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LIVESTOCK PRODUCTION IN CENTRAL MALI

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EDITORIAL

The International Livestock Centre for Africa (ILCA) began its research programme in Mali in early 1976. Based initially at the Malian Government's Station du Sahel at Niono, activities were soon extended into the surrounding Fourth Region, and then into the Fifth and Sixth Regions of the country. The aim of these extended activities, which formed the programme's baseline study, was to gain a comprehensive picture of the traditional livestock production systems of central Mali and identify the main constraints to their greater productivity.

This issue of the ILCA Bulletin summarizes a more detailed account of the baseline study, shortly to be published as ILCA Research Report 5 under the title *Systems research in the arid zones of Mali: Initial results*. The more detailed report was edited by Wilson, R.T., de Leeuw, P.N. and de Haan, C., and contains contributions by the following authors: Cissé, M.I., Cissé, S., de Haan, C., de Leeuw, P., Diallo, A., Diarra, L., Dicko, M.S., Fulton, D., Gosseye, P., Harmsworth, J., Hiernaux, P., Hulet, H., Marie, J., Milligan, K., Sangare, M., Swift, J.J., Toulmin, C., Wagenaar, K. and Wilson, R.T.

R.T. Wilson,
Bamako, Mali
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LIVESTOCK PRODUCTION IN CENTRAL MALI

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PRODUCTION SYSTEMS AND THEIR CLASSIFICATION

ILCA's West African arid and semi-arid zones programme caters for the five main Sahel countries (Senegal, Mali, Upper Volta, Niger and Chad) and the Sudan. These countries provide living space and food for more than a quarter of tropical Africa's domestic ruminant population. Their land area of 6 514 000 km^2 is occupied by over 35 million Tropical Livestock Units (Table 1)[1], an average density of 5.40 TLU/km^2. These animals provide varying degrees of subsistence to a rural population of over 33.839 millions, a ratio of 1.04 TLU/person. Within these countries, the distributions of both animals and people show a high degree of diversity, with the highest numbers of animals and their greatest density generally found in the semi-arid zones. It is in the more arid zones, however, that the highest ratio of animals to people is found. As can be seen from Table 2, Mali is no exception to this general rule, although the Niger inundation zone with its abundant dry-season fodder and water supplies complicates the picture to some extent.

There are various ways of classifying livestock production systems. The commonest one takes into account the duration and distance of livestock movements and gives rise to such categories as nomadic, transhumant and sedentary systems. While movement is an important aspect of animal production systems, it is a contingent one, often having the effect of diverting attention away from other major criteria. These criteria are: the degree of dependence on livestock products for the gross revenue or food supply of the household or production unit; and the various types of agriculture associated with the livestock. It was these criteria which ILCA took into account when classifying the production systems of central Mali.

Somewhat arbitrary limits were set when degree of dependence on livestock products was assessed. 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

[1] One Tropical Livestock Unit (TLU) = 250 kg liveweight of domestic ruminant.

Table 1.
DISTRIBUTION OF DOMESTIC ANIMALS BY COUNTRY IN THE SAHEL AND SUDAN ('000).

Country	Species								Total TLU
	Camels		Cattle		Sheep		Goats		
	No.	TLU*	No.	TLU	No.	TLU	No.	TLU	
Senegal	4	4.9	2 806	2 053.9	1 884	188.4	1 000	84.0	2 331.2
Mali	208	255.4	4 459	3 264.0	6 067	606.7	5 757	483.6	4 609.7
Upper Volta	87	106.8	2 700	1 976.4	1 800	180.0	2 700	226.8	2 490.0
Niger	330	405.2	2 995	2 192.3	2 500	250.0	6 400	537.6	3 385.1
Chad	410	503.5	4 070	2 979.2	2 278	227.8	2 278	191.4	3 901.9
Sudan	2 500	3 070.0	17 300	12 663.6	17 200	1 720.0	12 200	1 024.8	18 478.4
Total	3 539	4 345.8	34 330	25 129.4	31 729	3 172.9	30 335	2 548.2	35 196.3

* Tropical Livestock Unit of 250 kg calculated on the basis of 1 camel = 307 kg, 1 bovine = 183 kg, 1 sheep = 25 kg, 1 goat = 21 kg
Source: For numbers, FAO (1979); for mean weights, Wilson (1981).

Table 2.
DISTRIBUTION OF PEOPLE AND ANIMALS IN MALI.

Ecological zone	Area		Rural population		Camels		Cattle		Sheep and goats		TLU*		Density	Ratio
(annual rainfall)	km²	%	'000	%	'000	%	'000	%	'000	%	'000	%	TLU/km²	TLU/person
Arid (< 600 mm)	856	70	815	15	164	91	939	21	3 596	43	1 220	28	1.43	1.50
Semi-arid (600-1000mm)	191	16	2 355	43	15	8	1 468	32	2 418	25	1 315	31	6.89	0.56
Subhumid (> 1000 mm)	129	10	1 514	27	–	–	1 009	22	790	10	811	19	6.29	0.54
Niger inundation	54	4	840	15	1	1	1 114	25	1 489	18	954	22	17.67	1.14
Total	1 230		5 552		180		4 530		8 293		4 300		3.50	0.77

* For the basis of TLU calculations see footnote to Table 1, except that sheep and goats are calculated together at 23 kg for this table.

Source: Various, including country statistics.

from agriculture, was classified 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 ILCA's studies. It should also be pointed out that the concept of gross revenue includes returns to camels or other species used as transport animals, and the value of cattle for traction and manure production.

The two main criteria thus give rise to two major production systems, each with a number of subsystems. These are shown in Table 3, in which the main characteristics of each are listed. Mali has two rather peculiar, if not unique, subsystems for the Sahel countries. These are the pastoral system associated with floodplain grazing and farming in the Niger inundation zone, and the agropastoral system associated with irrigated rice cropping.

The relative importance of the domestic species found within the systems and subsystems varies. Camels are confined almost exclusively to the pure pastoral subsystem in the arid zone, with only a few occurring in the pastoral/dryland 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 (although, were an "urban" system to be considered, donkeys might well replace cattle, to be followed closely by goats). This is the case irrespective of whether the role of cattle is primarily milk production (as in the pastoral systems), draught power (as in the agropastoral systems), or a combination of these two roles together with meat production in areas where systems boundaries are not clear-cut. 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 here as elsewhere. Sheep are extremely important in the pastoral system, especially in the north and in the inundation zone, where the pure and floodplain subsystems are found. 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, seldom acknowledged in statistics or development plans, should not be overlooked.

In the agropastoral system, and especially in the irrigation and cash-crop 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 syndrome with which all livestock owners used once to be attainted.

Herds are built up by a variety of processes including natural increase, inheritance, gifts and loan arrangements. 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 reinvested in livestock, as they also are in the floodplain subsystem. In both these subsystems, women can own considerable numbers of animals, usually acquired by dowry and from the proceeds of milk sales. In the agropastoral system animals, particularly work oxen, are often acquired through credit arrangements with organizations such as the Office du Niger and Opérations de Développement Rural.

Livestock also play a role in savings, the returns from agriculture being invested in animals in the absence of alternative forms of investment. In fact, there is considerable evidence that rapid shifts in ownership patterns are taking place, and not only among farmers: the new owners include civil servants, service personnel and merchants, 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.

Table 3.
MAJOR CHARACTERISTICS OF LIVESTOCK PRODUCTION SYSTEMS IN MALI.

System	Pastoral			Agropastoral		
Sub system / Characteristics	Pure	Associated with dryland cropping	Associated with floodplain grazing and farming	Associated with rainfed millet cropping (mainly subsistence)	Associated with irrigated rice cropping	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./km²)						
People	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						
People	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-agnatic ties)	Extended family	Extended family	Extended family
Ethnic groups	Bella, Tuareg, Maure	Harratin, Bella, Tuareg, Maure	Delta Fulani Seno Fulani	Bambara, etc	Various, including 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 or 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	–	← 0 →		
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

THE PRIMARY RESOURCES FOR LIVESTOCK PRODUCTION

CLIMATE

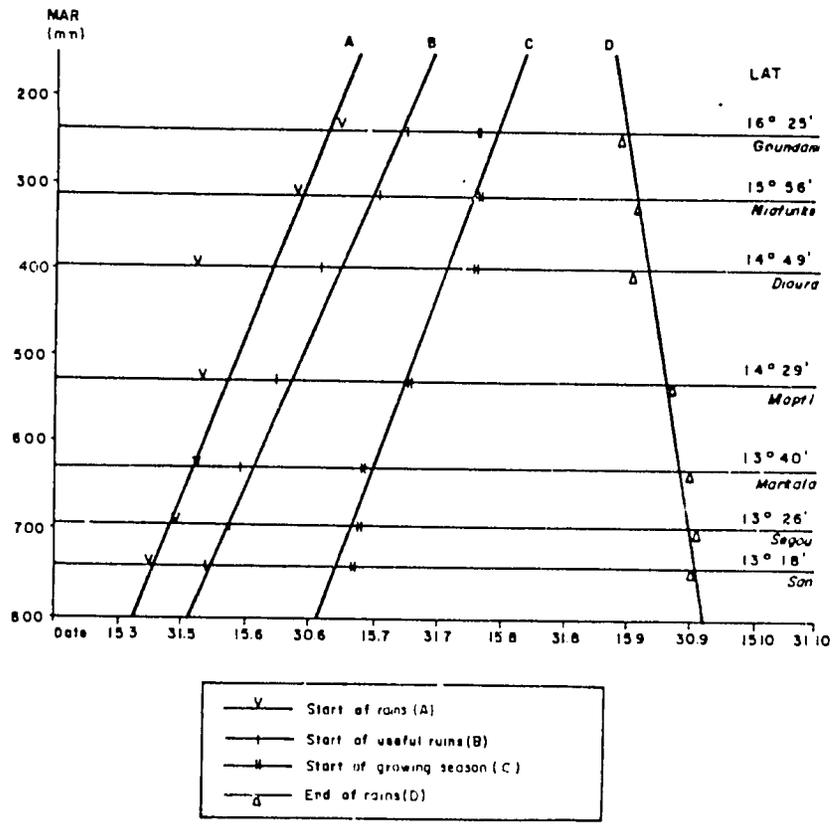
The West African arid and semi-arid zones are characterized by a single-peak monsoonal rainfall regime in which the duration of both the rains and the growing season is positively correlated with mean annual rainfall. The rainy season lasts from June to September, with the bulk of the rain usually falling in August.

The level and distribution of annual rainfall vary enormously. Rainfall at the beginning of the wet season (from May to early August) is crucial for both pasture and crops as it determines germination and survival, particularly of the annual plants that dominate the natural vegetation. Figure 1 shows the relationship between mean annual rainfall and growing season. However, the inter-annual variation in this relationship is considerable. At Niono (14°N 6°W), for example, the annual rainfall between 15 June and 15 October for each of the years 1977 to 1980 was about 375 mm, but the growing season for these years was 40, 70, 60 and 55 days respectively.

More than half the rain during the year is likely to fall in storms of 20 mm or more, with runoff reaching up to 37%. This high rate of runoff is due not so much to relief as to the texture of the soil surface. However, in many of the drier areas the presence of catenary sequences containing soils of variable infiltration capacity adds to the diversity of the environment.

It is mainly on sites 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, allowing exploitation by livestock for short periods in otherwise waterless areas.

Figure 1 RELATIONSHIP BETWEEN MEAN ANNUAL RAINFALL (MAR), LATITUDE NORTH (LAT) AND CHARACTERISTICS OF THE RAINY SEASON IN CENTRAL MALI.



Stress periods for animals occur mainly twice during the year: after the rains, when available fodder is drying off and diurnal variations in temperature are marked, causing in particular pulmonary diseases in small ruminants; and late in the dry season, when there is an absolute shortage of feed supply, maximum temperatures are high and humidity is also increasing.

LAND

Central Mali includes a variety of natural areas, the features and patterns of which have led to 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 distinguish two main grazing components: the area which they cover, known as the inundation zone, and the rainfed pastures or continental peneplain beyond their reach. Flooding in the past has also influenced a third area, known as the dead delta, which forms a distinct unit within the rainfed pastures because of its geomorphology, vegetation and human settlement patterns.

The study area covered by the ILCA programme thus includes three major natural areas:

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

The continental peneplain consists mainly of sandstone overlying palaeozoic schists. The schists themselves outcrop only in the northwest and northeast of the study area, in the Menia basin and in the lake areas around Goundam. 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 peneplain. The gradient follows the increase in overall average rainfall from 300 mm/year to 800 mm/year and has a sharp impact on vegetation.

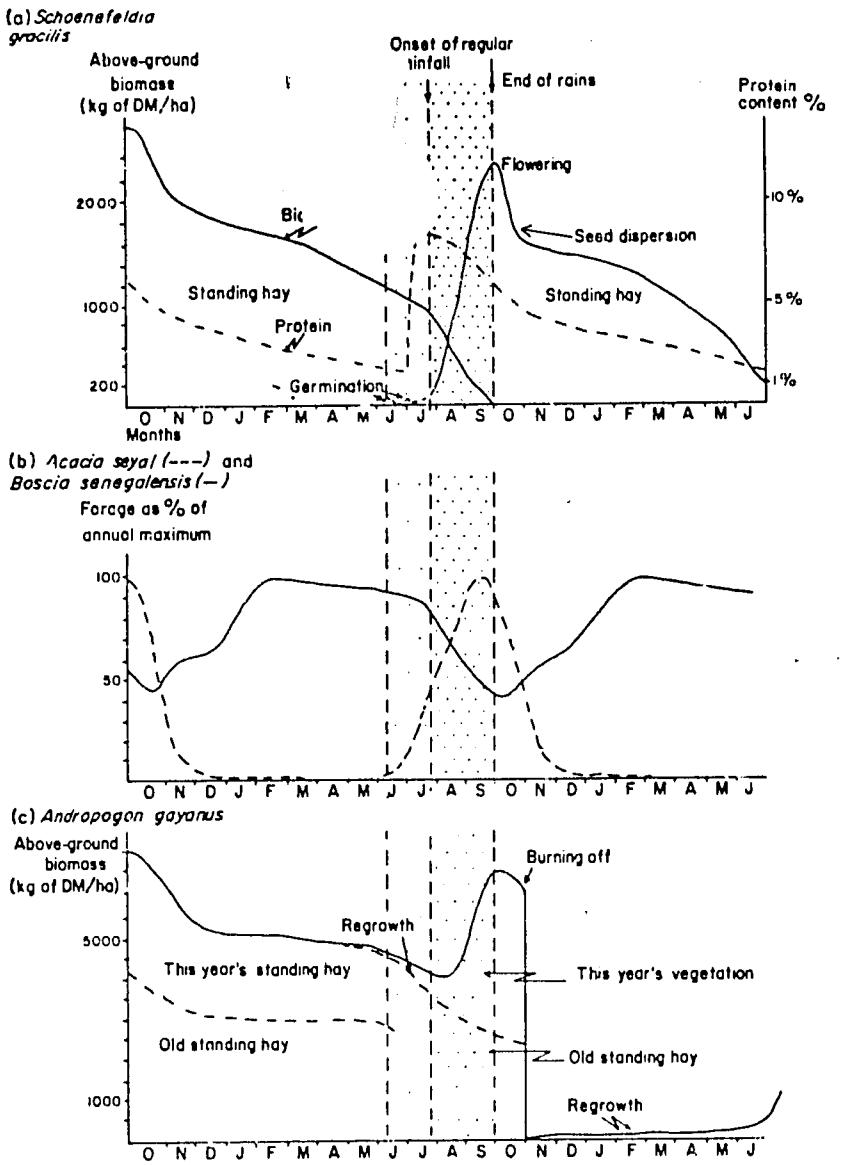
The dead delta consists of plains of alluvial origin, intermittently covered by a sandy film or mantle, with a few scattered hillocks or winding depressions indicating the pattern of runoff. The bioclimatic gradient of the dead delta is identical to that of the continental peneplain, but detecting the progressive changes in the vegetation is more difficult since the gradient is disrupted by local geomorphological features associated with the age and structure of the surface alluvial deposits.

In the inundation zone the bioclimatic gradient is of little consequence, being replaced almost entirely by the influence of the annual flooding of the Niger and its tributaries. The main parameters of this yearly flood determine the phytology, productivity and phenology of the rangeland, and are as follows:

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

Each of these parameters has an impact, through both its average or extreme values and its interannual regularity, as well as through its interaction with each of the others. The values vary according to position in the inundation zone relative to the course of the river.

Figure 2.
BIOMASS AND PROTEIN CONTENT FOR VARIOUS PLANTS ON SAHEL RANGELANDS.



VEGETATION

Rainfed pastures

The rainfed pastures have two major components: the herbaceous or field layer and the shrub and tree or browse layer.

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 fodder. The trends for biomass and protein content on *Schoenefeldia gracilis* rangeland (Figure 2) are typical, decreasing by over 60% between September and June. In other species the variation may be even greater, reaching 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 perennial formations, that of *Andropogon gayanus*, show a longer growth period and higher production than annual grasses. For browse plants, the examples of *Acacia seyal* and *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 of the Capparidaceae. Leaf production usually starts well before the onset of the rains and often continues long after they have stopped and the grasses have dried out. This time lag explains the special part played by browse plants in overall feed resources (Cissé, 1980).

The rainfall regime is crucial to the biomass and floristic composition of the dryland pastures. 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 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 further influences composition. In addition to rainfall regime, soil type and texture, topography and the ligneous plant cover are factors which affect the water balance. 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.

Growth is also limited by soil fertility (de Vries and Djiteye, 1982), especially by the levels of nitrogen and phosphorus which can be assimilated. Daily growth rates range from 20 to 50 kg of dry matter (DM) per hectare. Where water 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 of the following year.

Perennial grasses play a very minor part in the floristic composition of these low-rainfall rangelands compared with their importance in higher rainfall areas. The few species found do not prosper under the prevailing semi-arid conditions. A previous description of the Niono rangeland (Boudet and Leclerq, 1968) compared with a more recent one suggests that *Andropogon gayanus*, for example, regressed considerably during the drought years of 1972 to 1975 (Cissé, 1978). The periodicity and vigour of regrowth are both highly variable from one year to the next, probably in relation to residual soil moisture. But in most cases in the drier climates it is only under privileged soil and topographical conditions that soil moisture will last long enough to cover the *A. gayanus* cycle (Figure 2), in which early growth in May or June is combined with late seed-setting in October. Regeneration is made even more hazardous by the fact that the seeds germinate with the very first rains, since the resistance of young plants to subsequent dry periods is poor. Thus, on a 25 m^2 plot covered with 31 tufts, 125 seedlings developed in 1976, none in 1977, 46 in 1978, 1 in 1979 and 3 in 1980. By 1980 there were only seven plants left (4%) of those started over the previous years.

Generally speaking, the woody populations appear stable even though a series of rainfall-deficient years might lead to high mortality in some species such as *Terminalia avicennoides*, *Bombax costatum* or *Grewia bicolor*. As might be expected population levels do not appear to be as sensitive as leaf production to climatic variations. Regeneration can nonetheless pose some problems. Some populations of *Pterocarpus lucens*, for example, have shown no recent regeneration apart from a few non-viable seedlings. Existing stands of this species can thus probably be attributed to a series of exceptionally favourable years, which would explain why many populations consist almost entirely of individuals which are all of similar age.

The impact of pastoral utilization on the production and dynamics of rainfed 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 growing 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 plant species and period during the dry season, but averages around 10 to 15 kg of DM/TLU per day (Hiernaux et al, 1979). Over the longer term, however, dry-season grazing seems to have only very limited effects on subsequent production and composition. When annual grasses are grazed during the growing season, however, in addition to the actual removal of plant material there is also an effect on subsequent production.

Herd management therefore has important effects on subsequent protein availability, which differs according to whether a pasture is grazed early in the growing season or continuously throughout it. Long-term effects on range trend are highly variable, depending not only on the type of rangeland but also on the management strategy adopted. In annual grasses, such as *S. gracilis*, however, the effect on protein content is not as pronounced as in perennials. 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.

For browse plants a distinction must also 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 much depends on the timing and form of browsing, which may use green foliage, fruit or dead foliage lying on the ground. The impact also depends on the accessibility of the feed to animals. Bushes and young trees are directly accessible, whereas older trees and shrubs require intervention by the herders, who practise various forms of pruning which affect growth in different ways.

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 rangeland around the rice cultivation perimeter of the Office du Niger is losing its best species, *P. lucens* and *Combretum aculeatum* (due in part to their use as fuelwood, according to Wilson, 1982), which are gradually being replaced by unpalatable species such as *C. micranthum* and *Acacia ataxacantha*. A contrasting situation is provided by a population of *Balanites aegyptiaca*, *A. seyal* and *Ziziphus mauritiana*, which has replaced a population of *C. ghasalense* following browsing.

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*, *Z. mauritiana* and *C. aculeatum*, continue to produce new shoots. These species do so even after several years of regular cutting. Study of a 2-year fallow compared with uncleared land illustrated the important effects of clearing, not only on numbers (295 stems/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 scale remain noticeable for many years, and the fallow is often cultivated again before complete recovery. Comparison of an older fallow with a similar area 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 nonetheless remained severely affected.

The combined effects of farming and use by livestock are 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. Although fears of rapid overall degradation of the rainfed rangelands may be somewhat exaggerated, degradation on a local scale is certainly a problem. Bare ground around villages and major water points, as well as along transhumance tracks, is widespread. Degradation is at its worst around the Office du Niger land, due to increased human pressure leading to excessive firewood cutting and overgrazing (Wilson, 1982). 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 problems that require considerable additional research.

Table 4.
PHYSIOGNOMIC TYPES OF SOME DOMINANT GRAMINEAE AND CYPERACEAE FOUND IN THE NIGER INUNDATION ZONE.

Hemicryptophytes			Geophytes
Tussock grasses	Floating grasses	Lawn grasses	Rhizomatous grasses
Vetiveria nigritiana	*Echinochloa stagnina*	*Cynodon dactylon*	*Oryza longistaminata*
Andropogon gayanus	*Vossia cuspidata*	*Sporobolus spicatus*	*Echinochloa pyramidalis*
Eragrostis bartheri	*Brachiaria mutica*	*Sporobolus helvolus*	*Eleocharis dulcis*
Hyparrhenia rufa		*Brachiaria mutica*	*Scirpus brachyceras*
Panicum anabaptistum			*Cyperus maculatus*
			Cyperus denudatus

Floodplain pastures

The pastures of the Niger floodplain consist mostly of tall grass formations, with the exception of the rainfed shrubland found on the *toguérés* (man-made mounds on which villages are built), woody stands in the main riverbed and deeper depressions, and areas characterized by late and irregular flooding. These grass formations vary according to flood regime, as already described, and form *burgu* (*Echinochloa stagnina*) pastures and several other grassland types made up of perennial Gramineae and Cyperaceae. Four main physiognomic types, shown in Table 4, can be distinguished.

Tussock 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, such that the flood height reaches no more than 10 to 30 cm and the plant develops during both the rainy season and the submersion period, which overlap to a greater or lesser extent.

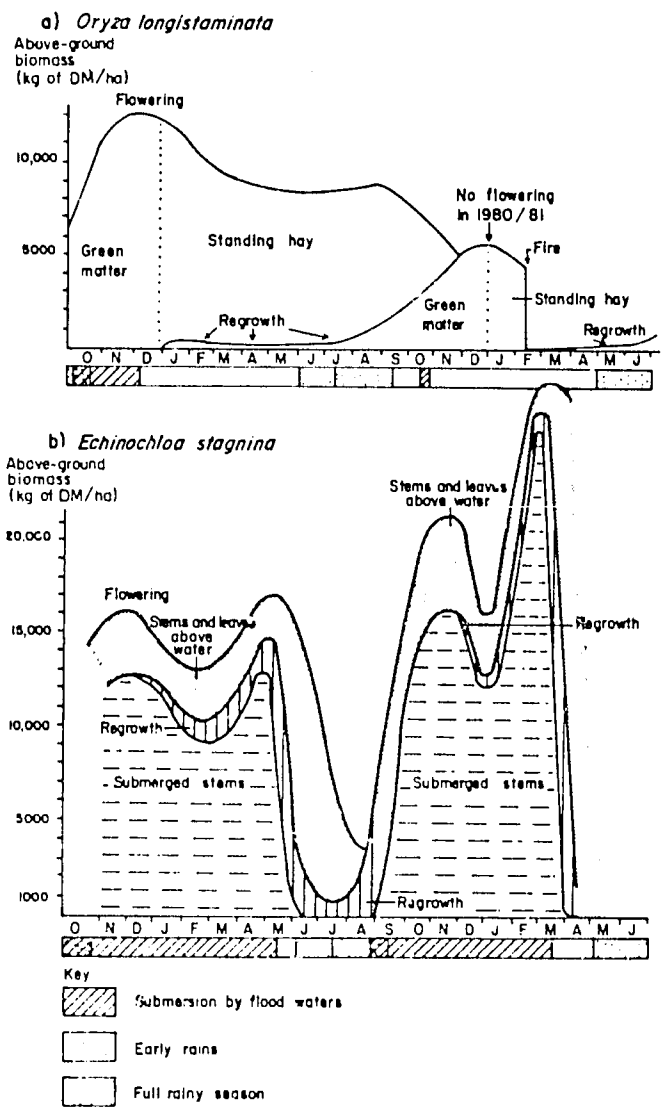
The floating grasses form the pastures known as *burgu*, although strictly speaking this appellation should be given only to *E. stagnina*. They are found on deeply submerged plains (up to 4 or 5 m), but the pastures do not survive deep flooding unless the waters rise sufficiently gradually to allow simultaneous growth of the stems.

The lawn grasses colonize the soil by means of stolons and form swards around 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 *toguérés*, on slopes and near 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*). Usually, however, they use the reserves stored in their rhizomes to develop rapidly, rising with the flood. They can survive fairly deep flooding (0.5 to 1.5 m) when the waters rise rapidly.

The different kinds of pasture complement each other as a function of flood regime and season, regulating herd movements within the inundation zone during the dry season. Where pastures are ungrazed, total DM production is very high, as can be seen from Figure 3. The growth

Figure 3.
ANNUAL BIOMASS CURVES FOR TWO UNGRAZED PASTURES OF THE NIGER INUNDATION ZONE.



periods are considerably extended over the year, contrasting with the rapid cycle of the rainfed pastures illustrated in Figure 2. Nonetheless, production varies considerably from one pasture to another and between years.

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 (around villages, on *toguérés* and embankments) the floodplain pastures are not used during the rains and flood season. On entering the inundation zone the herds thus find tall pastures, usually with a high biomass (5 to 10 t of DM/ha) but of average to poor quality and difficult of access. Initial grazing leads to enormous waste. After the first grazing, regrowth occurs, which is grazed together with any remaining standing hay, if this has not already been burnt off. The impact of grazing on forage availability and production is shown in Figure 4, which gives biomass curves for two types of pasture. These curves show the effects of traditional pastoral management, together with the production curve for regrowth obtained by cutting once every 2 weeks.

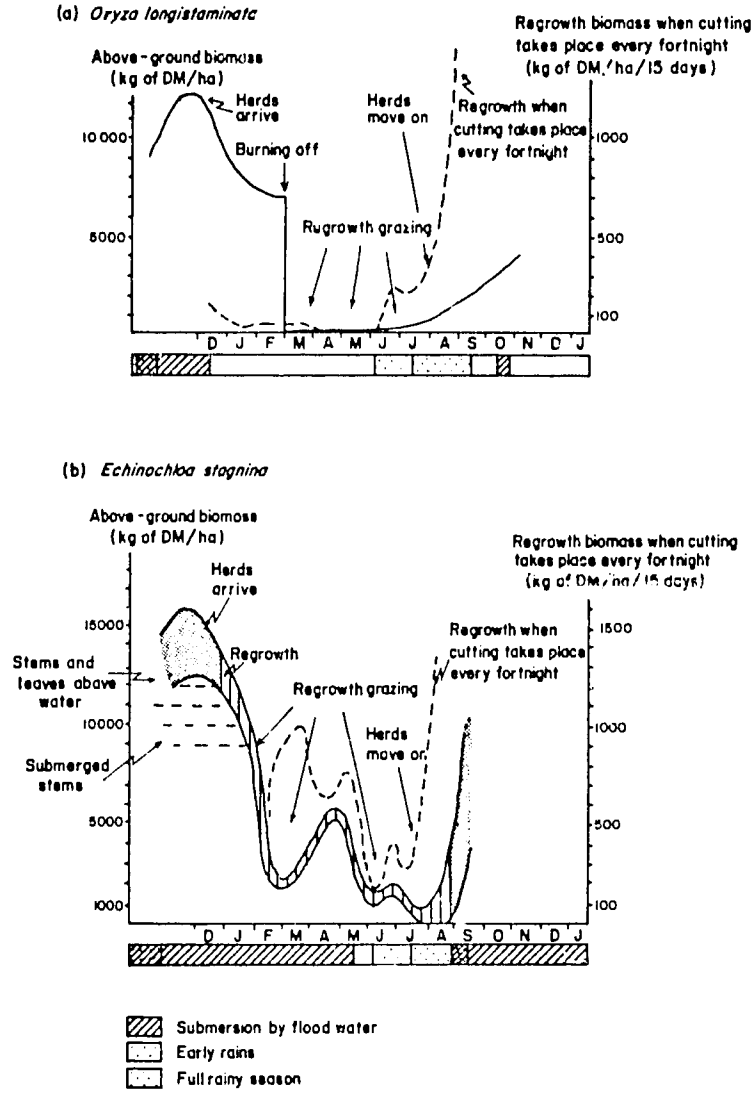
The effects of management on regrowth during the same year and on vegetation during the following year are currently being studied, but it is still too early to draw other than preliminary conclusions.

The effects of cutting, burning and grazing often seem beneficial and are generally the more so the earlier they occur, as the floods recede. Early grazing stimulates the growth of *Andropogon gayanus*, and a grazing cycle of 15 - 30 days would probably produce optimum growth for this species. In the case of *burgu* pastures, early grazing by 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. For *E. stagnina* the optimum grazing or cutting interval is as short as 10 - 15 days. Burning does not appear to stimulate regrowth to any great extent, although it makes fodder more accessible to animals. Its main effect is the loss of large quantities of standing hay of poor quality. Late burning appears to have a slightly depressive effect on regrowth.

Cropping in the inundation zone is an additional factor having an impact on grazing resources. The yearly cultivation of rice takes up a variable (but overall a large) proportion of the floodplain. This cultivated area has increased with the spread of animal traction in recent years. The range of rice varieties and cropping practices used (preliminary clearing, burning, repeated ploughing, partial control of flooding by dykes) means that all rangeland with *Oryza longistaminata* and *Eragrostis bartheri*, a large proportion of the *burgu* and some of the *Vetiveria* formations can be used for cultivation. There is thus considerable potential competition for land between rice cropping and animal production.

Cultivation has two main effects on grazing resources: loss of forage caused by planting rice on land previously used for grazing; and, since shifting cultivation is often involved, a further effect caused by the increase in fallow land. Although some rice plots can be grazed after harvest, loss of fodder depends not only 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 *Oryza*, *Eragrostis* or *Vetiveria* pastures, substitution of a perennial cover by an annual one rules out dry-season regrowth. For *burgu* the loss is considerable, estimated at maintenance rations for 6 TLU/ha for 6 months of the dry season at the minimum. No data are available on the productivity of fallow land, but initial observations indicate rapid regeneration of previous formations, taking 2 to 3 years in the

Figure 4.
ANNUAL BIOMASS CURVES FOR TWO GRAZED PASTURES OF THE NIGER INUNDATION ZONE.



case of *Oryza* and 3 to 5 years in the case of *burgu*. Regeneration is more variable for less regularly flooded formations, especially *Vetiveria*.

A secondary impact of cultivation arises from the extended use of burning in order to clear a plot of stubble or standing hay before ploughing. An additional but important indirect impact lies in delayed access of livestock to some existing rangeland areas, where access has to wait until harvesting is over and cultivated land can be crossed.

Where cropping is not intruding on pasture land, the inundated pastures appear fairly stable floristically, but in the longer term their vegetative composition will probably change. In areas where flooding is marginal or irregular owing to higher elevation and location in relation to water courses, the *Vetiveria* savanna is rapidly giving way to dry rangeland with *Acacia seyal*, *A. nilotica*, *Z. mauritiana* and a grass cover consisting of *Sporobolus helvolus* and some annuals. Changes of this kind are likely to become more widespread and less easily reversible as water development projects in the inundation zone or farther upstream permanently alter the natural flood regime. The consequences for crop and forage production in the inner inundation zone may well be far-reaching.

LIVESTOCK RESOURCES AND MOVEMENT PATTERNS

ILCA has carried out aerial surveys enabling quantitative data to be assembled on livestock numbers and movements in central Mali. These data are far more detailed than those previously available.

An estimated area of some 220 000 km^2 in central Mali is affected by the water and fodder resources of the inundation zone. In other words, animals in this area have possible recourse to the floodplain, either regularly or in times of stress. On a year-round basis there are approximately 1.85 million cattle and 2.79 million small ruminants in this area.

The Niger floodplain provides highly productive dry-season grazing and therefore acts as a magnet for livestock owners spread over a considerable surrounding area. However, its attractiveness diminishes with the increasing distance herds have to travel to it. The farther herds move away from the floodplain during the wet season and the more sedentarized they are, the less they depend on it as a dry-season grazing resource.

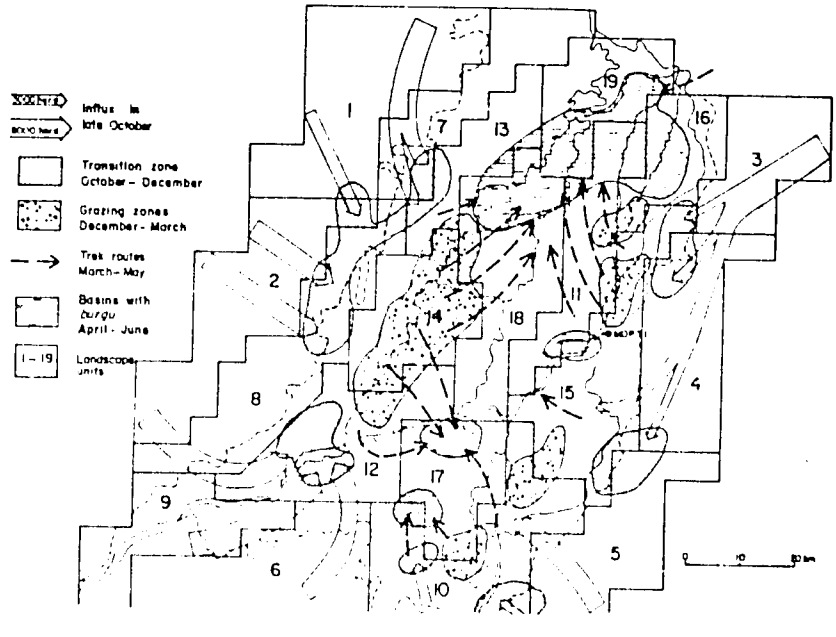
The major influx of herds into the inundation zone is from the west and northwest. These are mainly "resident" herds managed by transhumant owners having wet-season pastures in the dead delta, the Mema and the Hod Harki area of Mauritania. Sometimes a few nomadic herds also come in from this direction. A second influx, from the northeast, is associated mostly with "pure" pastoralists from the western Gourma and Farimake areas. A third influx comes from the south but seems to penetrate the inundation zone only as far as the south bank of the Niger river.

An aerial survey in late October 1980 counted some 810 000 head of cattle (only 60% of the total found in late March 1981), but the proportions making up this early dry-season count probably illustrate the relative importance of these three axes of entry to the inundation zone. 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.

During the aerial surveys the seasonal movements of livestock towards and within the inundation zone were mapped and quantified, while landscape units covering the delta area were also delineated (Figure 5). Table 5 shows cattle distribution and densities for the different units at different times. In October, high densities were encountered on the fringes of the inundation zone (in an area known as the "transitional zone") and in the elevated plains where flooding had not occurred. These high densities reflect the presence of cattle which had returned from their wet-season grazing areas in the Mema and Mauritania but had not yet been able to enter the inundation zone. These concentrations mainly occurred in units 8, 9, 12 and 14 (Figure 5); units 6 and 10 also had large concentrations of animals returning from the south. Other units with large concentrations at this time were 4 and 5, for cattle coming out of the Seno Mango, and 13, this last probably containing some Tuareg cattle awaiting a late entry to the delta from the west.

By March 1981, when most of the inundation zone had already dried out, the picture was completely different. Some 72% of cattle were now concentrated in the

Figure 5.
LANDSCAPE UNITS AND CATTLE MOVEMENT TOWARDS AND WITHIN THE NIGER DELTA DURING THE DRY SEASON.



floodplain proper, where they were to stay until June or July, before the annual transhumance cycle began again.

The distribution of small ruminants follows a pattern similar to that of cattle, although the return from the wet-season rainfed pastures is rather later. In October 1980, 45% of sheep and goats were still on rainfed pastures, with only 34% in the transitional zone. By March 1981, however, most of the sheep and goats with permanent bases in the inundation zone had returned there. Most small ruminant flocks in this area are fairly large – more than 100 head, while those of over 300 are not uncommon. In the central inundated plains and in the *burgu* units (11, 13, 16, 18 and 19 in Figure 5), the vast majority of small ruminants are Macina sheep. Outside these areas sheep and goats are of the Sahel types.

Grazing resources generally appear more than sufficient to meet overall demand, but so much depends on available water resources that overall carrying capacity estimates for the whole area have little value. During the height of the rains, from the end of July to late September, grazing is little restricted by lack of water supplies. However, immediately before and after this period – i.e. for about 3 months in all – water is scarce, placing large parts of the rainfed area out of bounds for grazing livestock. The population of 0.5 million cattle and 2.5 million goats and sheep which remains permanently outside the inundation zone therefore faces particular difficulties. Maps depicting potential carrying capacity based on standing biomass should include an assessment of the seasonal distribution of water resources if a realistic appraisal of actual carrying capacity is to be obtained.

Table 5.
CATTLE DISTRIBUTION ACCORDING TO LANDSCAPE UNITS IN AND NEAR THE NIGER DELTA AT TWO SURVEY DATES.

Landscape units*	October 1980			March 1981		
	'000	%	head/km²	'000	%	head/km²
1-6: Rainfed pastures (Sahel)	226	28	17	63	5	5
7-9: Transitional zone	237	29	41	91	7	16
10-12: Elevated plains	230	29	40	189	16	32
13-19: Inundated plains	114	14	10	871	72	78
	807	100	22	1 214	100	34

* As shown in Figure 5.

THE AGROPASTORAL SYSTEM

The agropastoral systems have traditionally been crop- rather than livestock-oriented, and it is only recently that livestock have assumed any importance 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 deficits 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.

In the rainfed 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 rice subsystem four out of five families (80.1%) own cattle, with slightly more than that number also owning ploughs. Evidently there is more mechanization in the irrigated subsystem than in the rainfed. The numbers of oxen and ploughs owned *per family* are also higher in the rice subsystem, so that the degree of mechanization and its effects on herd structure are in reality even greater than the above percentages 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, goats and sheep, particularly the former, can be considered truly 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.

The rice subsystem has certain advantages over the millet subsystem, leading to higher 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 year round, whereas in the millet subsystem it is scarce during the dry season.

Table 6.
MANAGEMENT AND ENVIRONMENTAL FACTORS IN THE MILLET AND RICE SUBSYSTEMS.

Factor	Millet subsystem	Rice subsystem
Water availability	Restricted in dry season	Abundant all year round
Crop residues	Limited availability 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 longer distance to water and sparse feed availability	Lower for longer period on account of proximity of water and longer growing period

Table 6 lists some of the main differences between the millet and rice subsystems which account in large part for the better performance of the latter.

THE MILLET SUBSYSTEM
General description

In the millet subsystem producer strategies are determined in an environment of high risk. Land is not at present a scarce resource, but there is evidence that pressure on both land and water resources is increasing. Competition for them between and within local groups is likely to intensify in the future. The area under cultivation is expanding as a result of population growth (now 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, both permanent and seasonal, of farmers from the south and west searching for more fertile land, and of others who have abandoned their farms near the irrigated zones, where depredation by birds inflicts heavy losses on crop yields. There is also conflict over rainy season pasture and water resources between the sedentary or short-distance transhumant groups native to the area and the longer-distance transhumant groups who are more recent users or merely temporary residents. These conflicts mostly concern damage to crops by transhumant herds.

Villages are autonomous in the sense that each is represented by its chief to the government and i 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 settlements in this territory, whether temporary farming hamlets, offshoots of older villages or immigrant communities, are considered as outsiders subject to the authority of the older village. But in practice, 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 Fulani settlement and movement in this outlying area, since this group is not part of the same jural and ritual community.

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 and so on. Each village has a mixture of such varieties and it is common for a farmer to experiment with different seed grains reputed to have particular characteristics, either from his own or from a neighbouring village.

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 (*Digitaria* spp.), 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 farther south does sorghum occupy a more important place.

The land-use pattern is typical of West African dryland cropping, with a series of concentric rings around the village. A ring of millet fields immediately surrounds the village, continuously cultivated and permanently owned. This inner circle grows outwards as the village grows and as individual households increase their capacity to manage a larger area. A second or intermediate zone beyond the inner circle 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. The third and outermost zone 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. Land in the two outer zones is not permanently owned, and abandoned fields revert to bush after various periods of cropping, whereas in the inner zone all the land is continuously cultivated. In the outer zones the cultivated area varies from 3 to 10%, depending on land pressure and the length of the fallow period.

Labour is mostly found within the family unit, but outside labour can be significant at harvest and threshing periods. Farmers commonly encourage transhumant pastoralists to spend the dry season on the continuously cropped inner zone. They do so by providing water in exchange for manure from the animals. Increasingly, they dig wells on their land in order to attract pastoralists. Yields of millet from this inner zone can thus be quite high (an average of 1150 kg/ha in surveyed villages in 1980). They can be maintained at high levels although they are always subject to the amount and, above all, the distribution of rainfall. The two outer zones give much lower yields.

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 items from the blacksmith, herding services from a Fulani, livestock and milk purchases from Fulani and Maure groups, sauce condiments (dried fish, peppers, etc) from village or travelling dealers, or assorted services such as hair plaiting, calabash repairs and so on. The role of millet as a medium of exchange in the system depends greatly on the distance from the nearest market, with villages nearer centres of commerce being more involved in the cash economy.

Such involvement in the cash economy as does exist arises from the need for cash to fulfil specific obligations, for instance tax payments or marriage expenses, or to 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 and craftwork. The commonest need for cash is the annual tax payment which each household must make, and it is this that forces all households into the cash economy at least once a year.

Crop improvement

Given the importance of millet in this subsystem, increasing grain production is seen as the first step in improving both the nutrition and the wealth, in a millet-based economy, of the local inhabitants. Increased millet production would also benefit the livestock component if larger amounts of crop residues were left in the field for grazing after harvest. More grain can be produced either by increasing yields per hectare or by expanding the area under cultivation.

Soil nitrogen and phosphorus deficiencies remain a major constraint on increasing grain yields per hectare, but reasonable millet yields can be achieved within the inner circle of village fields, where large amounts of animal dung can be applied. Animal dung is not available in sufficient quantities for large areas, however, and the shortage of cash in the rural economy places severe limitations on the purchase of nitrogen fertilizer.

Expansion of cropping depends largely on the availability of work oxen and their efficiency, which is a function of their size and nutritional status. If cattle are to plough efficiently, they must be better fed than at present through the long dry season that precedes their peak working period. Increasing animal feed supplies is thus a key factor in improving grain production, and it will also have important beneficial side-effects: not only will the work efficiency of cattle be improved, but also their output of meat and milk. Greater feed supplies are also needed for the growing population of small ruminants, as disease and management innovations bring about a decline in mortality rates.

In view of the need to increase soil nitrogen by the most economical means, these higher feed requirements can probably best be met through the introduction of nitrogen-fixing legumes. These can be planted on natural rangeland and fallows, or as a forage crop, either in mixed stands or in rotation with food crops.

The programme's work on legumes began with trials on the seeding [illegible] exotic and indigenous herbaceous and browse species in natural vegetation, with [illegible] and without phosphate fertilization. L[illegible] to low rainfall and competition from the natural vegetation, results were disappointing. Among the 40 or so herbaceous species tested, only *Alysicarpus ovalifolius*, *A. vaginatus*, *Macroptilium atropurpureum* (Siratro), *Stylosanthes fructiosa*, *S. hamata* and the varieties of *S. humilis*, *S. suburicea* and *S. viscosa* survived the first dry season, while despite reseeding almost all died out over the 3-year period of the trials. Of the eight browse species also tested, only two local species (*Bauhinia rufescens* and *Piliostigma reticulatum*) showed survival rates of over 50% (67% and 53% respectively) during a 14-month period to December 1979. These poor results were confirmed by further trials on the same site in 1980, after which it was decided to concentrate on cowpea agronomy as the main strategy for improving animal nutrition and soil fertility.

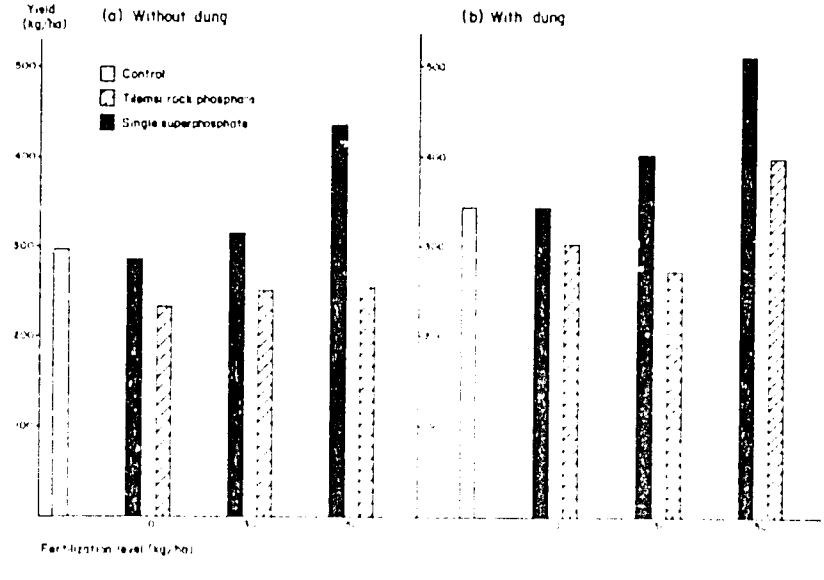
Trials in 1979 had led to the selection of 22 cowpea varieties for further testing in 1980. Selection was based on forage yield together with a yield of seed sufficient for planting in subsequent years. Creeping varieties produced more haulm than semi-erect ones, which in turn outyielded erect ones. For forage production creeping varieties are also preferred by farmers, as the haulms can be rolled into a ball and stored. Forage yields of up to 1500 kg of DM were achieved. Further work still needs to be done on variety selection to ensure adequate seed production even in years of poor rainfall.

In the traditional system cowpea seeds are distributed haphazardly amongst the millet, which is sown regularly 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, sheep and donkeys, while the grain is used for human consumption.

The ILCA team has carried out experiments on the effects of various types of intercropping. Sowing cowpea together with millet does not affect labour time, but harvesting the haulms of randomly distributed plants is time-consuming. If the cowpea is cultivated in pure ridges at regular intervals among the millet ridges, sowing is more laborious but harvesting becomes much easier. Both methods might create competition for minerals and/or water between the two crops. A third method, cultivating cowpeas alone in rotation with millet alone, would avoid all problems of water, light and nutrient competition but might also reduce the area under millet.

Since the local inhabitants rely on millet for survival, any innovation which reduces millet production has no chance of being taken up. Innovations with cowpeas

Figure 6.
AVERAGE ANNUAL MILLET YIELDS OVER 2 YEARS WITH TWO DIFFERENT FERTILIZERS AT VARIOUS LEVELS, WITH AND WITHOUT ANIMAL DUNG.



(or other forage legumes) should thus neither increase labour demand at the expense of millet nor in any other way adversely affect millet yields.

Results so far suggest that in a year when rainfall is well distributed cowpeas will not influence millet yields when intercropped at rates of less than 30%; but in a year when rainfall is less favourably distributed cowpeas are more competitive than millet and respond better to phosphate fertilizer.

ILCA research has shown that soluble phosphate fertilizer increases millet yields in a ratio of 5 kg of grain per kg of fertilizer applied. Insoluble rock phosphate, on the other hand, is probably ineffective under low rainfall regimes and may even adversely affect yields. The residual effects of long-term phosphorus application are encouraging. Figure 6 shows the results of trials with and without the additional use of animal dung. The high organic matter content of dung probably reduces the short-term effect of mineral fertilizers, but over the long term a combination of the two is better than fertilizer alone which, in turn, is better than manure alone. However, under the soil conditions and semi-arid climate of central Mali nitrogenous fertilizer is probably effective only if other nutrient deficiencies, and particularly phosphorus, are first eliminated.

The effect of organic and mineral fertilizers is influenced by the many other variables affecting crop yields. Fertilizers are efficient only if other conditions, such as early planting in moist soil and early and frequent weeding, are optimal. The results of fertilizer trials in three villages are summarized in Table 7. The increase due to fertilizer treatments ranged from only 13% in village A to 130% in village C. Fields in village A received large amounts of organic manure: in this village no nitrogen fertilizers were tested since farmers claim that they make plants more sensitive to drought. A preliminary economic evaluation of these trials shows that fertilization gives marginal yield increases after 1 year of cropping. It also indicates that fertilizers frequently do not pay in the first year, but that during the second year applying single superphosphate becomes economically worthwhile. As Figure 6 indicates, the response to single superphosphate over 2 years amounted to approximately 1.5 - 2.0 kg of millet per kg of fertilizer. Since 1 kg of P_2O_5 costs 357 Malian Francs (MF) as single superphosphate but only 304 MF as ammonium phosphate, it is more profitable to use the latter. These low marginal yields nonetheless demonstrate that there is an element of risk in using fertilizers.

Table 7.
AVERAGE MILLET GRAIN YIELDS (KG/HA) FOR *SOUNA* VARIETY FOR THREE VILLAGES RECEIVING FERTILIZATION OF INNER ZONE FIELDS.

Village	Fertilization		
	Control	Single super P_2O_5	P-N
A	1 397	1 585	—
B	637	782	990
C	405	833	929

about 10-12 years. This means that few cows achieve a total lifetime production in excess of four calves. In an extensive survey it was found that less than 4% of all cows produced more than four calves during their reproductive life. No practices to control breeding are undertaken, which means that calves may be born throughout the year, although there is a calving peak in May and June as can be seen from Figure 7. This peak is related to conception during the previous rainy season.

Birth weights are low, at 18 kg for males and 16 kg for females, and gains to 2 years of age average 160 g per day, resulting in weights of about 140 kg at that age. Mature adult weights of about 240 kg for females and 300 kg for males are not attained until the animals are at least 5 years old. The marked seasonal changes in the semi-arid zone do not only affect reproduction: they are reflected in the considerable weight changes in all classes of stock which occur over the year. Mature males vary in weight from as low as 280 kg at the end of June to about 340 kg at the end of September, while females show similar seasonal changes, losing about 20% of their body weight on average in the course of an annual cycle.

Mortality is the third factor contributing to low productivity. During a 2-year period 21% of all calves born died before reaching 12 months, while total herd deaths amounted to 6.2%. As a result of these three factors offtake is low, with animals marketed amounting to only 7.4% of the herd, sales being made up mainly of older, culled cows and exhausted work oxen.

Table 8.
CATTLE HERD STRUCTURES IN VARIOUS PRODUCTION SYSTEMS

Sex and age group	System (% of total animals)		
	Rainfed millet	Irrigated rice	Delta pastoral
Males			
< 1 year	5.6	7.2	9.9
1-3 years	8.5	9.3	12.5
> 3 years	32.7	46.3	15.6
Total	46.8	62.8	38.0
Females			
< 1 year	6.2	5.7	10.2
1-3 years	11.3	11.1	15.2
> 3 years	35.7	20.2	36.1
Total	53.2	37.0	62.0
Work oxen as % of total herd	32.3	43.4	9.3

LIVESTOCK PRODUCTION

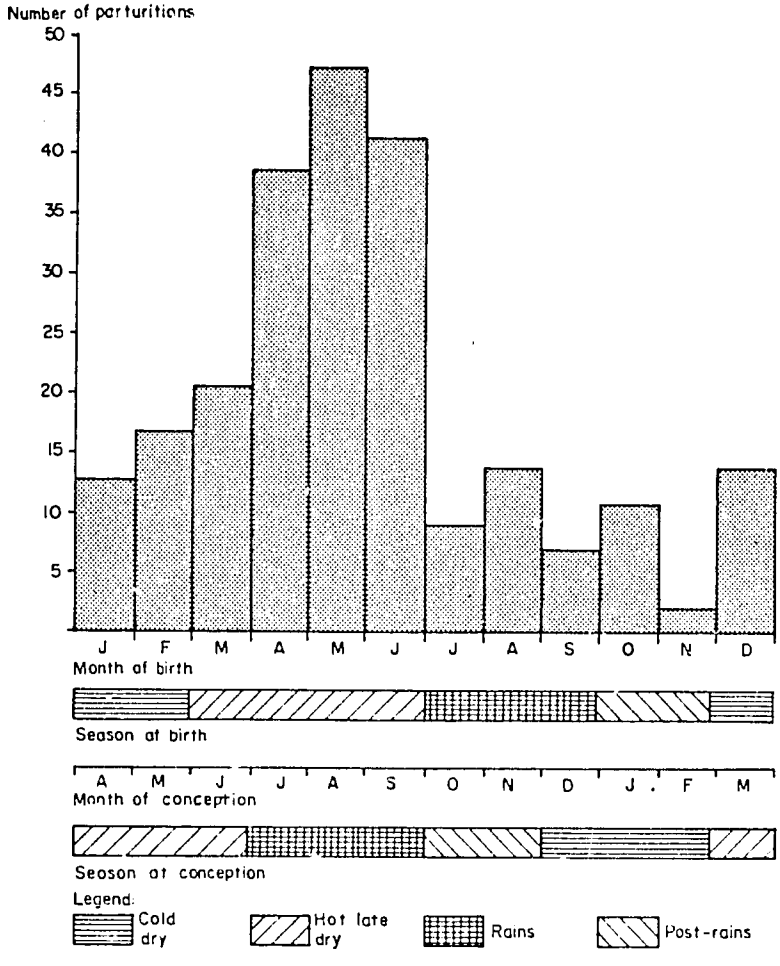
Cattle

In terms of biomass cattle are the most important species of livestock in the agropastoral system. As can be seen from Table 8, their chief function is work, and the relative importance of working males in agropastoral herds is comparable to that of milk-producing females in pastoral herds.

The productivity of breeding cows is relatively low in the agropastoral system, due mainly to three factors: poor calving rates, slow growth rates and high death rates.

Fewer than 17% of cows calve by 4 years of age, although by 6 years almost 90% have had a calf. The overall long-term calving percentage probably varies between 55 and 60%, equivalent to a calving interval of 600 to 660 days. For 58 observed intervals under traditional management conditions in the ILCA study area the average was 613 days. Cows on average live

Figure 7.
DISTRIBUTION OF PARTURITIONS BY MONTH OF BIRTH FOR CATTLE IN THE AGRO-PASTORAL SYSTEM.



Small ruminants

If cattle are the capital or deposit account of a livestock enterprise, then goats and sheep are its current account. Although flocks are characterized by a rapid turnover – particularly for males – the composition of the flock, as can be seen from Table 9, remains remarkably constant in terms of sex and age structure. Breeding females amount to about 55% of all animals in most cases. With few exceptions 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 males 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. Commercial offtake very often consists of 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.

Goats and sheep were not affected to the same extent as cattle by seasonal variations in feed resources. This was mainly reflected in the less pronounced peaks in births, which were spread more or less evenly over the year. Only a slight increase in births was evident in the cold dry season, related to conception just before and at the onset of the rainy season. In relative terms both goats and sheep were more efficient at reproduction than cattle, with total lifetime production of young being about 10 for goats and 8 for sheep. The difference in numbers between the two species was due only in part to longevity, its major portion being accounted for by the greater number of twin births to goats, in which average litter size was 1.24, while in sheep it was only 1.05. There is little difference in parturition intervals between species, the average being about 260 days. The effects of parity and season on parturition interval were significant, as were the management practices of individual owners. The annual reproduction rate for goats is

Table 9.
SHEEP AND GOAT FLOCK STRUCTURES IN VARIOUS 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/Maure	22.9	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	—	—	—	—

about 1.6 kids and for sheep 1.4 lambs per breeding female. First parturition in both species occurs at about 470 days (15.5 months).

In general growth might be considered satisfactory under the prevailing management system. Sheep were heavier than goats throughout their life, but there were greater differences between the rice and the millet subsystems than the differences due to any other variable with the exception of individual management. The differences in weight (of goats and sheep combined) due to system and flock are eloquently illustrated in Table 10).

The most important factor reducing total productivity in small ruminants was preweaning mortality. Overall, this amounted to 34.6% in goats and 30.3% in sheep. Mortality was significantly affected by type of birth (single, twin, triplet), by season of birth and by subsystem. Deaths in goats were 39.1% in the millet subsystem, compared with 30.1% in the rice subsystem, while the corresponding figures for sheep were 34.8 and 25.8%. The effects of the length of the previous parturition interval on preweaning mortality were also tested. 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 ($x^2 = 19.64$, $P < 0.01$) in the percentage preweaning mortality rate 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. Of the total deaths recorded, 16.4% were abortions (an absolute figure of 7.2% of all births for goats and 2.7% for sheep), while 21.6% were still births or occurred in the first day, with a further 14.5% occurring in the first 7 days after birth. Seventy per cent of all deaths occurred before 15 months.

Table 10.
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	—	—

Indices based on the weight of young at weaning have been calculated in order to illustrate the principal variables affecting production. Mean figures for these indices are given in Table 11, which also shows the effects of different variables on the indices.

ANIMAL NUTRITION

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 -0.92 respectively) were found between standing biomass and grazing time. Covariance analysis also showed that grazing time was significantly lower for a given biomass in the July-October period, when forage quality was high.

The distance walked is largely determined by environmental factors, namely the availability of biomass and drinking water. When biomass availability was low, for instance from April until July, the distances covered were quite high (14 km/day). In October and November, when the surface water in ponds had dried up but the presence of millet and rice crops prevented access to the more permanent waterpoints, the main reason for trekking over longer distances was the search for water. During this period up to 20 km per day was covered. Even in this system, a considerable amount of the total energy intake is therefore expended on walking. Monthly dry matter intake (DMI) varied considerably over the year, as can be seen from Table 12.

DMI 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 Zimbabwe

Table 11.
RATIOS OF VARIOUS PRODUCTION INDICES FOR SMALL RUMINANTS IN THE AGROPASTORAL SYSTEM*.

Source of variation	Ratio	Index I		Index II		Index III	
		Goats	Sheep	Goats	Sheep	Goats	Sheep
Overall mean		18.67	29.52	565.05	[illegible]3.30	147.12	230.85
Sex	Males/females	1.08	1.05	1.04	1.03	1.03	1.05
Parity	All parities/first	1.54	1.29	1.42	1.25	1.40	1.23
Birth type	Twins/singles	1.37	1.23	1.48	1.45	1.55	1.43
Season	Best/worst	1.17	1.11	1.26	1.16	1.23	1.14
System	Rice/millet	1.82	1.45	1.53	1.31	1.58	1.33
Flocks	Millet best/worst	2.17		2.62		2.43	
	Rice best/worst	9.34		5.30		5.58	

* Index I refers to total production of young (kg) per breeding female per year; Index II refers to production (g) per kg of breeding female; Index III refers to production (g) per kg of metabolic weight of breeding female.

Table 12.
LIVEWEIGHT AND FEED INTAKE MEASUREMENTS OF CATTLE IN THE AGROPASTORAL SYSTEM.

Month	Fodder type	Mean lwt (kg)	Digestibility coefficient (%)	Voluntary DMI (g/day)	Voluntary DMI (kg/100 kg lwt)	Voluntary DMI ($g/kg^{0.75}$)
August	Natural pasture	237	68.1	5 921	2.5	98
September	Natural pasture	258	61.5	6 916	2.7	107
October	Natural pasture	266	47.5	5 455	2.0	83
November	Millet stubble	261	48.9	6 203	2.3	95
December	Rice fallow	244	54.7	6 960	2.8	111
January	Rice fields	251	52.2	6 439	2.5	102
February	Rice fields	248	52.8	6 436	2.6	103
March	Rice fields	249	48.9	4 612	1.8	73
April	Rice fields	237	50.0	5 416	2.3	89
May	Rice fields	227	47.1	5 550	2.4	95
June	Rice regrowth	224	51.4	7 049	3.1	122
July	Natural pasture	230	62.2	8 888	3.8	150

(Elliott and Fokkema, 1961) and 1.5 – 2.1% in Botswana (APRU, 1978). The higher figures found in ILCA's study apparently reflect the higher energy expenditure in grazing activities in this system. Linear and multiple regression analysis showed that the forage crude protein content (N x 6.25) has much more influence on DMI (r =0.68) than had forage digestibility alone (r =0.48).

Regression analysis of liveweight changes showed a correlation of 0.68 with digestible dry matter intake (DDMI), 0.89 with crude protein intake (CPI) and 0.89 also as a multiple correlation with DDMI and CPI, indicating that CPI is the main determinant of intake. When metabolizable energy intakes were estimated, assuming that the metabolizability of digested energy was 0.81, the linear regression of liveweight change on metabolizable energy intake (MEI) gave:

Lwt change (kg/a)
= 0.034 MEI (MJ/d) – 1.513
= 0.034 (MEI – 44.5) (r = 0.88)

indicating a total maintenance energy expenditure of 44.5 MJ/d. If the MEIs are reduced by the estimated minimum maintenance requirements of about 112 kcal/$kg^{0.75}$ or about 30-32 MJ/d the regression becomes:

Lwt change (kg/d)
= 0.034 (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 plus DCPI as the measure(s) of feed intake in the equation:

Lwt change
= 0.264 DDMI + 0.448 DCPI + 0.0067 $lwt^{0.75}$ – (0.000750 Lwt x km) – 0.0343
(r = 0.979)

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

The statistical analyses suggested that DCPI was more influential on animal performance than DDMI. However, it was not the DCP content itself that was the restricting factor but rather the low DCPI resulting from a low DDMI. DCP content in the grazed diet calculated from the DCPI/DMI ratio was 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 was about 7%. It appeared that liveweight losses occurred when DCPI was below 200-250 g/head/day and DDMI less than 3.0 kg/head/day.

Although the multiple regression analysis showed a minor effect of grazing activities on liveweight change, this energy expenditure can take up a large proportion of MEI. For the period March to May, when weight losses were highest, average MEI was 33.2 MJ/d, while the theoretical level of ME required for maintenance and activity is respectively 36.1 and 5.8 MJ/d, leaving a negative balance of 8.7 MJ/d with about 80% of these theoretical requirements covered.

The low growth rate of 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 the continuous search for top quality fodder, involving much walking, reduces their grazing intensity and thus their DMI.

Small ruminants

The grazing orbit of the sheep and goat flock studied by ILCA differed from that of cattle in that the flock relied very little on irrigated rice fields and fallows, spending almost all its time on the rainfed pastures. This difference is reflected in the composition of the diet, which contained a high proportion of browse and little crop-related herbage. The different preferences of sheep and goats were striking, in that the latter survived almost entirely on browse (87%) while sheep depended on the field layer for 59% of their diet. This difference in feed preference was largely responsible for variations in diet digestibility between the two species. Digestibility was higher for sheep during the rainy season when herbage quality was high, but higher for goats when browse quality exceeded that of dried herbage during the dry season.

Monthly fluctuations in flock behaviour parameters were much less pronounced than those measured for cattle. Total time in the field varied from 6.2 to 7.5 hours, a range which shows far less adaptation to environmental conditions than was apparent in the cattle herd. 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 result, the time spent grazing fluctuated little over the year and the sheep and goats, once released into the bush, spent most of their time (70-93%) grazing and browsing. Walking time to and from pasture was shortest from April to July (0.8 hours), while total distance covered during the day (including grazing) was above average (13.8 km). During this period, shrubs begin to put forth leaves, but

grazeable 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 was true: average distance covered was only 6.3 km, while time spent without grazing amounted to 1.7 hours, which may indicate that the sheep were forcing the goats to adopt a more leisurely behaviour pattern because herbage was plentiful, or that the shepherd deliberately selected sites high in grass cover and low in shrubs.

DMI showed large fluctuations over time, ranging from 1.7 – 3.2% of live-weight for sheep and 1.6 – 3.2% for goats, with mean values of 2.6% for each with no obvious seasonal trends. For all animals the period from October to January showed low intake, while goats ate much less during the height of the rainy season than did sheep. DDMI followed the same trends as DMI, but variations were attenuated by inverse trends in digestibility. On average sheep and goats ingested 0.70 kg and 0.53 kg/d, and in spite of the relatively high diet digestibility during the rainy season goat DDMI averaged only 0.45 kg/d.

THE PASTORAL SYSTEM

GENERAL DESCRIPTION

This description relates mainly to the pastoral system associated with rice cultivation, found in the Niger inundation zone. The transhumant and semi-sedentary pastoralists have priority rights to the *burgu* pastures, where their animals spend up to 6 months annually. The other half of the year is spent on the rainfed rangeland in the areas surrounding the inundation zone. The main ethnic group within the system is the Fulani, although other groups entrust their animals to Fulani herdsmen.

Because of extensive rice cultivation and trading activities, the share of household income from pastoral activities in the floodplain subsystem is less than in other pastoral systems, and livestock products play a less important part in household nutrition. The greater part of domestic rice production is consumed within the household, with the proportion of overall production marketed estimated at 44% for the Fulani of the inundation zone.

Although occupying a relatively small area, the floodplain production system is of major importance within the Malian livestock sector. It is the home of about 25% of the national cattle herd and also contains an estimated 18% of Mali's sheep and goats. The system is to some extent atypical of the semi-arid zone, but comparable production systems are found on a smaller scale in other areas, for example around the shores of Lake Chad, in the Senegal river basin and in southern Sudan.

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 communal herds. Because women own many cattle, herds often contain animals belonging to owners related through matrilineal kinship ties.

Men perform the main pastoral and agricultural tasks. Some agricultural work is still done for the Fulani by their former slaves, the Rimaibe, who are paid in kind. During transhumance away from the base villages, the herdsmen are boys aged 10 years upwards and young unmarried men under the supervision of a senior herd owner, known as the *jowro*. Households cultivate rice or have rice cultivated on their behalf, using either natural flood waters or semi-controlled irrigation in the inundation zone.

There is a precisely determined annual migration of livestock which is strictly regulated by tradition and has the force of law. In addition, herd management is rather sophisticated, with a number of subgroups being used for different purposes. Herd fractionation and the necessity for frequent movement have resulted in a complex system of grazing management which dates mainly from the nineteenth century. The flood pastures are divided into about 35 grazing units or *leydis*, 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 those fractions of the herd devoted to milk production, and the tracks and resting places used by transhumant herds passing through the *leydi*. The Malian Government now recognizes the *leydi* system of territorial organization *de facto*, and the regional authorities enforce decisions on range use made jointly by herders' representatives and the local administration. Outside the inundation zone, the rainfed pastures are not allocated, but the major transhumance tracks are recognized and, in theory, are protected from agricultural encroachment.

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 herds with milk for direct consumption. The *garti* is the only management unit to participate fully in transhumance.

The majority of lactating cows, their calves, a few heifers, 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 with these objectives in mind. To maintain the productive capacity of the *bendi*, lactating cows are repeatedly transferred from the *garti* in exchange for dry cows. 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 inundation zone to exchange milk for rice during the January – March period. 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 *dumpti*, 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 rainfed grazing land. Their fairly low numbers allow supplementation with millet bran and salt. Cows allocated to the *dumpti* are usually of quiet disposition and, having calved recently, are amongst the best producers. 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 which go on transhumance with the *garti* and *bendi*. Secondly the herd

contains a small group of draught oxen, usually belonging to absentee farmers or Fulani cattle owners who also practise rice farming. For most of the dry season this last group, the *aladji*, is kept near settlements so as to plough the rice fields immediately after harvest (February – March) and again during the first rains (May – July). They usually join the *garti* when it departs for the dry rangelands.

LIVESTOCK PRODUCTIVITY

Animal production is greatly influenced by ownership structure and patterns of movement. The herder owns only some of the animals in a management group. In addition to his own animals there are cattle belonging to other people, who are interested in livestock mainly as a form of investment. These other owners might be farmers, fishermen, civil servants, military personnel or traders. Their cattle are herded against remuneration in either cash or kind. In three herds studied over a long period, less than 60% of all animals belonged to the herders or to other pastoralists, while the remainder belonged to outsiders. For two herds numbering respectively 220 and 263 animals there were a minimum of 48 and 29 people owning animals.

The constant and complex movement of animals in order to optimize exploitation of the various herd fractions means that the management of each herd is unique. An average herd with an average set of management fractions cannot therefore 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 milk offtake is both cause and effect of the frequent movements between management units.

Herd structures are typical of those found in pastoral systems in general, with the exception of a relatively high percentage of older males for pack and plough work. This results in lower proportions of females, about 62-65% of the herd compared with a norm of 70% in pastoral herds where work roles are not important. Management units ("herds") vary in size from under 100 head to very large ones of over 500 animals. About 45% of herds, corresponding to 60% of all cattle, are found in larger units of over 100 head. The considerable fluctuations in herd structure and numbers due to the movements already described make estimates of natural increase or decrease due to births, deaths and offtake unusually complicated. The present rate of increase is probably about 3%.

Calving percentages are probably slightly higher than in the agropastoral system and may approach 65% in the long term, although for the herds studied the average was 59% for 1979 and 53% for 1980, but with a range across the herds of 39 to 76%. In contrast to the agropastoral system there was no marked calving peak. This probably indicates less nutritional stress. Average age at first calving for 70 known cases was 45 months. The mean of 19 months for 247 observed calving intervals (giving a theoretical calving rate of 63%) lends support to a hypothesis of long-term calving rates in the region of 65%. Weaning is delayed to almost 12 months of age, although there are significant differences due to management ("herd") and to parity, with weaning age decreasing as cow age increases.

Birth weights of 416 calves were 17.6 kg for males and 16.3 kg for females, similar to those calculated for the agropastoral system. Overall growth rate to 12 months of age, at 180 g/day, was little better than in the agropastoral system. Adult weights were also similar in both systems.

In the three herds studied (A, B and C), mortality in calves up to 12 months was 28.3%, some of the variates in this parameter being shown in Table 13. Abortions and stillbirths amounted to almost 40% of all mortality in this category. Mortality in older animals was much less than for calves, being 4.2% in young animals between 1 and 3 years, and 5.5% in animals more than 3 years old. Herd was again a principal factor in mortality. Season also exerted a strong, though apparently anomalous influence, with most deaths in all classes of stock occurring in the rainy period.

As milk is the main product from cattle in this system it is worth detailing some aspects of its offtake. Note that figures in the discussion relate to offtake for human consumption and not to total milk production. It is possible that the higher death rate in calves in the pastoral system is due at least in part to competition for milk by human beings, a competition which is less severe in the agropastoral system owing to different dietary habits and preferences.

The milk offtake curves in Figure 8 show mean minimum and maximum production levels of 0.35 and 0.95 litre/cow/day. However, season of calving markedly affects the shape of the curves. All curves show peak offtake during the favourable pasture conditions of the rainy season. Thus for cows calving during the rainy season milk offtake falls from a maximum of 0.9 litre at calving to 0.4 litre after 8 months, but rises to a second peak of 0.9 litre 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 a similar rise 3 months after calv-

Table 13.
PERCENTAGE MORTALITY OF CALVES TO 12 MONTHS OF AGE

Herd and year	No. of calves born*	Mortality (%)			
		Abortions	Stillbirths	1-365 days	Total
A					
1979	55	1.8	9.1	16.3	27.2
1980	66	1.5	15.2	19.7	36.4
B					
1979	63	4.7	3.0	12.8	20.5
1980	42	14.3	4.5	21.4	40.2
C					
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

* Includes abortions.

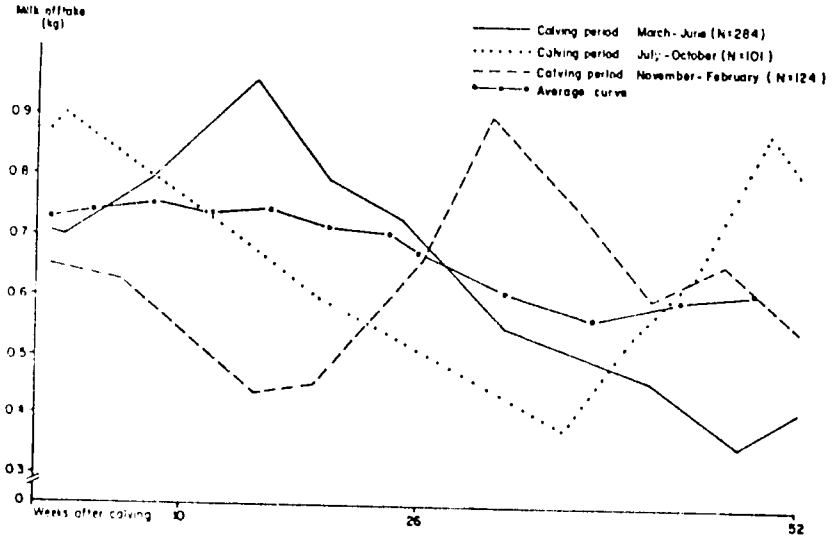
ing. Due to these interactive effects, the average offtake curve is a slightly descending straight line.

Up to weaning, after an average of 11.3 months, the average milk offtake was 235 kg, based on 509 lactations. Average offtake was significantly influenced by season of birth 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 had no significant effect.

The relationship between calf growth and milk offtake for individual cows indicated that during the first 8 weeks of the lactation, milk offtake was positively correlated ($r = 0.42$) with calf growth. This leads to the conclusion that the best cows were being milked to provide for human consumption, and that these cows still had more milk available for their calves than did poor producers. Later in the lactation this trend was less clear, because the calf relied progressively more on herbage and its growth became dependent on its genetic potential and on overall calf management, rather than on the milk output of the dam.

In general the advantages which might be expected to accrue to the pastoral system as a result of the abundant feed in the inundation zone and the seasonal movement to better rainfed pastures were not apparent at the level of the individual animal. This is amply illustrated by Table 14, which shows that production indices are similar for both the pastoral and the agropastoral system: the possible improvement in production is indicated by the results obtained at Niono ranch. These indices refer to individual production by single animals. If each animal is unable to produce to its genetic potential because of environmental, health and nutritional factors, it is obviously to the advantage of individual owners to maintain a large number of animals to ensure their own welfare. This is the principal reason for the so-called prestige syndrome of pastoralists, and while animals are individually owned and land or pasture is held in common this phenomenon can be expected to persist.

Figure 8.
EFFECTS OF CALVING SEASON ON MILK OFFTAKE IN THE DELTA PASTORAL SYSTEM.



FUTURE RESEARCH

THE AGROPASTORAL SYSTEM

Future research on the agropastoral system will focus on three areas of major significance, not only to the particular subsystem under study, but across the entire semi-arid as well as other zones. These areas are the introduction of forage legumes, the efficiency of animal traction, and the improvement of small ruminant production.

Table 14
PRODUCTIVITY TRAITS OF DIFFERENT PRODUCTION SYSTEMS.

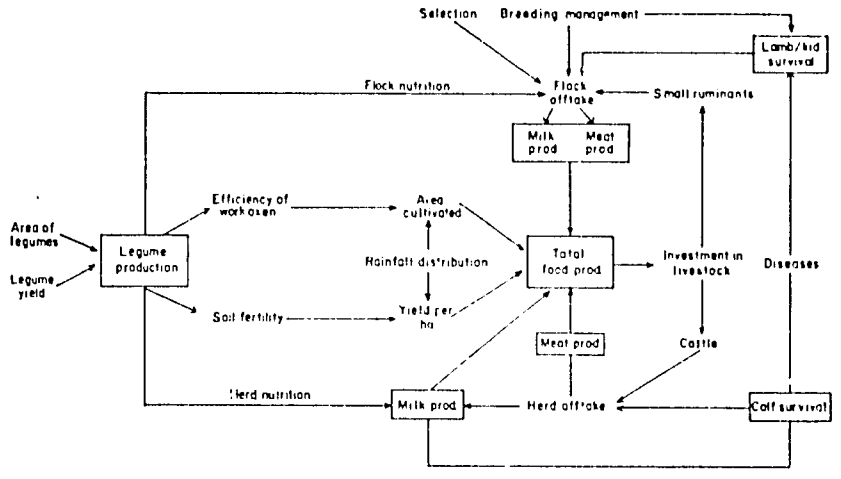
Character	Pastoral		Agro-pastoral	Niono ranch
	1979	1980		
Cow viability (%)	95.1	93.8	96.5	97.2
Calving rate (%)	59.0	52.6	57.4	78.0
Calf survival (%)	77.1	66.2	75.0[a]	69.2
Calf weight at 12 months (kg)	82	82	81	125
Milk offtake (kg/year)	235	235	193[b]	586
Productivity index/cow/year (kg)[c]	50.1	39.1	45.5	114.9
Cow liveweight (kg)	218	218	210	317
Productivity index per 100 kg of cow maintained per year (kg)	23.0	17.9	21.7	36.3

[a] Twenty-one per cent calf mortality plus an assumed abortion rate of 4%.
[b] Estimated from total annual offtake divided by average number of cows in milk (Dicko, 1981)
[c] Total weight of 12 month-old calf plus liveweight equivalent of milk produced.

Introducing forage legumes would improve total food production in a variety of ways (Figure 9). Meat and milk production would both increase through the improved nutrition of herds and flocks, while gains in soil fertility and the efficiency of work oxen would benefit both yield per hectare and the area cultivated in the case of food grain crops. Once total food production increases, further gains would result as more cash became available for increased investment in livestock or farm inputs.

However, ILCA's experience so far with legume introduction shows that in central Mali there are two major disadvantages which have to be taken into account: any legume introduced must have a high degree of drought tolerance, and its introduction must in no way prejudice food

Figure 9.
POSSIBLE IMPROVEMENT PATHWAYS FROM CEREAL LEGUME INTERCROPPING IN THE AGROPASTORAL SYSTEM.



grain crop yields. The main research themes in legume introduction for the future can therefore be summarized as:

(a) further selection of drought-tolerant legumes based on forage (and to a lesser extent grain) yields, conservation potential and contribution to soil fertility;

(b) experimentation on cultural practices designed to produce optimum human food grain yields at the same time as high-quality fodder for animals;

(c) determination of the acceptability of legume introduction to target populations and quantification of the risk involved in acceptance.

Work on legume introduction will be closely linked with studies on the efficiency of animal traction. At present, animals lose some 15-20% of their body weight during the dry season, and are at their weakest during the period when maximum work output is required. The weight loss can be largely compensated by dry-season feeding, but it is not yet known what effects this will have on tractive effort and total work output. Future research will therefore concentrate on measuring the impact of different supplementary feeding strategies on liveweight and power output (tractive effort times duration of work). The subsequent effects on crop yields will also be measured.

Small ruminant production would improve dramatically if one major constraint were lifted, namely the high mortality of young stock. High mortality rates are caused by a combination of nutrition, disease and management factors: as a general rule poor nutrition makes young animals more susceptible to disease, but the data collected by ILCA show clearly that management also plays an important part, since mortality rates vary considerably from flock to flock, probably in response to individual management practices. Figure 10 shows how a variety of measures might be introduced to improve small ruminant production, beginning with the identification of key management practices in those flocks where mortality is low, and continuing with veterinary and further management innovations.

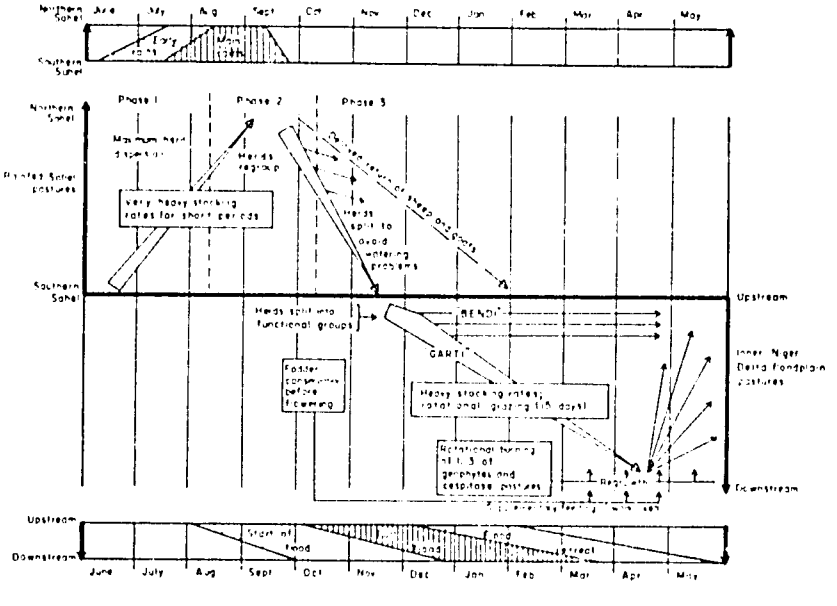
THE PASTORAL SYSTEM

Future research on the delta pastoral system will concentrate on two related areas, management practices and social-territorial organization.

As regards management practices, a number of proposals have already been put forward. They are based on existing livestock management practices and their observed effects on the growth of natural pastures, but also take into account other factors such as water distribution and herd fractionation in relation to season. On the rainfed Sahel rangelands the practices proposed would involve the careful tailoring of stocking densities to suit seasonal grazing availability, increased fractionation of herds to overcome watering problems as they return from transhumance, and the delayed return of sheep and goat flocks in order to take advantage of their greater tolerance of poor feeding conditions. Within the inundation zone, the practices would consist of cutting an early hay crop, increasing stocking density and herd mobility, burning off selected types of grassland, and rotational grazing. An improved management system incorporating these practices is illustrated in Figure 11.

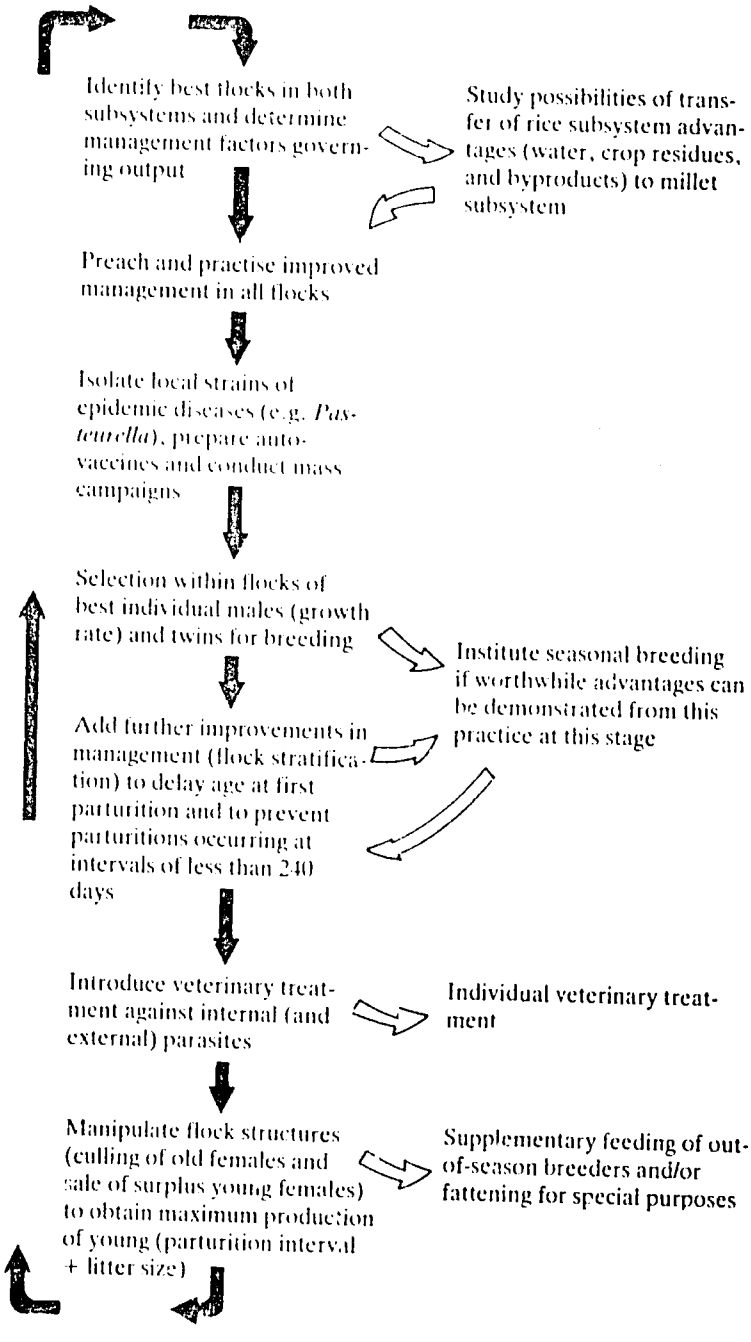
Studies on social-territorial organization will be geared to completing the mapping phase currently under way before moving on to a second phase in which land-use plans can be agreed upon and implemented. Once complete, the maps of the existing *leydis* will give a detailed picture of land use as it stands at present, including

Figure 11.
IMPROVED MANAGEMENT SCHEME FOR THE PASTORAL SYSTEM ASSOCIATED WITH FLOODPLAIN FARMING.



the geographical limits of each *leydi*, trek routes, campsites, farmed or fallow land and other features, which will be linked with data on human and livestock populations, their established grazing rights and existing management practices. Proposals for improved land use can then be drawn up, probably involving the reinforcement and restructuring of local institutions such as herders' and farmers' associations, as well as the more formal definition of the existing *leydis* and land-use rights within them. These proposals can then be discussed and agreed on by both pastoralist and government representatives, before a limited number of pilot pastoral units are established. If these units are successful, they will serve as a model for similar units to be established throughout the inundation zone.

Figure 10.
INTERVENTION PATHWAYS FOR SMALL RUMINANTS IN THE AGROPASTORAL SYSTEM.



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