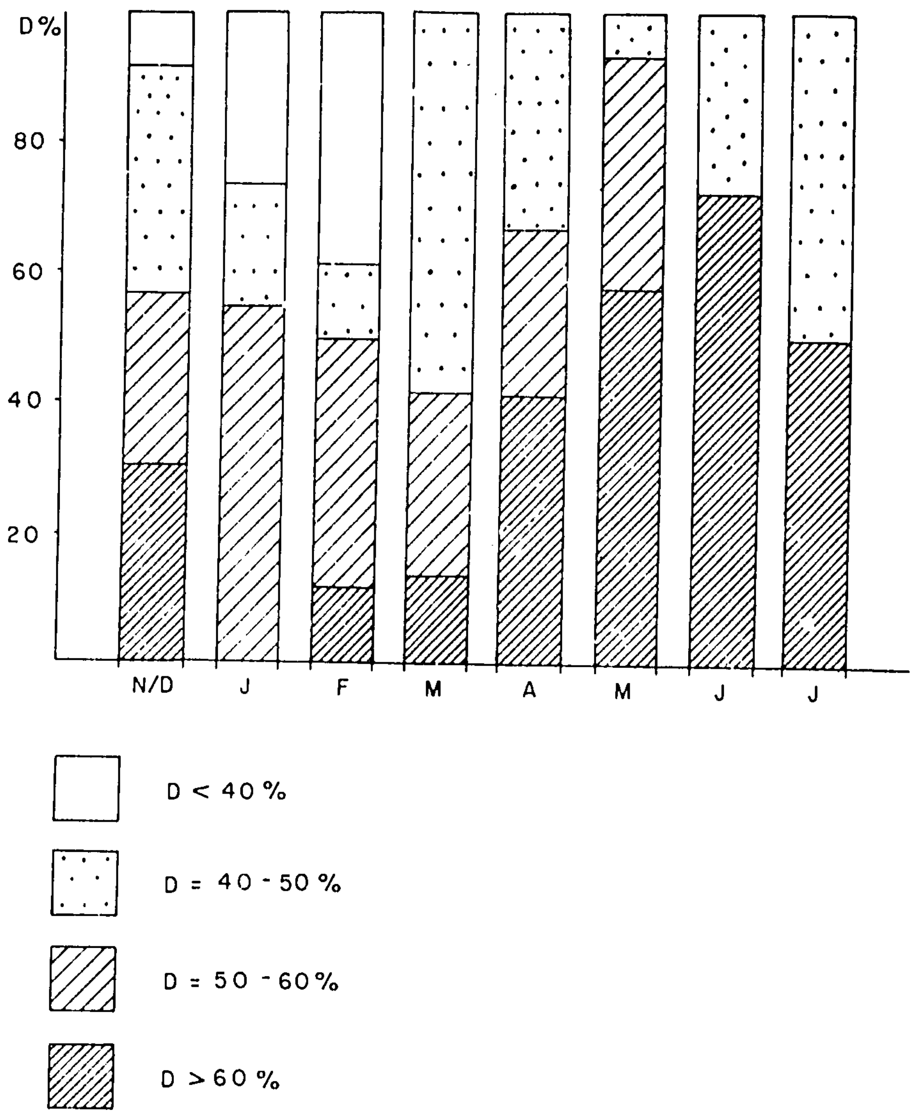
Figure 64. *Range of average digestibility coefficients and crude protein content in grazed diets in the delta*



Digestibility ▽– – –▽ adapted from Breman (Pers. comm.)
○——○ adapted from Diallo (1978), annex and table III.

Crude protein ●– – –● adapted from Diallo fig. III-1
○——○ adapted from Diallo (1978), table III-1 and Traore (1978) table 19 and 20.

Figure 65 *Frequency distribution of digestibility (in vitro) coefficients (in % DM) in diets of Diafarabé herds grazing delta grasslands (adapted from Breman; pers. com)*



Since severe weight losses have been recorded towards the end of the delta transhumance period, it is worth examining if these losses could be caused by feed constraints. This leads to the crucial question concerning the carrying capacity of grazing lands and their degree of utilisation. Aerial surveys in February-March have indicated cattle densities from 30-185 head/km^2, the highest densities occuring in the Yongori-Pondori and Debo-Wallodo backswamps (unit 17: 185 head/km^2, unit 19: 153 head/km^2). A theoretical calculation based on a set of untested assumptions provides a tentative estimate of 1.4 head/ha or 140 head/km^2 5/ The outcome leads to the conclusion that these two backswamp units are indeed overgrazed, while the surrounding units fall short in carrying their maximum load. However, since the carrying capacity estimates are based on a 40% proportion of *bourgou* land, more reliable carrying capacity calculations have to await the publication of the vegetations maps.

A summary of the conditions prevailing during the two transhumant period is given in Table 76. From this, it can be concluded that herd performance is the resultant of a complex set of factors, in which herd nutrition plays a primordial role. However, this role can not be isolated from other factors that together make up the total burden of stress to which herds are exposed in time and space.

Table 76. *General characteristics of the transhumance orbit of the Diafarabe herds.*

	Dec-Febr.	March-June
Water quantity	abundant	abundant
Water quality	good	good to bad
Biomass quantity	high	low
Biomass quality	medium to low	medium to high
Climatic stress	low-medium	medium to high
Daily distance (km)	10-12	17-21
Disease risks	medium (?)	high (?)

5/ These assumptions are the following:

1) Grazable biomass of an average *bourgou* pasture is 225 kg DM/ha/15 days and is equivalent to 60% of total production.
2) The grazing rotation is 15 days and the total grazing period 90 days, thus *bourgou* pasture is grazed six times during this period and total herbage yield for use is 1350 kg DM/ha.
3) Apparant DM intake per TLU is 10 kg/day while 60% of the daily ration consists of *bourgou* regrowth, the rest being obtained from other vegetation types.
4) Forty per cent of the backswamps consist of *bourgou* grasslands.

Characteristics of the Sahel grazing orbit

The Sahelian pastures are located in the Mauritanian Hod Harki, where the herdsmen distinguish between two major grazing areas, The first of these is characterized by the absence of mosquitoes and the high quality of annual grasses, especially *Schoenefeldia gracilis*, while the second has plentiful water supplies and mosquitoes, but is colonized by species with a good feed value.

Primarily associated with more humid conditions, the second zone contains three types of plant cover:

a) a type dominated by *Schoenefeldia gracilis* and *Cenchrus biflorus* found in sandy, upland areas not subject to flooding; this formation is heavily grazed in July and August, before the grasses set seed;

b) a type found in areas to shallow flooding, containing *Ipomea verticillata* and *Panicum laetum*; species which are highly sought after by animals in August and September;

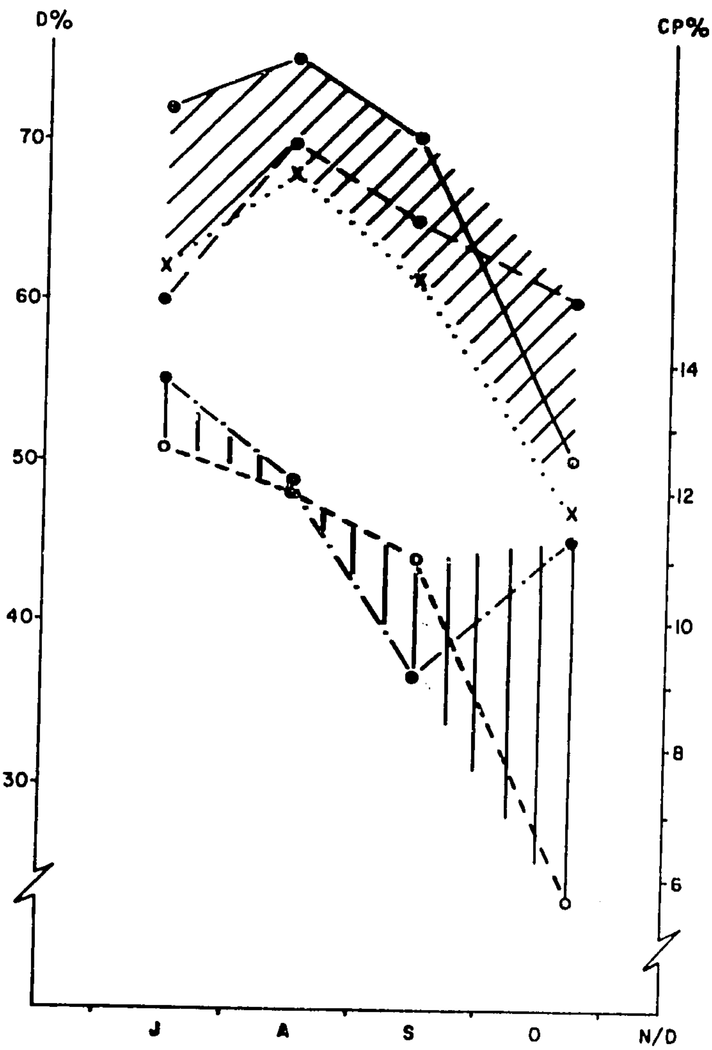
c) a type found on bottom land, where the main species found are *Echinochloa colona*, *Sporobolus helvolus* and *S. iocladoe*; this type is the major grazing resource for September and October.

As regards nutritional constraints, there is much similarity between the Sahelian orbit and that of the later part of the dry season: i.e. a relatively low available biomass with a relatively high quality, as shown in Figure 66.

Digestibility follows much the same trend as in the southern Sahelian upland area around Niono (see 3.4), but it is interesting to note that southern values are on a somewhat lower plane, in line with the general hypothesis of an inverse relationship between herbage quantity and quality (Djiteye and de Vries, 1980).

The crucial management periods fall at the start and the end of the northwestward migration. The decision to move out of the delta seems to depend more on information on water supplies along the transhumant routes than on certainty about grazable fodder resources. Since very large herds are moved "en masse", flexibility in mobility is reduced and abundant surface water has to be guaranteed. In contrast, as the northwestward exodus is of rather short duration (16 - 22 days), fodder constraints are rather minor, in view of the plentyful supplies lying ahead.

Figure 66. *Range of digestibility and crude protein content in grazed diets in the upland Sahel*



Digestibility
Adapted from Diallo (1978 figure III-1
Adapted from Diallo (1978), annex and table III-Ia
Adapted from Figure 39, p. 123

Crude protein
Adapted from Diallo (1978), table III-1
Adapted from Diallo (1978), table III-I and Traore (1978) table 19 and 20.

The arrival in the Hod is scheduled for the end of July when rainfed pasture is usually available, even though herbage yield is small. According to Section 2.1, p. 25, effective rainfall, sponsoring germination, starts on average between 8 and 15 July, leading to grazable herbage growth (100-400 kg DM/ha) between 1 and 10 August. However, rainfall reliability in this 300 - 400 mm belt is low and the risks of intermittant droughts, causing the drying up of water and herbage, remain high. Although fodder resources in the Hod are lower than further south, grazing pressure seems to be below carrying capacity, so that from mid-August to the end of September herds have a period of plenty.

The end of the growing season is abrupt, usually falling between 15 and 20 September. While grazing resources remain good (500-1000 kg DM/ha), it is once again the problem of water supplies which forces herds to move back to their home grounds in the delta. The entry into the transitional zone is usually considered the start of another critical period, during which low-quality fodder and the drying up of water supplies leading to overgrazing around remaining water points combine to inflict considerable stress. However, the ecological survey done in conjunction with the cattle count failed to pinpoint large areas of overgrazed ground (see 4.2.3).

4.3.6 A comparison of production systems

The two livestock systems described in this study - although differing in the choice of production alternatives, mobility and others features, are similar in that they attempt to exploit a bimodal feed supply through seasonal movements from one well-endowed range resource area to another. Both the pastoral and agropastoral herds use the upland Sahel in the rainy season, and when water resources become scarce the agropastoral herds move to the rice fallows and fields of the Office du Niger, while the transhumant herds return to the delta.

In contrast, the unimodal feed supply situation, in which feed quantity and quality reaches a peak in the rainy season and declines throughout the dry season to a low before the onset of the next growing season in June, is not discussed in this study, although certain herds in the Niono area remain permanently in the upland Sahel.

While all aggregate production parameters are bound to be influenced by herd nutritional plane, seasonal effects on productivity are primarily demonstrated in conception and calving rates, mortality, growth rates in different age/sex classes and finally in the seasonal fluctuation in milk production and offtake. These variations are being examined in some detail in order to see how they relate to the feed supply situation.

Calving rates

Since controlled breeding in traditional herds is supposedly non-existent, conception rates tend to follow a seasonal pattern in line with the level of stress to which herds are exposed. Data from agropastoral herds in Mali and sedentary/migratory herds in Sudan show that over half the calves are conceived in the 3-month rainy season, when water and feed supplies are optimal (Table 75). In contrast no such relationship exists in the four transhumant herds. Whether this implies that general grazing conditions are less affected by seasonal variations or evened out by skillful management is not known. It is also possible that the policy of herd splitting and the continuous exchange of reproductive stock between management groups in effect results in breeding control, a hypothesis that needs further investigation.

Table 75. *Seasonal distributions of calves born in different production systems*

Calving Period	Agropastoral Mali	Sedentary Migratory Sudan [a]	Transhumant Mali	Conception period
Jan-Feb-March	20.0	22.5	25.5	April-May-June
Apr-May-June	55.5	61.7	32.8	July-Aug-Sept
July-Aug-Sept	13.5	13.3	22.6	Oct-Nov- Dec
Oct-Nov-Dec	11.0	2.5	18.7	Jan-Feb-March

Source: Authors and [a] Adapted from Wilson and Clarke (1976).

Calf growth

Seasonal variations in calf growth are likely to be a sensitive indicator of nutritional stress level, provided there is no strong interaction with general herd management and with seasonal variations in strategies of milk offtake for human consumption or sale.

For the two Malian systems, calf performance up to 1 year is similar (Table 78 and 79), but somewhat below that found in Chad, while ranch-raised calves do much better. On the Niono ranch calves may have benefited from supplementary feeding of their dams, while the good performance in Toukounous (Niger) appear to be related to the high lactation yields of (selected?) Azouak cows. Calf performance in Chad was measured in traditional herds, ranging from sedentary to short-distance transhumant. Milk yields of cows were similar to those measured in Mali and calf consumption was between 60 and 90% of total milk yield.

In Toukounous, date of birth had a significant effect on calf growth, resulting in a 25 kg higher weight of calves born in January than in July. The dry-season calves profitted fully from the wet season "flush" but it is likely that at 18 months of age weights would again be equal. In transhumant herds, a similar response curve is found, except that weight differences even out much earlier at 12 months of age (Table 70).

Table 78. *Growth performance of male calves up to 6 months of age in different production systems.*

System	0 days	90 days	180 days	30 days
Agropastoral, Mali	18	38	54	28
Transhumant, Mali	18	40	59	25
Agropastoral, Chad a/	20	46	70	29
SERZ, Mali b/	21	49	75	30
Toukounous, Niger c/	22	70	100	39

Sources : Authors and a/ An. Rep. 1979, IEMVT, Farcha, Tchad. b/ ILCA (1977), adjusted for Peuhl breed. c/ Bartha (1971).

Table 79. *Growth performance (kg) of cattle in different production systems.*

System	Males					Females				
Age	1yr	2yr	3yr	4yr	5yr	1yr	2yr	3yr	4yr	5yr
Agropastoral Mali	85	152	180	225	280	77	130	180	215	230
Sedentary - Migratory Sudan[a]	105	175	255	310	360	105	150	210	250	285
Transhumant Mali	84	126	185	223	244	82	116	168	200	203
Niono Ranch Mali[b]	128	233	-	-	-	122	202	-	-	-
Toukounous Niger[c]	130	199	298	-	-	122	177	258	-	-

Sources: a/ Wilson and Clarke (1976)

b/ ILCA (1977)

c/ Bartha (1971) ILCA data

Growth in older stock

Yearly growth of male and female stock up to 5 years listed for the three systems (Table 79) shows the comparatively poor performance of the transhumant herds and the much better output of those in Sudan, in spite of the poor grazing conditions to which the latter are subjected. (Wilson and Clarke, 1976). Breed differences may account for a fair amount of the difference, since the Sudan cattle are mainly tall Red Bororo in contrast to the smaller Peuhl, which reach only 266 kg and 216 kg at 6 years for male and female respectively. Even in the better environment of the Niono station average adult female weight was only 302 kg (ILCA, 1978).

A comparison of seasonal stress levels would be possible if seasonal weights of large sets of individual animals were available. Unfortunately, in all three systems such weighings were infrequent. Instead, only weight changes within age classes have been calculated, but these imply that for each consecutive weighing, sets of animals have been continually changing. The Sudan and agropastoral herds in Mali are showing similar dry-season weight losses amounting to 10-12% of initial weight followed by rapid rainy season growth of the same magnitude for older or more for younger animals (Table 80).

Table 80. *Seasonal weight changes of age/sex classes in two production systems.*

Age/sex		Agropastoral (Mali)			Sedentary Migratory (Sudan)		
		Initial wgt	loss	gain	Initial wgt	loss	gain
>48 m :	male	310	-30	+58	310	-22	+69
	female	245	-28	+46	250	-25	+23
30 m :	male	197	-17	+33	220	-8	+30
	female	187	-19	+27	-	-	-
24 m :	male	165	-17	+32	175	-14	+56
	female	154	-19	+48	150	-16	+44

Sources: Wilson and Clarke (1976) and ILCA field research.

In the transhumant system, losses are similar (Table 81) to other systems but subsequent gains are lower, which is in agreement with the yearly growth shown in Table 79. Table 81 also demonstrates that adult stock lost weight in 1980 - 81, which together with the much higher mortality indicates the poor conditions prevailing during that year.

Table 81. *Seasonal weight changes in age/sex classes in the pastoral system.*

Age/sex class	Initial wgt Jan 1979	1979 Jan-June	1979-80 June-April	1980 April July	1980 July Nov.	1980-81 Nov. March	Final wgt March 1981
>48 m : male	313	-35	+5	-18	+35	-29	271
female	240	-27	+11	-25	+26	-21	204
24-36 m:male	164	0	+36	+3	+29	-4	228
female	153	+4	+26	-17	+41	-15	192

Source: Authors.

Liveweight changes of cattle grazing upland Sahel rangeland seem to be influenced by management system and the quality of the dry-season fodder. On the Niono ranch, free-ranging cattle loose about half the weight they gain during the previous rainy season, producing an overall annual gain of about 50 kg. Paddocked cattle have similar wet-season gains, but in the dry season loose practically all they have gained, even when grazing is in rotation (Table 82). These losses are due to lack of selective grazing rather than to a shortage of biomass, and it seems likely that liberal access to browse does reduce weight loss in free-ranging cattle[6/]. Furthermore, they often begin compensatory growth earlier, because they can benefit from localized pockets of new green herbage emerging after early and widely scattered showers.

No or little weight loss occurred in cattle grazing the Ekrafane ranch (Niger), on which a low stocking rate combined with rotational grazing

6/ A local herd grazing upland Sahel with a very low grass cover spent 35% of its grazing time on browse (Dicko, personal communication).

ensured a continuous supply of 300 - 400 kg of standing biomass of good nutritonal value[7/].

Table 82. *Animal performance on the Niono and Ekrafane ranches (Niger Republic).*

	Niono		Ekrafane
Annual rainfall (1977 - 1980) mm	387		268
Average biomass (kg of DM/ha/yr)	1000[a/]		375
Grazing system	Rotational	Free-ranching	Rotational
Annual stocking rate, ha/UBT	4	7	14
Liveweight gain (kg/ha/yr)	15	43	79
wet-season gain:	+87	+87	+82
dry-season loss:	-72	-44	-3
Average liveweight (kg)	312	326	337

a/ Standing biomass ranging from a peak of 1500 - 2000 kg in September to 400 - 500 kg ha in May/June.

Source: Authors and IEMVT (1980).

Milk production

It can be expected that in the unimodel feed situation, milk supplies are very seasonal and linked to the rainy season, because of the high conception rate of cows during this period. It is only through multi-species herding that a more constant milk supply can be obtained, as Swift (1981) has shown for the Adrar Tuareg, who exploit camels, cattle, goats and sheep simultaneously.

Although less variable than in the extreme conditions of the Northern Sahel, milk yields in the agropastoral herds around Niono show marked seasonal fluctuations in line with the plane of nutrition. In a herd of about 90 head, Dicko (1981) recorded a peak in total milk offtake of 24

7/ Djiteye and de Vries (1980) claim that there is an inverse relationship between standing biomass and its nitrogen content, arguing that N-uptake by short-season annuals and available soil nitrogen are fairly constant; thus, assimilated total N varies with narrow limits, and N content decreases with increasing plant growth through dilution.

litres in September constrasting with a low of 5 litres per day in January. However, as Table 83 shows, it is not milk offtake per cow that contributes most to these differences (maximum 1.0 litre; minimum 0.6 litre) but the number of cows in milk, which reaches 23 head in September and drop rapidly to 8 in December with an upturn to 16 in February. The herder or rather his wife attempts to compensate these ups and down in offtake by playing the market and its seasonal price differentials between fresh milk, sour milk and butter and when possible to revert to direct barter between millet and rice for milk products so as to achieve a regular cash income and food supply.

Table 83. *Seasonal milk offtake in an agropastoral herd.*

Period	Type of grazing	Cows in milk	Daily milk offtake (lr)	
			per cow	total
1 Aug - 1 Oct	upland Sahel	23.4	0.91	21.2
1 Oct - 1 Jan	millet fields and fallows	10.6	0.80	8.5
1 Jan - 15 March	rice fields and fallows	14.5	0.66	8.3
15 March - 15 June[a/]	rice and millet fallows, upland Sahel	17.0	0.65	11.2
15 June - 1 Aug	upland Sahel	16.7	0.95	15.9

a/ During this period cows in milk received 1-2 kg of cowpea hay per day

Source: Adapted by authors from Dicko (1980).

In contrast to the multi-species management of some Sahelian Tuareg and the exploitation of single herd units around Niono, the transhumant delta Fulani adopt another strategy. Being almost wholly dependent on milk production for food and generating cash they have opted to intensify the exploitation of certain fractions of the herd: the *bendi* and *tjipi* during the dry season from January to August and the *dunti* during the rainy season. Thereafter, the cows are put into the *garti* to recuperate because this fraction, through skilful management of the grazing resources along the 500 km long transhumance traject has the function of restoring the short-term and maintaining the long-term productivity of the herd as a whole. This strategy may

Table 84. *Productivity estimated of cows by system of production.*

Character	transhumant 1979	transhumant 1980	Agro-pastoral	Niono-ranch
Cow viability (%)	95.1	93.8	96.5	97.2
Calving percentage	59.0	52.0	57.4	78.0
Calf survival (%)	77.1	66.2	75.0[a/]	69.2
Calf weight at 1 year (kg)	82	82	81	125
Lactation milked-out yield (kg)	235	235	193	586
Productivity index per cow per year (kg)[c/]	50.1	39.1	45.5	114.9
Cow weight	218	218	210[b/]	317
Productivity index[c/] per 100 kg of cow maintained per year (kg)	23.0	17.9	21.7	36.3

a/ 21% calf mortality plus an assumed abortions rate of 4%.

b/ 193 kg is the average annual yield per cow calculated from total annual off-take divided by average number of cows in milk (Dicko, 1981).

c/ Total weight of 1-year-old calf plus liveweight equivalent of milk produced.

Source: Trail and Gregory (1981) and authors.

also explain why, although it is often inferred that the delta Fulani over-exploit their cows to the detriment of their calves, the average portion of calf-consumed milk is as high as 69%. These values have mostly been derived from the records within the *garti* and it is expected that lower values will be obtained when more data have been collected from the other herd fractions.

Index of cow productivity

The characters of reproductive performance, cow and calf viability, milk production, growth and cow weight can be combined to build up an index of the total weight of 1-year old calf plus the weight equivalent of milk produced, both per cow per year and finally per 100 kg of cow maintained per year (Trail and Gregory, 1981). The cow productivity index is computed as the product of cow viability (%) x calving percentage x calf survival (%) x calf weight at 1 year (kg) + cow viability (%) calving percentage x lactation milk-out yield (kg)/9. The lactation milked-out yield or offtake is divided by a factor of 9 based on the results by Drewry et al (1959).

It is seen that the cow productivity index for the two systems do not differ much but that for the transhumant system the year 1980 was much worse than 1979. The 1980 index would probably have been lower if instead of the means for 1979-80 of calf weight, cow body weight and milk production, the 1980 values had been used. The ranch herd of Niono station was 2 times more productive because all characteristic except calf survival were substantially higher than in the traditionally managed herds (Table 84).

It may be questioned if the cow index is a suitable measure to compare the productivity in traditionally managed herds, in which the aims of production vary considerably. To assess productivity in terms of milk offtake and calf growth, which is the prime objective of transhumant pastoralists, the proportion of adult females should be incorporated in the index. This would put productivity on a whole herd basis and the index would express the ratio of growth (calf growth plus milk offtake) and total herd biomass. Further consideration is needed to include other forms of production such as traction and transport in the index.

4.4. HUMAN RESOURCES

4.4.1. Introduction

The two main components of any pastoral system are land and animals. Their proper use, however, depends on man and his skill in manipulating these rangeland resources. His main opportunities for increasing productivity, both in the delta system studied by ILCA and in pastoral systems across the Sahel in general, lie in a more rational use of natural vegetation. This will be possible only if the present form of communal land tenure evolves into a system in which land-use rights become defined more clearly and are given to specific groups.

In the last decade much has been written on the establishment of social-territorial units in pastoral systems. Eastern African efforts in this direction have been only modestly successful at best. In West Africa, several development projects have also been launched that include the building up of social-territorial organisations as one of their main objectives, but again results, although not yet conclusive, have certainly not been encouraging. Nonetheless, an effective social-territorial framework is rightly seen as the necessary prerequisite for a more balanced use of grazing resources. As long as a system of communal land tenure prevails, the individual pastoral producer will invest all his surplus labour and skill in order to maximize the number of animals he can keep, rather than to improve the grazing resources which he would have to share with other producers.

In addition to being clearly defined and rigorously implemented, any new form of social and territorial organization would also have to be flexible enough to maintain the present mobility of the pastoralists and their herds, since this represents the best and probably the only way of exploiting the ecological diversity of different zones. In the delta pastoral system, territorial units should therefore include areas of both the rainfed Sahel and the floodplains, with well defined trek routes in between. Within each unit, the rights of groups belonging to other pastoral units that pass through them, should be preserved, so that these groups can reach the pastures in which they, in turn, have recognised priority grazing rights. The implementation of new social-territorial units would thus have to rely heavily on the cooperation of pastoralist groups and farmers, rather than on law enforcement.

Since traditional forms of social-territorial organization have existed in the delta since the end of the 19th century, it is anticipated that these units might be studied and, where appropriate, reformed and modernized so as to serve as a model for the creation of similar units elsewhere.

According to the administrative census the population of the delta in 1976 amounted to 440,000 inhabitants. Population density in the delta remains moderate (under 20 inhabitants/km^2) and does not contrast sharply with the surrounding dry areas. Traditionally, there are five main ethnic groups inhabiting the region: (a) the Fulani and the Rimaibe; (b) the Marka; (c) the Bambara; (d) the Bozo and the Somono; (e) the Tuareg and the Bella. Each social group is engaged in a dominant economic activity most suited to its specific ecological environment. The Bambara practice rainfed millet cropping on upland, the Marka and the Rimaibe - formerly slaves to the Fulani - cultivate rice in the flood plain, while the Bozo and Somono are fisherman and the Fulani are transhumant pastoralists. The delta-based Fulani through their transhumance movements exploit the constrasting resources of the delta and its dryland surroundings, and, were forces to foster reciprocal links with the Fulani and Tuareg herdsmen having their base elsewhere. Thus, human occupation of the inner Niger delta should be understood in terms of a vertical stratification of land, ranging from upland to flooded basins, rather than as a regional population grouping.

To the unique quality arising from the close relationship uniting certain socio-ethnic groups with a specific ecological environment, is added another unique historical feature. The area has traditionally been dominated by a single ethnic group, the Fulani, which reached its apogee during the 19th century under the *Dina*, the theocratic Fulani empire of Macina, the founder of which, Sehu Amadu, codified its socio-political and territorial organization. Thus since the 19th century the delta has been endowed with a precise and strong system for organizing land tenure, in contrast to other regions of the Sahel, where land tenure organization is absent or very law, as it is largely based solely on usufructary rights. The land was divided into about 30 territories, (Fulani: *leydi*) providing a geographical structure in support of an agropastoral organization in which pastoralism was the dominant activity. This priority of grazing use over cropping and fishing was enforced to create and maintain a social hierarchy dominated by Fulani stockowner.

Each *leydi* is based on a territory containing a Fulani village and its grazing land, and a Rimaibe village situated amongst its cropland. The Fulani own a number of herds, each of which has at least one well-defined area for grazing. The aims of *leydi* are geared to establishing a balance between pastoral and agricultural activities. Under the *Dina* this balance was achieved because all rangeland and farms were held by and managed to the advantage of the Fulani socio-political groups. Within this context, a further objective was to mantain a balance between available pasture and the livestock population through limiting the numbers of outside herds by imposing a tax on their owners. This tax was shared between the men of the family who possessed the grazing rights and were responsible for land management.

Nowadays the twofold balance pursued by the agropastoral organisation of the *Dina* no longer exists, for several reasons. Current developments are characterized by other groups contesting the traditional rights of the dominant socio-ethnic group over land, by a thrust in crop production and by changes in the system of livestock production. Between 1952 and 1975 cropping has taken over a considerable area of land formerly reserved for livestock grazing. The total area under cultivation is increasing at about 2.2% per year and rainfed cultivation by about 2.6% yearly. Since it appears that over the last 25 years agriculture has undergone little intensification, it may reasonably be assumed that this trend of expansion in cropping will continue in the near future.

Current and future growth in agriculture is the combined result of two factors. First, it seems likely, on the basis of the few demographic surveys undertaken in the Sahel, that the population growth rate is hihger amongst sedentary farmers (2.5 to 3% a year) than among nomadic herdsmen (around 1.5% per year). Second, the mode and organization of livestock production have been modified: under the impact of veterinary care livestock numbers have increased at the same time as crop cultivation has reduced the land available for grazing. In addition, both agricultural surpluses and spare cash (rural exodus, trade, savings by civil servants) have been invested in cattle production. Such investment has changed cattle ownership structures: a growing number of herdowners do not herd themselves while at the same time traditional herdsmen have lost their animals and have become salaried herdsmen of owner investers. This situation is an important factor in changing the traditional relationships between man and herds in the delta and its fringes, in particular those related to land tenure and usufruct rights of grazing land.

In the traditional system, the Fulani pastoralist could leave the distribution of crop land to a reliable care-taker, but the loosening of the ties of dependence of farming groups during the colonial era and their almost total disappearance after independence left the head of the village, being invested by the village council with authority that became recognized by government, a great deal of latitude in the allocation of cropland. This means that in practice the pastoralist class exercises little more than distant control over the allocation of land or last its control completely.

Under the current post-independence legislation the state has arrogated all rights over land at the highest level. However, this general law is unmatched by a body of land tenure laws, which specify land ownership, usufruct rights etc. The absence of such laws as well as the continued predominance of shifting cultivation has generated a whole gamma of land use conflicts between farmers, between pastoralists and most frequently, between farmers and pastoralists. These are often further aggravated by the fact that the "commandant de cercle", in representing the state, is the sole authority to settle land conflicts. This often leads to arbitrary decisions, freqcently motivated by partisan preferences or self-interst. In this context it is not surprising that many decisions in land disputes are unfavourable to pastoralist interests, for the simple reason: that land clearance followed by cropping leaves a tangible mark on the landscape. Thus, the farmer can support his claims on user rights by showing "his field", while on the contrary, the herdsman in using natural grazing land can only make verbal claims.

During the last decade the low level of floods has brought about rapid increase in land use conflicts, as lack of irrigable land forced farmers to encroach on the deep basins that contain the best *bourgou* pastures of the delta. Conflicts have also been arising over the temporary camping sites and transhumance routes which have been cultivated or obstructed by fields. In addition, protests by herdsmen are often weakened by the ambivalent practices of some of their own people who, caught between their agricultural and pastoral interests, show no hesitation in clearing their own grazing land.

It is in this context that since 1979 efforts have been directed to develop a suitable research methodology that is aimed at assessing the present situation, both in terms of balance between grazing resources and livestock population, and between the conflicting interests of the pastoralists and the farming community.

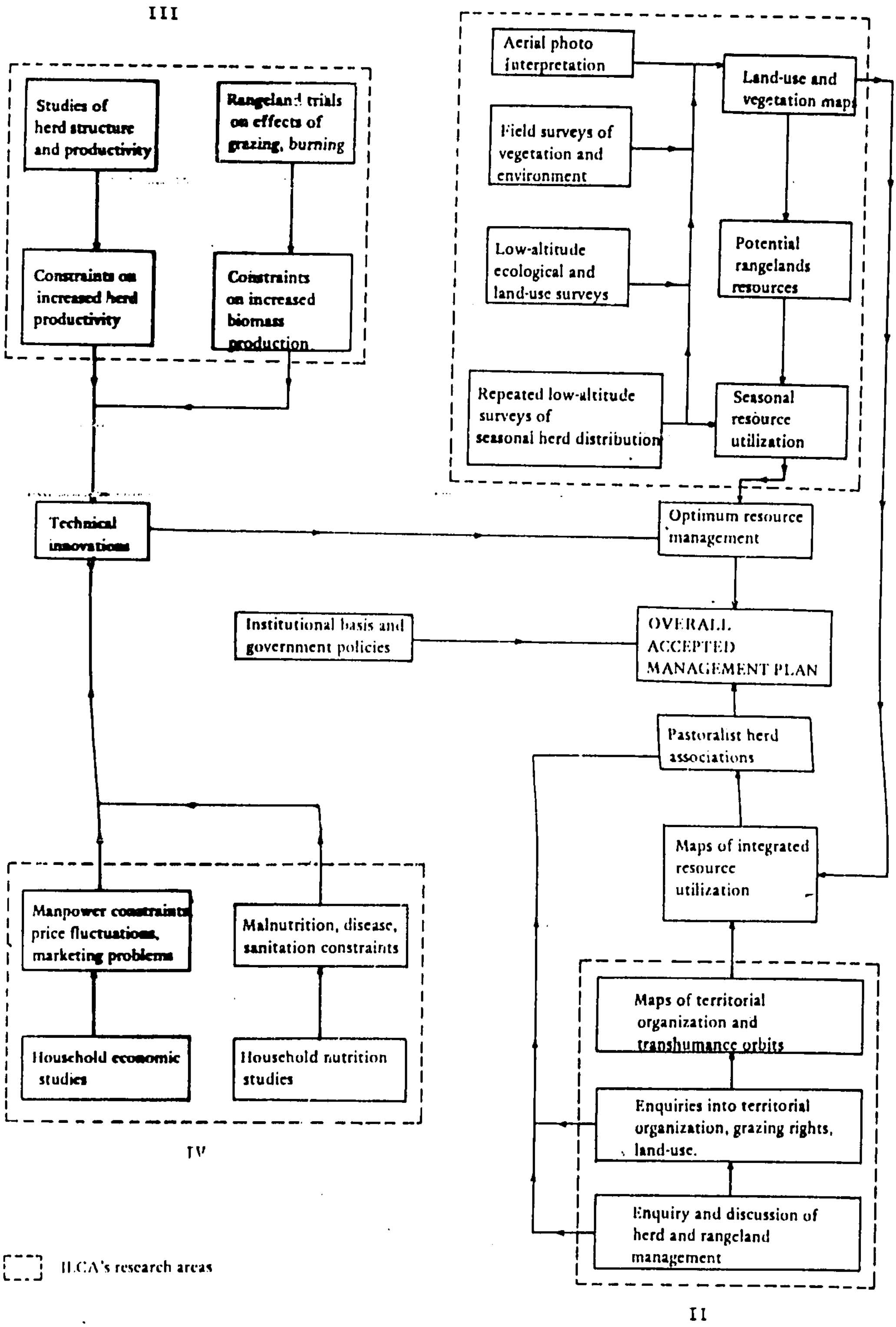
4.4.2 Research methodology

The diagram presented in figure 67 attempts to show the interrelationships and complementarity of the various research components in a multidisciplinary frame, with four blocks representing the major subject matters of the study. The elements in block I deal with the plant and animal resources, while block II lists the enquiries aimed at a better understanding of the existing territorial organisation of pastoral and farming groups. This enquiries are supported by field studies of the economy at village level (block IV). Similarly, a series of supporting studies as described in block III are made to further identify the constraints to improved productivity of the range and livestock components.

Plant and animal resources

Rangeland resources are studied at three levels: first, distribution and location of the major rangeland types are mapped on a scale of 1 : 50,000 for the delta and 1 : 200,000 for the surrounding upland through photo-interpretation (dating from 1971 and 1975) combined with extensive field inventories.

Figure 67. *ILCA's research on social-territorial organization and pastoral development in the arid zones*



ILCA's research areas

Apart from identifying the ecological factors that determine the extend and distribution of rangeland types (see figure 13), the mapping also provides information on settlement patterns and associated land use, degree of erosion and degradation. Second, low-altitude flights at various crucial periods (see section 2.3) are made to further assess the seasonal fluctuation in resource availability and utilisation by herds and herders in the ecological mapping units. While assessing seasonal distribution of livestock, ecological parameters (degree of flooding, agricultural land use, woody and herbaceous cover, degree of burning and erosion) are also recorded as a supplement to the more static data provided by the photo-interpretation. Third, for a correct interpretation the productive capacity of the rangeland types, seasonal uninterrupted growth of the major rangeland types is determined in sites unaffected by management while the impact of grazing and burning at different times and frequencies measured (see section 4.2.4) to simulate the effects of resource exploitation. In addition to providing data on how the different rangeland types react to several modes of management, the trials will provide useful indications as to the weaknesses in the present utilisation system and will point at innovative practices to overcome them.

When these studies are continued over several years, it will be possible to predict longer-term trends in rangeland succession and associated productivity, and to give prognoses on the stability of the ecosystem components given the present level of livestock utilization, as well as on the longer-term effects of further encroachment of rice cultivation on grazing land. Although the simpler interrelationships between range resource use and its resulting seasonal fodder supply and livestock productivity parameters have been explained in chapter 4.3, further integration of these studies, with special emphasis on herder perceptions of grazing conditions and trends and the effects on his herd output, will assist in building up a body of knowledge to convince the herders themselves, and others with a stake in the rational exploitation of natural resources, that modifying the practices of grazing and herd management is worth trying. With respect to the livestock productivity study, more effort should be directed to the less mobile herd management units (*bendi, dumti* and *tjipi*) which suffer much more from seasonal imbalances between fodder supply and demand than does the *garti*, to which most attention has hitherto been given.

Social and territiorial organisation

As has been schematized in figure 67, research in the socio-economic aspects of the management and exploitation of the delta ecosystem is carried out at several levels. First, the existing territorial units are mapped on a scale of 1 : 50,000 using the IGN maps as a base. Surveys seek to establish the geographical limits of the pastoral units and locate, within each villages, recognised trek routes for transhumance, temporary campsites, farmed and fallow land and, most important of all, the extent of the grazing area and the different customs and rights governing its use. The survey team is in constant touch with representatives of the different interest groups within the *leydi* using meetings, discussions and open-ended questionaires to enquire into the history of the *leydi* since the establishment of the *Dina* up to the present, and requesting help to verify the exact location of the geographical features to be mapped.

Second, data on population and tribal composition are collected for each village, and used as a control on the existing local census records. The enquiry also includes livestock population parameters, the size of *leydi* herds and their division into management units, their respective use in time and pastoral space within the *leydi* itself and their grazing rights in territorial units that belong to their transhumance orbit. This survey is complemented with a study of the grazing rights and terms of reciprocity of pastoralists whose home is based elsewhere, either within or without the delta. The special extent of farming is determined together with who farms, where, how pastoral and agricultural use are linked and whether conflict situations appear to exist. To complement these specific enquiries, further information is gathered on the more general aspects of livestock husbandry, such as disease incidence and available services to combat them, as well as on the local perception of government interventions such as irrigation schemes etc.

During the second phase of this survey, acceptance of general ideas and more specific proposals generated by the land resource inventory and the studies on range and herd management, will be tested against local traditional beliefs and customs. Once a certain basis for agreement on the aims of improving pastoral management at the local level has been established, implementation pathways can be proposed, with emphasis on the re-enforcement or restructuring of local institutions such as herders and farmers associations and the like.

Although the prime objective of this integrated body of research is to assist ODEM in establishing a limited number of pilot pastoral units, the mapping of natural resources and their utilisation combined with that of the existing territiorial organisation, will provide an efficient tool to work towards an overall land use management plan for the delta and the surrounding hinterland. This data base will not only serve ODEM but also the various 'operations' and other para-statal organisations involved in the development of this area.

5. FUTURE PROSPECTS

5.1 CROP LIVESTOCK RESEARCH

Work on crop/livestock production in Mali is presently focused on farmers who cultivate millet and also rear livestock for additional subsistence, transport, traction and investment. The aim is to increase food production both directly and indirectly; directly through improved farming practices and increased small ruminant productivity, and indirectly through the introduction of drought-tolerant legumes and improved nutrition of work oxen. Problem analysis in ILCA villages will continue until mid-1982, and will be followed by three main research activities:

Millet/legume intercropping and better utilization of fallow land through:

(a) further selection of drought-tolerant legumes, based on their forage and grain yields, conservation possibilities and contribution to soil fertility:

(b) further experimentation and testing at whole farm level of cultural practices designed to conserve soil moisture and produce optimal grain yields and high quality fodder;

(c) assessment of the risks involved in the application of these interventions.

Feeding strategies for improved efficiency of animal traction, including:

(a) studies on the impact of different supplementary feeding strategies on animal growth and performance;

(b) studies on the interactions between nutrition, animal management, cultural practices (including traction) and farm productivity.

Improved health, management and nutrition packages for small ruminants through:

(a) investigation of disease prevalence in small ruminants;

(b) development and testing of prophylactic and feeding regimes, with particular reference to decreasing lamb/kid mortality,

(c) studies on controlled breeding and other management practices conducive to increased offtake.

By 1986, an integrated crop/livestock production system, characterised by improved traction, enhanced soil fertility and an increased contribution of small ruminants to the rural meat supply, should have been developed and tested. Field work will be complemented with mathematical modelling, directed mainly towards defining optimal enterprise combinations.

5.1.1 Plant introduction

The extensive testing of a large number of species on the Niono ranch (see 3.5.2) has made it clear that cowpeas are most adapted to the rainfed millet farming system. Thus, screening of promising forage varieties yielding some grain most years needs continuing. It is likely that the combined efforts of the national research institutions in West African countries, assisted by ICRISAT and IITA will provide new material which it will be worthwhile to test in the marginal millet zone. Considering the local practice of harvesting cowpea and transport by donkey cart, emphasis should focus on creeping varieties capable to mature in a 50 - 90 day growing season. Reduced leaf shattering after harvest and during storage would be an added advantage. Although high grain yields may not be a prime objective when varieties are selected, it is crucial for continued production that farmers living far away from towns and main roads be able to produce their own seeds for the next year. Even if this self-reliance can be assured through provision of dual purpose varieties, ILCA should retain its seed multiplication centre and grow a wide range of varieties.

As the success of forage cowpea production is directly linked to the performance of millet, research to develop adapted millet varieties for the marginal rainfall belt is worth continuing. The initial screening of several hundred of local Malian millet varieties, started in 1979 by ICRISAT in Bamako and other centres, is a useful step in this direction. ILCA will intensify screening promising material from this collection in the 300-500 mm rainfall belt, as was already started on the Niono ranch site. In spite of much research in Senegal (Dancette and Hall, 1979) it seems that the growth characteristics of the Malian *sanyo* and *souna* millets, as recognized by the local farmers, are poorly identified. To assist in this identification, the soil-water-nutrient- plant model developed by PPS (Djiteye and de Vries, 1980) to predict annual biomass production of the Sahelian grass cover will be extended and adapted to millet.

Although cowpea is the only grain legume (not counting groundnuts and voandzou) of any importance in the zone, other short-season dual purpose legumes should be tested, both on experimental scale and at farmers' level. In this context, it should be realised that the local farmers with whom ILCA has been working, respond more than expected to the introduction of new plants and varieties.

5.1.2 Cultural practices

Millet will remain the sole subsistence crop, and the survival strategy of the farmers is geared to keeping their granaries full. Thus, any intervention that would reduce the prospect of a good millet yield will be met with resistance. Since the yield-reducing effect of intercropping cowpea is inversely related to the amount and distribution of effective rain, cowpea will be a welcome secondary crop in good years but much less so in bad years.

Further studies need to be made on the extent to which tillage practices,including optimal use of work oxen for interrow cultivation, contribute to the reduction of moisture stress in millet, particularly during bad rainfall years. Analysis of the farming operations timetable over two consecutive years (1980 and 1981), its relationship to labour and traction available to the family, to rainfall distribution and family crop yields should provide clues on how time and space allocation influences farm output.

Although further research on millet and millet/cowpeas mixtures responses to NP fertilizers is required, the transferability of the results to remote, cash-short farmers is questionable. However, considering the importance of animal manure for sustained high millet yield in village fields, the interactive effect between manure and different P-sources covering the whole range of P-solubility should be studied. The ICRISAT group in Mali, assisted by the World Phosphate Institute and the Malian Research Institutions, are working in this direction and ILCA should participate in this multi-locational research.

Risk assessement of interventions

Multivariate analysis of the factors affecting farm output will show which current practices contribute most to stabilizing and optimizing grain yields. It will hopefully provide a basis for a 'best bet' selection of interventions, which can be tested on a on-farm scale in the study villages.

5.1.3 Animal traction

In contrast to traction-assisted cropping in the subhumid zone, where lack of stock to be trained as work oxen is often a constraint, most families in the millet system have one pair of oxen and ploughing equipment, and plough teams using 3 oxen in rotation are frequently seen. Local herds are structured with sufficient young males and further supplies can be obtained from transhumant Fulani who pass through the area during the November-December period.

In the millet system, work oxen are used to plough new bush fields from late July to early August, after the village fields have been tilled (Figure 23). Weeding with a single-blade plough in order to destroy weeds, break the surface crust and build up ridges, starts after the first sowing in bush fields in early June and continues throughout the growing season up to mid-September. Thus, draught animals are being used during at least 3 months, ploughing some 340 ha and repeatedly 'weeding' some 760 ha, although a considerable proportion of bush fields are abandoned when crop failure is obvious.

Data on work output (work hours/ha, ha/day etc) and frequency to determine time series of work load as well as time ratios between grazing/working and resting will be forthcoming after the 1981 cropping season. These data will help to detect interactions between energy budgets and resulting nutritional requirements, and to determine to what extent the latter are met in the present management system.

A general impression about the nutritional status of work oxen can be deduced from seasonal weight fluctuations (Figure 37). These indicate that adult males drop from 340 kg in October to 290 kg at the beginning of the cropping season in June. It was calculated that feeding 2-3 kg of cowpea hay during April to June would reduce loss by 10-15 kg, requiring 1-2 ha of intercropped millet/cowpea for each oxen pair. The crucial question is whether low weight and poor condition affect traction force and make supplementary feeding worth the effort. It should be realized that most millet soils are sandy, requiring a modest traction force, and daily output may count more than force so that a maximum amount of land can be cultivated in the shortest possible time.

Whether weight losses could be minimized by improved management practices should be investigated At present, work bulls join the village herds and after January do bush grazing without herder. They may return home every day for watering or stay away for 2-3 days. West of Niono, herbage quantity is no constraint, although much depends on the degree of burning in anyone year, while nutrient intake depends mostly on the proportion of browse in the diet. Since the Fulani herders who manage the village herds are unemployed during that period, special groups of draught oxen could be formed and put to pasture under skillful management and instead of cowpea hay, mineral supplement and millet by-products could be fed.

As long as the impact on traction efficiency of feeding cowpea will not have been analyzed, the present practice of feeding hay to horses, donkeys that pull carts and 'moutons de case', should remain a possible alternative (see p. 118).

5.1.4 Small ruminants

The technical pathways for improving the productivity of small ruminants have been shown in Figure 38 and described on p. 118-121. As disease prevalence constitutes a major constraint and its control a first priority, it is most urgent to divide the mortality races into its components (disease, losses due to predators, breeding and management practices) and to ascertain what these losses mean to the family meat supply and cash income, in view of the fact that many morbid animals are not a true 'total loss' (see p. 108).

More detailed analysis is needed to detect which factors determine the remarkable variations in individual flock productivity, (cf. table 38). The rôles played by disease control, breeding management and supplementary feeding should be assessed, and since these are mostly influenced by the owner they should be contrasted with the grazing management as carried out by the shepherd, The higher productivity of flocks owned by rice farmers may be due to a variety of factors and it seems unlikely that, as was found with cattle, access to rice fields and fallow is a contributing factor. Nevertheless, an enquiry into the grazing management practices of the two systems may reveal differences and could at the same time verify that the flock activities and seasonal energy intake patterns described in the nutrition study are representative for both agropastoral flocks.

Since no parallel socio-economic enquiries accompanied the flock productivity study the motivations and attitudes of flock-owners underlying their production strategies are not precisely known. Therefore, intensifying the flock studies in the ILCA villages would do much to help detect these much needed linkages.

5.2. RANGE LIVESTOCK RESEARCH

The present stage of problem analysis will lead to the establishment of local development units by the Office de Développement de l'Elevage de la Région de Mopti (ODEM), which helps funding this part of ILCA's programme. The development phase will probably start in 1982 and the same approach will be applied to the drier Sahel in 1983-4. Concurrently ILCA will seek to extend its activities outside Mali into other Sahelian countries where development activities are under preparation, the objective being to create a framework within which range management and technical interventions are possible.

5.2.1 The rational exploitation of rangeland resources

To discuss the intervention strategies that will lead to a more rational range resource management, target areas and target groups must first be identified. Given the contrasting environmentc of the inner delta and the upland Sahel, it is evident that, despite of similar management aims, technical interventions differ, because of contrasts in utilisation periods and characteristics of the grass cover. The first target group to address are the technocrats and government officials, who have to be convinced that the management proposals are scientifically sound and politically feasible. Second are the producers themselves, who must be persuaded to adapt their perceptions and attitudes to new realities and their consequences.

In the delta

The technical aspects of the management proposals are simple in that they are based on the growth characteristics of perennial grasses and on manipulating them to opimise long-term productivity, taking the differences between plant communities into account. Through analysis of growth patterns and response to induced levels of use varying in time and frequency, management principles have evolved defining optimum grazing pressures, their timing and frequency. With the aid of the vegetation map, sectorial utilization schedules and rotations will be developped in order to ensure a balanced exploitation of the different rangeland types in time and space. The pilot pastoral units are the initial target areas to which management plans will be applied. Once accepted as technically sound and feasible, the enquiry procedures outlined in section 4.4.2 (figure 57) will be put in motion to sound out the involved producers. Their perceptions as to what is good management will be confronted with the management proposals and lead to the adoption of mutually agreed modifications. Once, the management guidelines have been accepted they will be converted into a set of rules and regulations, that is a pastoral management code.

In the upland Sahel

The management principles touched upon in section 4.2 (p. 151) envisaged to spread the grazing pressure as widely and equally as possible over the upland Sahel. Thus, low capacity surface water would encourage the greatest herd dispersion, resulting in short periods of high grazing pressure followed by long rests. During most of the rainy season, the dead delta has a well-distributed network of surface water due to its geomorphological structure and since stocking rates are low (see 2.3.2), overgrazing is believed rare in normal ranfall years (Diarra and Breman, 1975). Only around the irrigation schemes of the Office du Niger and in the western transition zone is overgrazing and soil denudation a problem. Sedentary herds and flocks are the main cause, while in the latter zone, the *bendi* milk herds graze the zone from January to August and it also bears the brunt of the herd influx before the river crossing in December (cf. Figure 18). It is for this reason that special management measures for this area will be proposed (see below).

The present extent of the different transhumant orbits north and north-westwards should be retained as this outward trek insures the greatest degree of wet season dispersion, while the distances involved are probably far outweighed by the grazing of higher quality pastures further north (Breman et al, 1980), which accelerates rapid herd recuperation. Although severe overgrazing should be prevented, well-distributed pockets of overgrazed sites are an advantage as they add to herbage quality due to the combined effect of fertility transfer through dung and the lower growth rates of species (mainly herbs) adapted to overgrazed sites. To quote Breman et al (1980)... 'Overgrazed areas do not produce much feed, but this very fact means that most of it can be used from the quality point of view (with the exception of small areas with unpalatable species). In places where run-off is simulated by trampling, etc., the quantity/quality balance changes in favour of quality...'

5.2.2. The balance between cropping and livestock

In the delta

A rational approach to determine optimal use of land in accordance with its potential capacity is often deflected by other considerations such as the existing power structure, which determined historically established land use rights and created strong defense mechanisms against change. Thus conflict situations arise between various interest groups: for example, the expansion of farming into grazing land is seen as a threat to their existence by the pure pastoralists, as a means to improve their lot by the farmers and finally as a necessary development for increasing rice production so as to satisfy the demands of the urban population and reduce rice imports by the Malian Government. However, in so far decisions concerning the proper land use in the delta are political in nature, there are technical considerations that can assist and guide the decision-making process. This is where ILCA can contribute because of its relatively large multi-disciplinary research input in this area.

First of all, the detailed mapping of the whole delta will provide the basis for a land capacity map, on which the suitability of the different vegetation types for livestock and for crop production will be indicated. Given the enormous variations in flooding conditions, proirity areas for dry season grazing and rice growing can easily be distinguished, in particular since the optimal growing conditions for floating rice have been studied by the West African Rice Development Association (WARDA) in Mopti.

Secondly, the current controversy about the 'balance' between grazing resources and livestock population in the delta will hopefully loose some of its emotional flavour once the forage productive capacity of the most important vegetation types is better known and guidelines for their proper use have been developed. It will also help to put the term 'overgrazing' in its proper ecological context rather than its present connotation with herders and their 'advocates' as 'a reduction of available forage resources (usually based on a subjective judgement of what happened in the past and during good years) and constituting a threat to herd survival! Thus overgrazing should be re-defined as a rate of exploitation that endangers the long-term and sustained productivity of the ecosystem. For the perennial grassland of the delta, overgrazing in that sense is unlikely to occur on a large scale, since restoration of soil fertility and respite from use is assured during the 6-month flooding season, thereby making high short-term utilisation rates possible.

However, no one contends that the expansion of cropping in the delta does not imply a reduction of overall fodder resources, but its impact is difficult to assess and it is believed that a better integration of farming and livestock husbandry would go far in minimising it. This impact depends much on the flooding regime during any one year. In years of low floods, the higher land, ploughed up for rice, is not flooded and rice is not planted or if so, the crop perishes. This results in land that is either bare or carries a low-productive annual pioneer vegetation. More serious is the destruction of fodder resources through fire after the rice harvest. It is true that rice stubble and regrowth in rice fallows are much less productive than *bourgou* pasture (see figures 53 and 54), but such land can carry as much as 100 head/km^2 for 2-3 months, as aerial counts in the irrigated area of the Office du Niger have shown. In the delta most rice straw is burned to enable farmers to start ploughing their fields when the soil is still fairly moist. They claim that destroying the stubble is essential because their ploughs cannot cope with dense rice stubble[1/].

In the upland Sahel

In areas with rainfed crops, land use conflicts are less common except perhaps in the densely settled fringe around the Office du Niger irrigation schemes and the parts of the transition zone of the delta (Figures 13 and 15). Apart from conflicts arising from livestock trespassing on growing crops, farming has only a minor impact on grazing resources in that presently farmed land is not accessible to grazing. Fallows are often more productive than the original vegetation they replace and when herbage biomass is lower it usually consists of the legume *Zornia* which has a high nutritive value.

1/ The same problem arose in the Office du Niger and it was found that the ploughs used by the farmers were meant for sandy soils and not for heavy soils and plant cover. Thus, a new prototype plough has been developed which can turn the swath. It would be of interest totest this plough in the delta. If this plough could successfully tackle rice stubble, the need for burning would decrease and rice stubble better be utilised. If herders could be convinced to cooperate with farmers and applied high grazing pressure on rice fields immediately before land preparation so as to reduce residues, tillage would be easier.

The effect of converting grazing land into cropland shows mainly on the woody cover, contributing to reduction of available browse.

5.2.3 Water resource development in the upland Sahel

As in several other sahelian countries, water supply improvement has been an important component in many Malian livestock development projects, often absorbing a large part of the on-site investments. For instance, the semi-arid region of Mali has been subdivided in a series of project zones, each of which has been allocated to a bi-lateral or international donor agency, and water development has a high priority in most of the project plans (World Bank, 1980). Much has been written about the disastrous effects of water supply projects, many of which have resulted in disturbing the long-term balance between grazing resource and their use due to rapid changes in the mobility and movement patterns of herds. This has led to serious overgrazing and to the establishment of agricultural settlements in environments too dry and fragile for such changes in land use.

ILCA is directly concerned with water development in that ODEM has constructed a series of wells and boreholes and has deepened a number of surface ponds. These are located along the western fringe of the transition zone and along the recognised transhumance routes in the "dead delta". The aims of improving the water availability in the area is to extend the grazing season in the upland Sahel, delay the entry of herds into the transition zone, thereby reducing the grazing pressure. Thus, instead of the sudden rush of herds from the Mema and Mauritania towards the delta, there should be a staged and slow descend through the development zone during the October-November period. Provided early burning is controlled, the grazing resources in most of the area are believed adequate, as was shown by the low-altitude survey done in October 1980. However, ODEM is rightly concerned that the use of these water supplies and that of the surrounding grazing lands should be regulated before being opened up, and therefore stipulates that the pastoral organizational framework based on the territorial units proposed for the delta should be extended to the outlying uplans Sahel. This entails the establishment of a body of rights and controls including:

1) No watering, grazing or farming around water points from mid-August onwards in order to prevent water pollution and to reserve the grazing resources for later use.

2) The establishment of a sequential grazing plan regulating the timing of herd movements of the different pastoral units. This would mean

that each unit has grazing and watering rights around specific water points for a pre-defined time-span and for an agreed number of TLU.

The entire schedule should be at the same time flexible and rigidly controlled: flexible in the sense that each year the time schedule is fixed according to the end of the rains and the flooding characteristics in the delta, these two points in time determining when the descend period starts and finishes; controlled in the sense that the movement is in strict accordance with the *ad hoc* water and grazing resources along the traject.

To prepare the ground for the controlled water and rangeland utilisation based on an extension of the pastoral organisation envisaged for the delta, ILCA intends to:

1) convert the existing vegetation map of the intervention zone into a rangeland capacity map on which grazing resources and their carrying capacity for specific periods; existing water resources; the extent of sedentary livestock population and of settlement and cultivation will be defined.

2) analyse the current mode of descend in terms of herd numbers; their affiliation to the territorial units in the delta; existing priority rights on water resources etc.

5.2.4 Browse

If population growth, and thus demand for land and firewood, continue at the present rate, the overall woody cover is bound to decrease at an accelerated speed. Increased farming and the resulting sedentarisation of livestock will promote a shift from cattle to small ruminants and consequently increase the demand for browse. Hence, all trends point towards an increased demand/supply imbalance. To exacerbate the situation, increased mechanisation of land preparation will tend to reduce tree cover both on farms and fallows. Up to date, ILCA research has focussed on 1) re-afforestation techniques for the upland Sahel with local and exotic browse species planted through seedlings and seed (Gosseye, 1981), 2) assessing the effects on browse productivity of lopping, pruning and cutting practices, their timing and their frequency (Cisse,1981) and 3) predicting the trends of firewood and browse use by semi-urban centres such as Niono (Wilson, 1981).

Although it has been shown that the planting of dual purpose species (for fuel and browse) is economically justified in certain situations (ILCA, 1981 d), it is questionable whether the political climate and will are ready to support such long-term investment. Nor is it believed that it is within ILCA's mandate to do the supporting research. Its role should be more in support of efforts that lead to a more rational management of fodder resources by stressing the part played by browse in an animal feeding during strees periods (see 4.2.2). For example, it may be worth looking at the browse resources surrounding the millet villages under study, identify how these resources are exploited at present and see if such use can be intensifies without damaging the environment.

5.2.5 Stratification of livestock production

The stratification of livestock production in a number of specialised components has long been a much-loved brainchild of development agencies. The rearing of young stock in the arid and semi-arid zone, where disease incidence is less and grazing resources limited, to be sold for growing out and finishing or for training as work bulls further south, where grazing and water resources are better, is - in theory at least - a rational approach to increased productivity. However, the political balkanisation of West Africa impeding the free movement of stock along the climatic gradient as well as the existing traditional marketing system have proven serious obstacles to overcome. This is not to say that stratification on a smaller and regional scale is not occurring. The existence of a continuum of livestock production systems, from the rice and millet farmer using only a pair of work bulls to similar farmers having invested in smaller or larger herds, to the transhumant pastoralist having at least some stake in rice cultivation, can be seen as forms of stratification. The herd structures found in these systems are ample proof that specialisation already exists and will become more pronounced.

Existing prices for young males stock have been quoted as a disincentive for early sales, since the price per kg liveweight of 2-year old animals are only half that of 5-year old ones (World Bank, 1980). However, there is reason to believe that the price structure will change with increased demand for traction stock and in view of the eagerness of smallholders in the sub-humid zone to engage in cattle fattening. Such price developments will provide incentives to pastoralists to alter their production aims and restructure their herds accordingly.

It is in this context that the reduction of calf mortality in transhumant herds becomes a more important management goal, not only to reduce this obvious waste of resources, but even more because it is in the producers' interest. With the continuing expansion of rainfed and floodplain farming, demand for milk products is bound to rise, giving pastoralists the incentive to increase milk output. As milk yield per cow is likely to remain the same in the short term, the herder will be inclined to keep more female stock, the more so because grazing resources will gradually contract and with the implementation of a regulated territorial organisation of land use, stock numbers will be controlled. If it is in his interest to retain as many female calves as possible to increase his future milk output and if - as is likely - male stock will attract better prices, he will intensify the care to all his calves. Thus, demands for more effective veterinary care to improve the survival rate of calves can be expected.

Transfer to other Sahelian environments

It has been stressed above that major improvements in pastoral herd productivity cannot be expected until a framework of pastoral organisation has been established. It is felt that this is a conditions *sine qua non* of pastoral development, and a priority area of pastoral research. The integrated approach ILCA is applying has already raised a considerable amount of interest. If it is successful and results in working pastoral units, this approach should be applied to pure Sahelian situations, where traditional forms of land tenure are much less pronounced. At the same time, more emphasis will then be placed on the training of African scientists and development agents in the techniques used to delineate and develop such units on a regional basis.

5.2.6 Interventions at the herd level

The major potential areas of interventions at the herd level seem to be in reducing calf mortality, better feeding of milk cows and supplying more efficient veterinary services. However, they should not be carried out in isolation, because as the herd productivity analysis has shown, the present productivity levels are the resultant of current management strategies.

It has been suggested that the competition between people and animals for milk is a major cause of calf mortality, although the regression between milk offtake and calf growth in this report does not support this view. A change in human diet away from milk has been advocated, but it is believed that in contrast to other pastoral societies the transhumant Fulani drink little milk. More studies on this aspect are required, and the link recently established with a specialized institute in this field, combined with the surveys on household economics currently underway in ILCA's programme will throw light on these issues. It should be realized also that the main supplies of milk for human consumption are not in the *garti*, which forms the main focus of this report, but in the other fractions of the total pastoral herd. Due to the lesser mobility of the latter categories interventions are also easier to apply in them than in the rather inaccessible *garti*. However, high calf mortality is still most probably the combined result of poor nutrition (both milk and herbage) and disease with a high interaction between the two. The relative importance of these two factors is not known, but the introduction of a simple health control package for calves and their dams will be enlightening in this respect. If the results of these studies, and the human nutrition work envisaged, substantiate the interaction between disease and nutrition, then more work on calf milk replacements and their adaptability to the pastoral conditions, could also contribute to the increase in productivity of the pastoral herds.

Strategic feeding of milk cows and calves is then another possible intervention, once land use is controlled. In the transhumant system studies in this report, seasonal fluctuations are less severe than in the pure Sahelian system although still occurring. In the transhumant delta system supplementation of the milk cows with *bourgou* hay could well be envisaged. Planting of forage crops, especially on the rice fallows, seems feasible. Encouraging results obtained with irrigated perennial grasses (*Brachiaria mutica* and *Echinocloa stagnina*) in the Niger flood plain south of Niamey support this possibility. In the pastoral system relying completely on rainfed vegetation, strategic feeding, using within this environment sites of higher potential, is even more important, and should receive more attention in the future. Also here a combination of biological (species selection, agronomic practices, utilization) and socio-economic research (herder's perceptions on distribution mechanisms) would be necessary.

As indicated in the introduction, the Sahelian systems are in a very delicate balance with their environments, and the opportunities for improvement are limited. This study has attempted to quantify the major constraints and gives indications for future development and research. If introduced, their impact will probably only slightly increase the productivity of the Sahelian livestock production system. However, their implementation might well be vital for the survival, and longer term stability, of a production system which uses resources which cannot otherwise be used and which provides the livelihood for an important part of the population of the Sahelian countries.

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